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(54) Title: METHOD FOR CAPTURING THERMAL AND SPECIFIC RADIATIVE SPECTRUM VISIBLE, AND DEVICE FOR IMPLEMENTING SAID METHOD

(57) Abstract: This invention relates to a method and to a device for the implementation of said method, for selectively picking up some frequencies of a radiative spectrum, for a first use and, at the same time, to use the residual frequencies for thermal purposes. The method is characterized in that it includes the following steps: • to pick up said electromagnetic radiation; • to induce the reflection of said one or more frequencies using a reflector coloured by colours corresponding to said one or more frequencies; • to receive said one or more frequencies reflected by said coloured reflector; • to convey said one or more received frequencies towards a user device; • to use said residual frequencies for increasing the temperature of said coloured reflector; • to take the thermal energy produced by said coloured reflector. The device (A) is characterized in that it includes: - first means (3), fitted to reflect said one or more frequencies and to absorb said residual frequencies, in such a way to produce thermal energy, said first means (3) being coloured by one or more colours corresponding to said frequencies to be reflected; • second means (5), fitted to receive said one or more frequencies reflected by said first means (3) and to transmit them to a user device.

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METHOD FOR CAPTURING THERMAL AND SPECIFIC RADIATIVE SPECTRUM VISIBLE, AND DEVICE FOR IMPLEMENTING SAID METHOD

DESCRIPTION

This invention refers to a method and to a device for the implementation of said method, for selectively picking up some frequencies of a radiation spectrum, for a first use and, at the same time, to use the residual frequencies for thermal purposes.

It is strongly felt the need to have effective systems for recovery of thermal energy, to feed heating systems and processes in general. This need is particularly felt in the low enthalpy systems, by the ever more widespread use of heat pumps, to exploit environmental resources (Renewable Energy Sources). The efficiency of thermal solar panels is compromised by the insulating structures used to draw from environmental resources, and are mainly aimed at picking up the portion of energy deriving from the only irradiation. Even for the not glazed panels, they were not developed specific strategies to exploit the natural dynamics of the convective motions that are generated to the heat taking in front of the vertical or anyhow inclined surfaces. Another need, strongly felt, is the possibility to have specific components of the visible spectrum, selected and in appropriate assortment for specific processes (for example for biological ones).

In summary, in the current state it is not possible to selectively pick up some frequencies of the radiation spectrum and, at the same time, to use the residual frequencies for thermal uses. Moreover, it is not optimized the taking of the environmental energy simultaneously with the one of the radiant energy.

In particular, it is not possible, by a single device, to pick up some specific frequencies for a purpose and to use the residual frequencies to produce thermal energy for another purpose.

The object of this invention is to propose a method and a device to implement said method, respectively conform to claims 1 and 2, to selectively pick up one or more frequencies of an electromagnetic radiation, at least in part visible and to use the residual frequencies to produce thermal energy.

The method is characterized in that it includes the following steps:

- to pick up said electromagnetic radiation;
- to induce the reflection of said one or more frequencies using a reflector coloured by colours corresponding to said one or more frequencies;
- to receive said one or more frequencies reflected by said coloured reflector;
- to convey said one or more received frequencies towards a user device.

According to a preferred embodiment, the method is further characterized in that:

- to use the not reflected part of said electromagnetic radiation to increase the temperature of said coloured reflector;
- to take the thermal energy produced by said coloured reflector.

The device is characterized in that it includes:

- first means (3), fitted to reflect said one or more frequencies and to absorb said residual frequencies, in such a way to produce thermal energy, said first means (3) being coloured by one or more colours corresponding to said frequencies to be reflected;
- second means (5), fitted to receive said one or more frequencies reflected by said first means (3) and to transmit them to a user device.

Other characteristics, such as for example the possibility to pick up the environmental energy, will be the subject of the dependent claims.

The use of a device according to the invention allows, for example, to pick up the frequencies that are useful for the growing of certain crops and, simultaneously, to heat the environment in which said crops are carried out.

The invention will now be described for illustrative and not limitative purpose, according to a preferred embodiment and with reference to the attached figure 1, which shows the device according to the invention.

With reference to Fig. 1, with (A) is indicated a device, according to the invention, able to pick up, for example: the frequencies concerning the colours red and blue and to use the residual frequencies to produce heat. Said device (A) includes:

- a first reflector (3), hit by the solar radiation, whose surface is painted in red and blue, so that it reflects only the wavelengths relevant to these two colours, said first reflector (3) being fitted to heat up due to the effect of the not reflected radiation;
- a second reflector (6), fastened on a rod (6a), which it is fastened itself on a support (7), said second reflector (6), capturing the light, red and blue, reflected by said first reflector (3);
- a receiver (5) fitted to receive the red and blue light reflected by said second reflector (6), said receiver (5) being connected with an optical fiber (5a) fitted to transmit towards a user device (not shown) said red and blue light;
- means (8, 9), placed in a heat exchange relationship with said first reflector (3) and fitted to pick up the heat produced by said first reflector (3) due to the effect of the absorbed radiation.

According to a preferred embodiment, said means fitted to pick up the heat produced by said first reflector (3), include a coil having an end (8) and (9) through which a thermal fluid flows.

The described device (A) uses a Cassegrain dynamic, that provides for the use of said second reflector (6) positioned in correspondence with the focus of said first reflector (3), which has the shape of a paraboloid. According to said Cassegrain dynamic, the second reflector (6) focuses the reflected rays on said receiver (5) located in correspondence with the vertex of the paraboloid which constitutes the first reflector (3). Alternatively, the reflector (5) can be positioned in correspondence of the focus of the paraboloid.

According to a preferred embodiment, shown in Fig. 1, there are provided means fitted to pick up the environmental energy and to transfer it to said coil (8, 9). Said environmental energy can be, for example, the heat content of the air or of another medium such as, for example, of water taken from a source or of steam waste taken from a plant.

Said means fitted to pick up the environmental energy act by driving the laminar flows of fluids (gaseous or liquid) to lap the coil (8, 9). According to a preferred embodiment, said means include suitably oriented blades, for example, of stretched sheets (1, 2), fitted to create specific convective motions.

Said means (1), (3), (8, 9) allow a significant energy exchange in their basic configuration, that will be increased when, slaved to heat pumps, being able to take advantage of larger gradients and therefore of greater energy volumes. Particular attitudes of the blades in stretched nets, in the state of energy taking from the environment (conveying towards the inside), involve the progressive cooling of the contiguous materials, that for a greater density will generate descendants convective laminar motions, favouring the inflow towards the means (1), (3) and (8, 9) designed to pick up the thermal energy. The fins of the stretchched sheet will have to assume a symmetrically reverse configuration in the event of the transfer of energy to the adjacent materials.

Said coil (8, 9) may be advantageously shaped so as to ensure a uniform exchange (roundtrip, according to a square, circular, elliptical or other spiral).

According to a further embodiment, the first reflector (3) and the coil (8, 9) comprise a single element of the type called roll bond, which is shaped according to the surface of a paraboloid, whose concave side act as the reflector (3).

Said means (1), (3), (8, 9), replaced by panels "roll-bond" make the device more economical, the novelty is in their coupling with the function of the first reflector (3) and subsequent means to capture and to convey one or more frequencies of a electromagnetic spectrum towards the user device. The "roll bond" are composed by a sandwich of two sheets of aluminum (metals or equivalent alloys) between which it derives a pipe run by heat transfer fluids (gas or liquids such as refrigerating gas or aqueous liquids).

The invention finds applications in various sectors:

- algal crops, in which serves both the radiative spectrum and the thermal energy;
- (b) vegetable cultivations in greenhouse, to punctually convey specific radiative spectrum and thermal energy in other points more functional to the developments of the foliar and radical apparatuses;
- to convey only some frequencies useful to the effects of specific processes (e.g. photovoltaic ones) and in regimes concentrated with simultaneous recovery of residual frequencies to thermal purposes (together with the thermal energy from the environmental condition);
- vegetable crops in pits or cellars in schemes for hydroponic and aeroponic cultivation in urban structures;
- (e) to allow the vegetation of meadows in natural grass sports centers or in general in tensile pressostatic structures.

The invention has been described for illustrative and not limitative purpose, according to some preferred embodiments. The person skilled in the art could find many other embodiments, all included within the scope of protection of the enclosed claims.

CLAIMS

1. Method to selectively pick up one or more frequencies of an electromagnetic radiation, characterized in that it includes the following steps:

- to pick up said electromagnetic radiation;
- to induce the reflection of said one or more frequencies using a reflector coloured by colours corresponding to said one or more frequencies;
- to receive said one or more frequencies reflected by said coloured reflector;
- to convey said one or more received frequencies towards a user device.

2. Method to selectively pick up one or more frequencies of an electromagnetic radiation, according to claim 1, characterized in that it further includes:

- the use of the not reflected part of said electromagnetic radiation to increase the temperature of said coloured reflector;
- the pick up of the thermal energy produced by said coloured reflector.

3. Device (A) fitted to selectively pick up one or more frequencies of an electromagnetic radiation, characterized in that it includes:

- the first means (3), fitted to reflect said one or more frequencies and to absorb said residual frequencies, so as to produce heat energy, said first means (3) being coloured with one or more colours corresponding to said frequencies to be reflected;
- second means (5), fitted to receive said one or more frequencies reflected by said first means (3) and to transmit them to a user device.

4. Device (A), according to claim 3, characterized in that said first means (3), fitted to reflect said one or more frequencies, include a surface shake in such a way fitted to focus the reflected rays of said one or more frequencies in a circular zone.

5. Device (A), according to claims 3 and 4, characterized in that said second means (5), fitted to receive said one or more frequencies reflected by said

first means (3) and to transmit them to a user device, are positioned in correspondence of said circular or linear shaped area.

6. Device (A), according to claims 3 and 4, characterised in that it includes third means (6), fitted to receive said one or more frequencies reflected by said first means (3) and to reflect them on said second means (5), fitted to receive said one or more frequencies reflected by said first means (3) and to transmit them to said user.

7. Device (A), according to claim 6, characterized in that said first means (3), third means (6) and second means (5) are arranged according to a dynamic of Cassegrain.

8. Device (A), according to at least one of the claims from 3 to 7, characterized in that said second means (5), fitted to receive said one or more frequencies reflected by said first means (3) and to transmit them to said user, include an optic fitted to concentrate in an optical fiber (5a) the reflected rays of said one or more frequencies.

9. Device (A), according to at least one of the claims from 3 to 7, characterized in that said first means (3), fitted to reflect said one or more frequencies and to absorb said residual frequencies, so as to produce thermal energy, are in heat exchange relationship with a coil (8, 9) inside which a heat transfer fluid flows.

10. Device (A), according to at least one of the claims from 3 to 8, characterized in that it includes fourth means fitted to pick up the environmental energy and to transfer it to said coil (8, 9).

11. Device (A), according to claim 10, characterized in that said fourth means, fitted to pick up the environmental energy and to transfer it to said coil (8, 9), are fitted to direct the laminar flows of the concerned fluids (gaseous or liquid) so as to lap the said coil (8, 9).

12. Device (A), according to claim 11, characterized in that said fourth means, fitted to direct the laminar flows of the concerned fluids (gaseous or liquid) so as to lap the said coil (8, 9), include some blades oriented in such a way as to create specific convective motions.

13. Device (A), according to claim 12, characterized in that said fourth means, fitted to direct the laminar flows of the concerned fluids (gaseous or liquid) so as to lap the said coil (8, 9) include said blades that are oriented in such a way as to create specific convective motions, include some stretched sheets (1, 2).

14. Device (A), according to at least one of the claims from 3 to 13, characterized in that said first reflector (3) and said coil (8, 9) are integrated in a single element of the type called "roll-bond", said element roll-bond being shaped according to the surface of a paraboloid, whose concave side assumes the role of the said reflector (3).

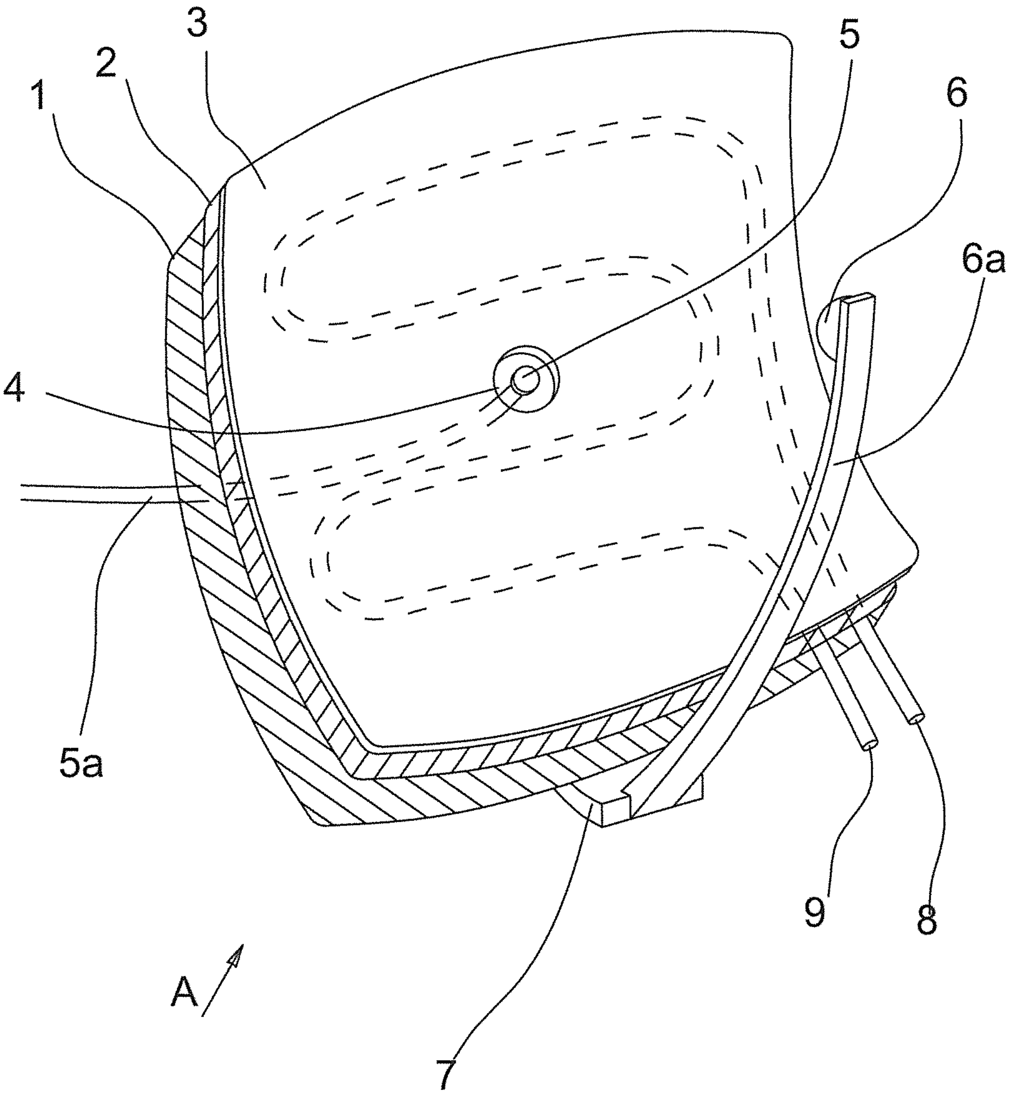

Fig. 1

US005578140A

United States Patent [19]

Yogev et al.

[11] **Patent Number: 5,578,140**

[45] **Date of Patent: Nov. 26, 1996**

[54] **SOLAR ENERGY PLANT**

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[73] Assignee: **Yeda Research and Development Co., Ltd.**, Rehovot, Israel

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[52] **U.S. Cl.** **136/246**; 60/641.5; 126/685; 126/686; 126/600; 126/572; 136/248; 422/186

[58] **Field of Search** 136/246, 248; 126/685–686, 600, 572; 422/186; 60/641.15

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,645,601	2/1972	Doctoroff et al.	359/360
3,972,183	8/1976	Chubb	60/641.8
4,025,783	5/1977	Fletcher et al.	359/193
4,154,219	5/1979	Gupta et al.	126/575
4,158,356	6/1979	Wininger	126/579
4,273,103	6/1981	Uroshevich	126/658
4,281,294	7/1981	Volkin	372/79
4,395,582	7/1983	Damsker	136/248
4,536,847	8/1985	Erickson et al.	364/516
4,553,531	11/1985	Rosende	126/600
4,784,700	11/1988	Stern et al.	136/248
5,005,958	4/1991	Winston et al.	359/727
5,294,075	5/1994	Vertatschitsch et al.	244/75 R
5,374,317	12/1994	Lamb et al.	136/246

OTHER PUBLICATIONS

"Technical Note", Solar Energy, vol. 18, pp. 269–271, Pergamon Press 1976.

"Approaching the Irradiance of the Surface of the Sun", Solar Thermal Technology: Research Development and Applications, R. Winston, P. Gleckman and J. J. O'Gallagher, pp. 579–586, 1990.

"Solar Thermal Central Receiver Systems", vol. 1, Design, Construction and Operation of CRS–Plants, pp. 187–197, 1986 (Springer–Verlag, Berlin).

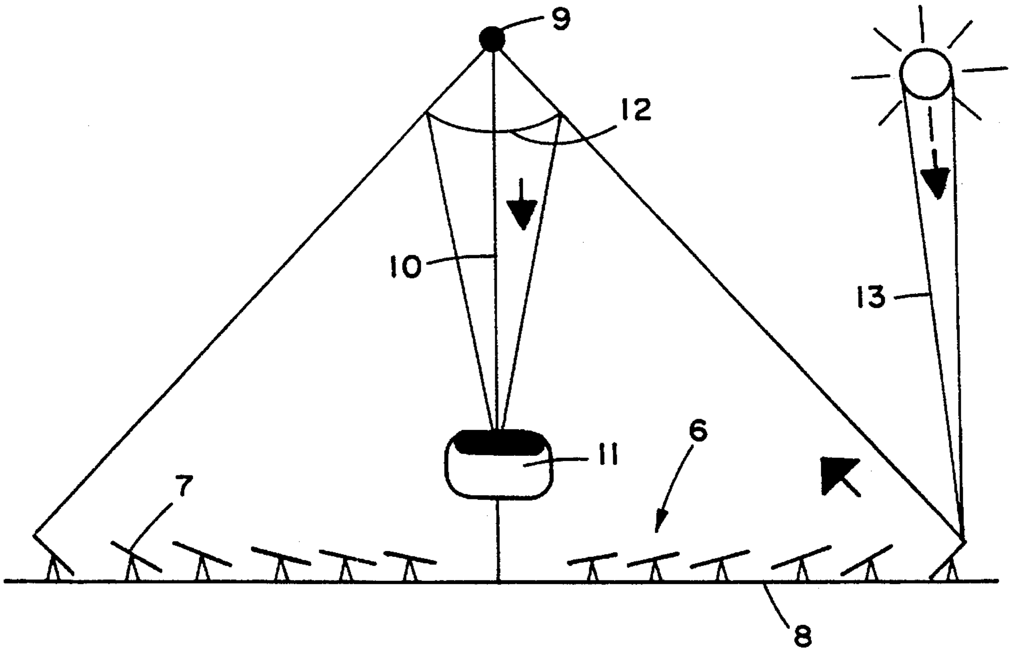
"Beam Quality and Tracking Accuracy Results of the Weizmann Institute of Science Heliostats", Solar Thermal Technology: Research Developments and Applications, M. Epstein, pp. 109–111, 1990.

Primary Examiner—Aaron Weisstuch
Attorney, Agent, or Firm—Wigman, Cohen, Leitner & Myers

[57] **ABSTRACT**

The disclosure concerns various improvements in a solar energy plant of the kind in which incoming solar radiation is concentrated by a Fresnel reflector, i.e. a field of concentrating mirrors, and the concentrated radiation is focused into a solar receiver. By one improvement a dielectric mirror is provided at a suitable level above the solar collector, to reflect the concentrated solar radiation into the collector. By another disclosed improvement a plurality of non-imaging secondary concentrators arranged in concentric zones is provided intermediary between the dielectric mirror and receiver. By yet another improvement the solar receiver is directly attached to a heat storage system.

52 Claims, 3 Drawing Sheets



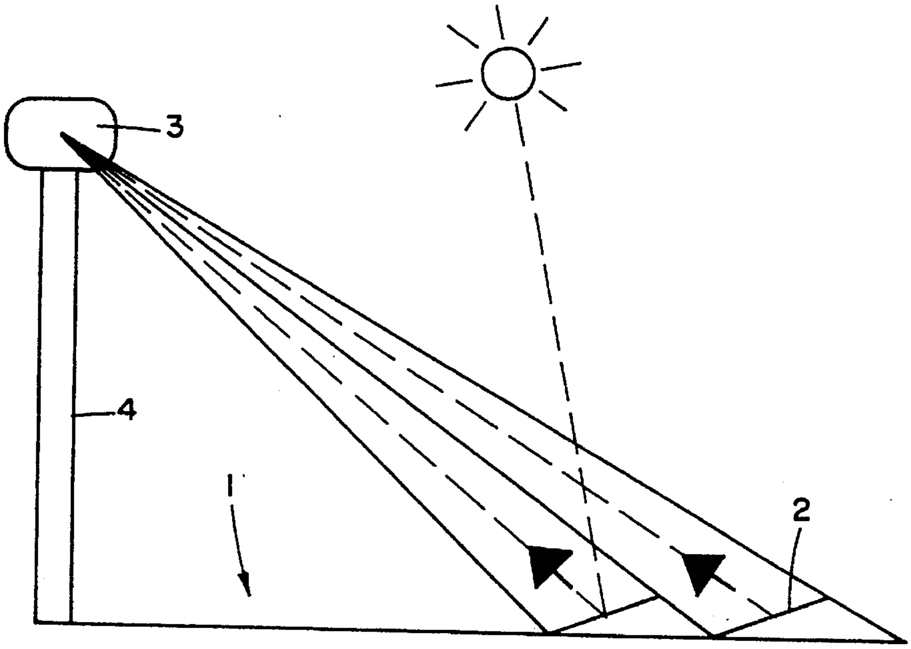


Fig. 1
(PRIOR ART)

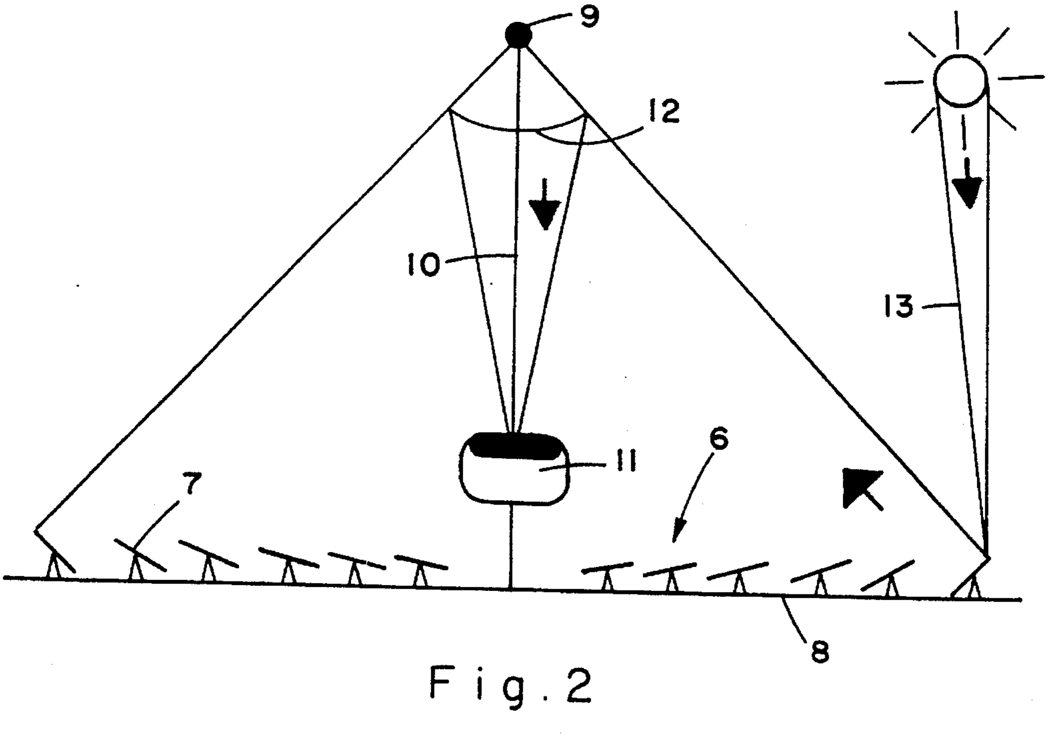


Fig. 2

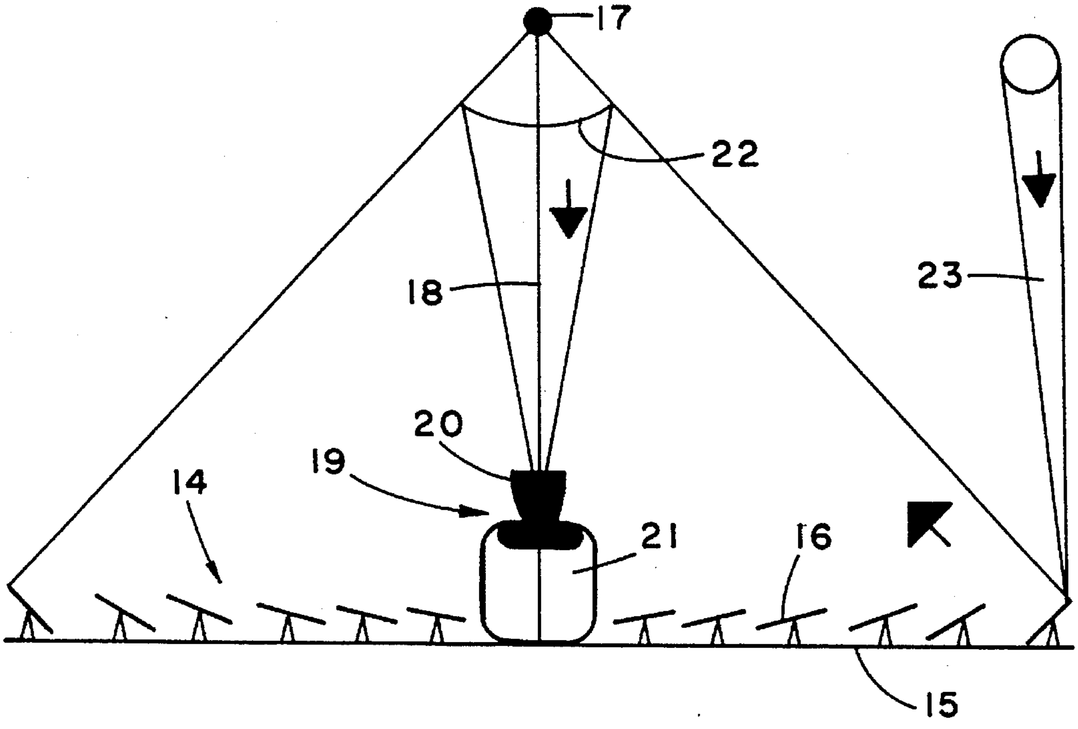


Fig. 3

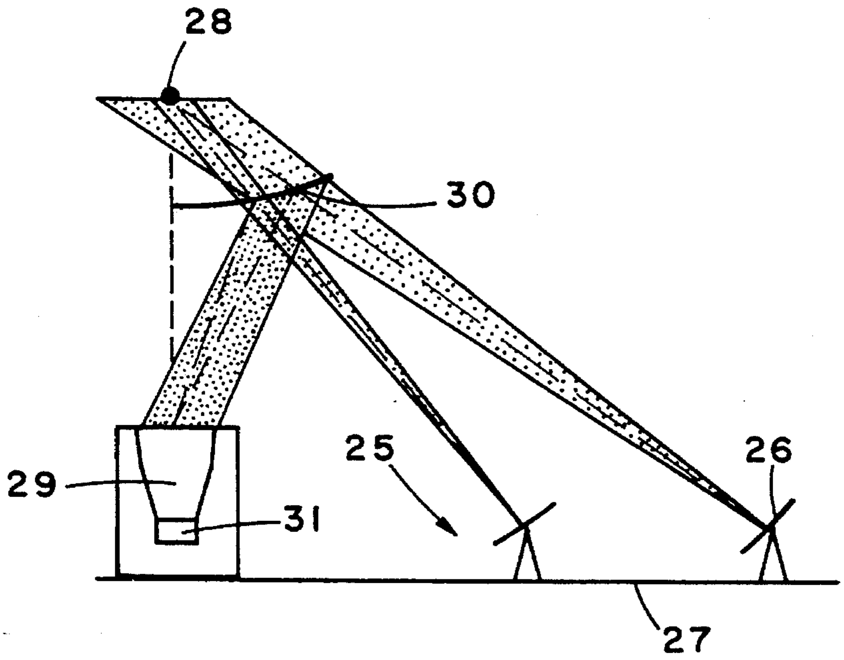


Fig. 4

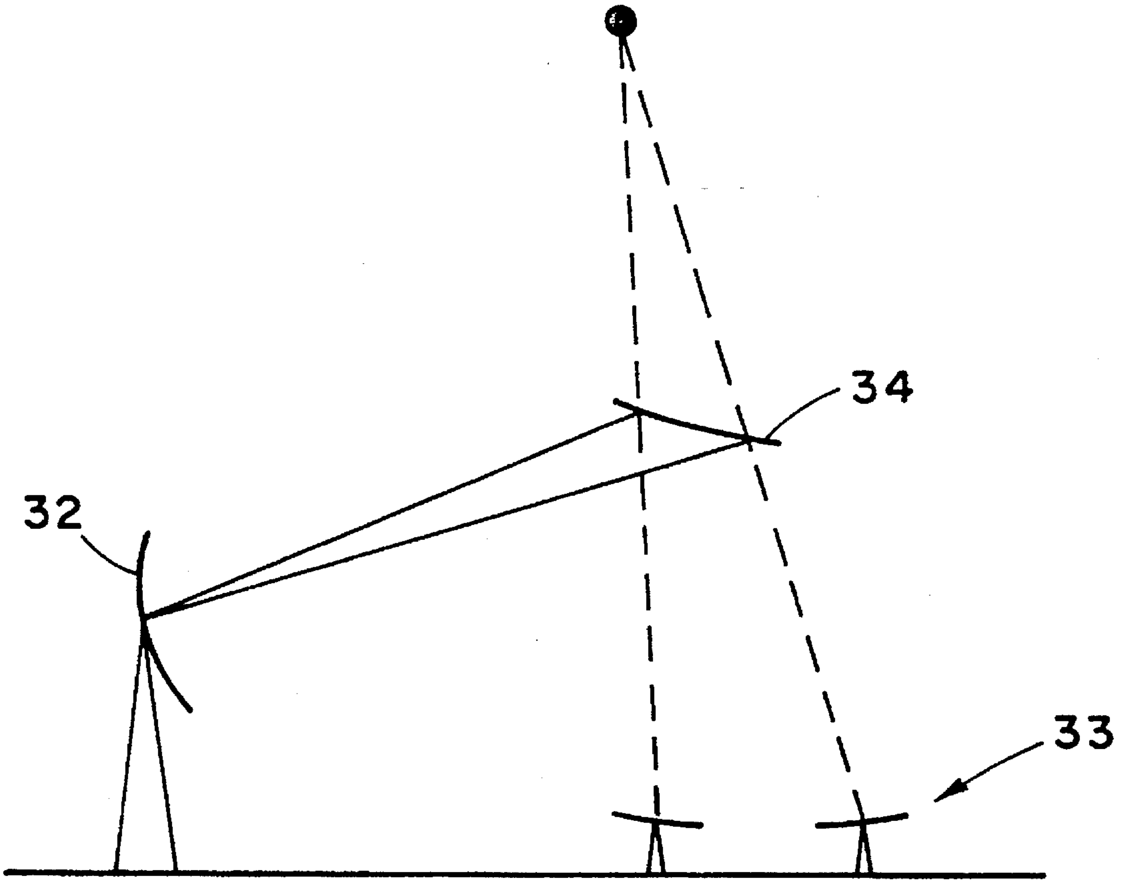


Fig. 5

SOLAR ENERGY PLANT

FIELD OF THE INVENTION

The invention relates to a solar energy plant of the kind comprising a solar radiation concentrator in association with a high-power solar energy receiver.

BACKGROUND OF THE INVENTION

Solar energy technology aims at providing economically competitive and environmentally friendly power for a variety of commercial applications. The efficiency of the conversion of solar energy into utilizable heat or electric power depends to a great extent on the light brightness achieved on the entrance surface of a solar energy receiver as well as on reflection, shadow and other losses, and is dependent on the available solar energy concentration.

Phase-space conversion and thermodynamic considerations place a theoretical limit on the concentration of sunlight that ally optical device can achieve (R. Winston et al. Approaching the irradiance of the surface of the sun, *Solar Thermal Technology,* Proc. 4th Intern. Symposium, Santa Fe, N.M., pp. 579–587, 1988). This limitation is expressed by the equation

$$C_{max}=\frac{n^2}{\sin^2\alpha} \tag{1}$$

where C_{max} is the maximum attainable concentration, n is the refractive index of a target surface and α is the half-angle of incidence, of the sunlight. This theoretical limit is derived under the assumption that the target area is large enough to collect all of the concentrated light.

The concentrations attainable in practice by conventional imaging devices fall far short of this limit owing to aberrations. For example, a parabolic mirror produces a perfect image on axis but the image blurs and broadens off axis.

By dispensing with image-forming requirements ill applications where no image is required, much higher concentration can be achieved. Non-imaging optics is known to allow light concentration close to the thermodynamic limit and, therefore, this technology is frequently used in powerful concentrators.

A practical approach for high concentrations of sunlight usually utilizes a two-stage optical system that incorporates a first-stage (primary) imaging concentrator which redirects incident solar radiation towards the focal point, and a second-stage (secondary) non-imaging concentrator which directs the concentrated solar radiation onto the solar absorber of a solar receiver. The secondary concentrator is placed close to the focus of the primary one and provides acceptance of all redirected solar energy as well as high brightness at the entrance of the receiver. The overall concentration for a two-stage system is a product of the concentration of the primary concentrator with that of the non-imaging concentrator:

$$C=C_p\frac{n^2\sin^2\beta}{\sin^2\alpha} \tag{2}$$

where C is an achievable concentration factor, C_p is a concentration factor of a primary concentrator and α and β are the maximum angles of distribution of the incoming and outgoing light.

The size and overall performance of the system are greatly affected by the nature of the primary concentrator. This imaging, first-stage concentrator may often be in a form of a parabolic or spherical mirror. The concentration provided by a parabolic dish may be calculated as follows:

$$C_p=\frac{r^2\sin(\tan^{-1}(h/r))}{h^2\sin^2(\alpha)} \tag{3}$$

where C_p is the concentration factor for a parabolic dish, α is the maximum angle of distribution of incoming light, r is the radius of the parabolic dish and h is the so-called focal distance, i.e. the distance from the dish to the focal plane. The concentration usually achieved by a parabolic dish is less than 25% of a thermodynamic limit.

In an effort to concentrate the incoming solar radiation close to the thermodynamic limit, attempts have been made to use an imaging reflective telescope, e.g. a Cassegrain telescope, as a primary concentrator (W. Zittel, "Design Studies for Solar Pumped Lasers", DFVLR-FB 87-39, Stuttgart, 1987). However, such a telescope formed by a parabolic primary mirror and a hyperbolic secondary mirror has very low aberrations only for a very narrow acceptance angle. Therefore, to provide a high-power concentration, the telescope has to track the sun, which is practically impossible for this kind of system where the size of a primary reflective area may be of the order of tens or even hundreds of thousands of square meters.

For stationary receivers, the Fresnel reflector is often a primary concentrator of choice because of its construction and tracking simplicity (M. Epstein, "Central receiver facility at the Weizmann Institute of Science", ***Solar thermal central receiver systems,*** Proc. III Intern. Workshop, Springer-Verlag, Berlin, FRG, pp. 187–197, 21986. M. Epstein, "Beam quality and tracking accuracy results of the Weizmann Institute of Science Heliostats", *Proc. 4th. Intern. Symp. on Research, Development and Applications of Solar Thermal Technology,* New York, pp. 108–111, 1990).

There are different types of Fresnel reflectors. Two-dimensional (2-D) Fresnel reflectors with focal lines have been developed for use in commercial plants; three-dimensional (3-D) Fresnel reflectors with focal points, usually called heliostats field, arc used in conjunction with central solar receivers and solar towers, particularly in the megawatts scale systems, as they can operate at higher power fluxes and temperatures, thus allowing to achieve high conversion efficiencies. The heliostats field consists of a plurality of computer controlled mirrors which redirect solar radiation towards a secondary concentrator located in the region of the focal points usually located on a central solar tower, and followed by a volumetric central receiver. The concentration factor of the heliostats field may be calculated by the equation

$$C_f=C_p\cdot\frac{2\pi\int_r r\sin(\tan^{-1}(h/r))dr}{\pi\cdot r_2} \tag{4}$$

where C_f is the concentration factor of the heliostats field, C_p is the concentration factor of an individual constituent parabolic or spherical mirror of the field, h is the focal length of the heliostats field and r is the field radius. Because of shadowing effects, even when the sun remains in zenith, and because the area of the redirected solar radiation is smaller than the reflective area of the heliostats, and the aggregate area of the heliostats is smaller than the gross area of the heliostats field, the available concentration of the heliostats field is less than that of a parabolic dish, and usually does not exceed 21%. It is clear from the above equations that the larger the focal distance of the concentrator or the larger the h/r ratio, the higher the concentration achievable. Thus, for better overall concentration the focal length of the heliostats field, which actually determines the height of the solar tower, should be as large as possible.

In a 100 MW scale solar system the height of a solar tower has to be 100 meters and more. Therefore, the secondary concentrator and the associated central solar receiver as well as some components of the energy conversion systems must all be installed at the top of the tower. This requirement poses difficult and expensive engineering problems which are aggravated by shadowing problems arising out of the fact that the solar light reaches the secondary concentrator from below. The focal distances of heliostats often exceed 300 meters for a solar field with a high solar tower which leads to significant aberrations and loss of concentration (L. L. Vant-Hull, M. E. Izogon and C. L. Pitman, "Results of a heliostat field: receiver analysis for Solar Two", *Proceedings of the ACME International Solar Energy Conference,* Washington, D.C. pp. 2243–2251, May 1993).

To sum up, high power solar energy plants with a heliostats field concentration system and a central solar receiver on top of a high tower, optionally in association with a secondary concentrator, poses serious problems of design and efficacy of primary concentration.

These problems have already been acknowledged in the past and in the attempt to solve them a so-called "tower reflector" concept has been proposed (A. Rabl, "Technical Note. Tower reflector for solar power plant", *Solar Energy,* Vol. 18, pp. 269–271, 1976). In accordance with this concept, a solar energy plant comprising a solar receiver and a heliostats field installed on a base plane and having a focal point above said base plane is provided with an additional, flat Fresnel reflector mounted on a solar tower close to the focal point, whereby concentrated solar radiation reflected by the additional reflector is redirected onto the solar receiver placed close to the base plane. To improve the radiation concentration achieved by the system, a compound parabolic concentrator placed in the vicinity of the receiver is employed. Thus, due to the use of the tower reflector, the solar receiver and any associated equipment can be installed close to the base plane rather than being mounted on top of a high tower.

However, as acknowledged in Rabl's disclosure, there exists a serious problem connected with a necessity to avoid overheating of the tower reflector which is to be exposed to the concentrated solar light of 100 suns or even more. With an ordinary construction of the reflector, based on metallic layers, a significant amount of this energy would have been absorbed by the reflector requiring an intensive cooling thereof, which is quite difficult and onerous at high altitudes of the tower. In order to solve the overheating problem, Rabl suggests that the elements of the tower Fresnel reflector be in the form of rectangular prisms with total internal reflection. In such a design the tower reflector of the solar energy plant has to be of relatively large dimensions anti have an extremely large mass. Moreover, with the tower reflector in the form of the flat Fresnel reflector, shadowing and blocking effects will take place causing deterioration of primary concentration, losses of solar radiation and, consequently, a rather low conversion efficiency of the solar plant. Finally, the costs of such an arrangement would be prohibitive. All these disadvantages render the construction proposed by Rabl practically inapplicable anti may explain why, until now, the tower reflector concept has not found its use.

It is the object of the present invention to provide a highly efficient solar energy plant with a tower reflector in which the above disadvantages are avoided.

SUMMARY OF THE INVENTION

In the description of the present invention and claims the term "dielectric mirror" means a composite body comprising a transparent substrate coated with a plurality of relatively thin layers made of dielectric materials transparent for at least a part of the spectrum, which mirror, when illuminated by radiation of a limited spectral distribution, provides for an integral reflection effect. Generally, the dielectric mirror operates as a beam splitter transmitting substantially all non-reflected radiation. A desired amount of the reflected radiation Call be achieved by a proper choice of indices of refraction of the materials, thicknesses, number and sequence of the layers. To improve the beam-splitting, a distribution of angles of incidence of the radiation has to be substantially limited.

In accordance with one aspect of the present invention there is provided a solar energy plant for the conversion of solar radiation into utilizable energy of the kind that comprises a Fresnel reflector consisting of a plurality of concentrating mirrors installed on a base plane and having a focal point above said base plane removed from the Fresnel reflector by a focal length, at least one solar receiver placed close to said base plane and an additional reflector mounted above said Fresnel reflector close to said focal point whereby concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver, characterized in that said additional reflector is in the form of a dielectric mirror, whereby overheating thereof is avoided.

The beam-splitting ability of the dielectric mirror makes its absorption coefficient negligible and, consequently, a necessity of cooling arrangements is eliminated. As mentioned above, to enable the use of the dielectric mirror, a spectral distribution of the radiation has to be limited. With the solar energy plant, according to the present invention, this requirement is satisfied due to the fact that the concentrating mirrors of the Fresnel reflector, usually used in solar energy plants of the kind to which the present invention refers, arc silver reflectors which cut off a significant short-wavelength portion of the solar radiation.

If desired, the dielectric mirror may be designed to provide a very high, substantially total reflection of radiation, which is actually a particular case of the beam-splitting with all the losses being transmission losses. Alternatively, the dielectric mirror may be provided with a metallic back coating. In this case layers of the dielectric mirror are designed to provide reflection of most of the radiation which would be absorbed by the metallic coating.

In the preferred embodiment of the present invention, the dielectric mirror is a curved mirror in which each sector is exposed to a limited range of angles. Thus, the limited distribution of angles of incidence of the radiation is provided, whereby the efficiency of the mirror is increased. Preferably, the mirror is a convex mirror mounted in front of the focal point. It may, however, be concave so as to be mounted behind the focal point.

The use of additional reflector in the form of the dielectric mirror allows for its design according to specific needs. Thus, the reflector may have a color or color range selective, e.g. bandpass, coating.

The additional reflector may be made in one piece or be segmented. It may also be of the Fresnel type.

In the preferred embodiment of the present invention, the Fresnel reflector of the solar energy plant is of the heliostats field type in which at least some of said concentrating mirrors tracks the sun.

If desired, the plant according to the invention may comprise a secondary concentrator placed between said additional reflector and said at least one solar receiver.

Preferably, the secondary concentrator is of a non-imaging type, e.g. a compound parabolic concentrator (CPC) or a tailored edge-ray concentrator (TERC) such as disclosed, for example, in H. Reis and R. Winston, "Tailored edge-ray reflectors for illumination", *J. Opt. Soc. Am.*, May 1993; J. M. Gordon and H. Reis, "Tailored Edge Ray Concentrators as ideal stages for Fresnel reflectors", *Applied Optics,* Vol. 32, No. 13, pp. 2243–2251, May 1993; H. Reis and R. Winston, "Tailored edge-ray reflectors for illumination", *J. Opt. Soc. Am.*, May 1993, J. M. Gordon and H. Reis, "Tailored Edge Ray Concentrators as ideal stages for Fresnel reflectors", *Applied Optics,* Vol. 32, No. 13, pp. 2243–2251, May 1993. Alternatively, the secondary concentrator may be of an imaging type.

Preferably, the base plane on which the heliostats field is located is inclined relative to the horizontal whereby the angle that the incident solar radiation forms with a normal to the base plane is reduced.

If desired, the receiver may be distanced from the Fresnel reflector and the additional reflector in this case should be tilted to redirect radiation onto the receiver.

If desired, said at least one solar receiver in a plant according to the invention may be associated with a heat engine and an electric generator whereby the plant becomes a solar power station. In cases where energy storage is required, the receiver, according to the present invention may be associated with a suitable storage system, e.g. a heat storage tank. If desired, the solar receiver may be in form of a heat storage tank. Thus, the need for expensive and energy consuming communication systems which would be required if the central solar receiver were mounted on the tower, is eliminated.

Alternatively, said at least one solar receiver may be associated with means for the withdrawal of utilizable heat; or be designed as a chemical reactor, as a photovoltaic system, as a concentrated solar radiation pumped laser device, etc.

In a preferred embodiment of the invention the ratio between the distance of the additional reflector from said focal point and the focal lengths of the heliostats field is within the range of from about 1:5 to about 1:10.

It is further preferred that the ratio between the diameters of the additional reflector and the heliostats field is about 1:10.

More than one receiver may be used in a plant according to the invention. For example an additional solar receiver may be placed behind said additional reflector in the focal point region of said heliostats field.

If desired, a plant according to the present invention may comprise at least one supplementary reflector placed between said additional reflector and at least one of said solar receivers. The supplementary reflector may be of the beam splitter type, or fabricated so as to be color selective. The supplementary color selective reflector may provide different bandpasses for different solar receivers.

It can, therefore, be concluded that due to the fact that the additional reflector, according to the present invention, is in the form of a multilayered structure, it may have a large variety of features allowing for conversion of practically most of the solar radiation incident on the reflector into utilizable energy and thereby increasing efficiency of the solar energy plant.

According to another aspect of the present invention, there is provided a solar energy plant for conversion of solar radiation of the kind that comprises a working fluid for the withdrawal of absorbed heat, comprising a Fresnel reflector consisting of a plurality of concentrating mirrors installed on a base plane and having a focal point above said base plane removed from the Fresnel reflector by a focal length, at least one solar receiver assembly placed close to said base plane and holding said working fluid and an additional reflector mounted above said Fresnel reflector close to said focal point whereby concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver assembly, characterized in that the plant comprises intermediary between said additional reflector and said at least one solar receiver, a plurality of non-imaging secondary concentrators arranged in concentric zones, each secondary concentrator associated with a dedicated aperture in said receiver assembly, whereby concentric zone of different temperature are formed inside the receiver and the working fluid is gradually heated when passing from the outermost zone with the lowest temperature to the innermost zone with the highest temperature.

By one embodiment, the receiver assembly comprises a plurality of receiver units each having one aperture.

By another embodiment the receiver assembly comprises one single receiver unit with a plurality of apertures.

According to a still further aspect of the present invention, there is provided a solar energy plant comprising a Fresnel reflector in the form of a heliostats field installed on a base plane and having a focal point above said base plane removed from the Fresnel reflector by a focal length, at least one solar receiver placed close to said base plant and an additional reflector mounted on a tower close to said focal point whereby concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver, characterized in that the plant comprises means for monitoring a displacement of said additional reflector, which monitoring means may be in the form of laser scanning device or TV imaging system, and means for dynamic adjustment of the heliostats so as to track the displacement of the reflector whereby any impairment of the performance of the plant in consequence of reflector displacement is avoided.

According to still further aspect of the present invention, there is provided a solar energy plant for conversion of solar radiation into heat, comprising a Fresnel reflector consisting of a plurality of concentrating mirrors installed on a base plane anti having a focal point above said base plane removed from the Fresnel reflector by a focal length, at least one solar receiver placed close to said base plane and an additional reflector mounted above said Fresnel reflector close to said focal point whereby concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver, characterized in that said receiver is attached directly to a heat storage system.

DESCRIPTION OF THE DRAWINGS

For better understanding the present invention will now be described, by way of example only, with reference to the accompanying drawings in which

FIG. **1** is a schematic illustration of a section of a conventional solar energy plant with central solar receiver;

FIG. **2** is a schematic illustration of one embodiment of a plant according to the invention;

FIG. **3** is a schematic illustration of another embodiment of a plant according to the invention;

FIG. **4** is a schematic illustration of yet another embodiment of a plant according to the invention; and

FIG. **5** is a schematic illustration of still another embodiment of a plant according to the invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Attention is first directed to FIG., **1** which shows a prior art arrangement for converting solar radiation into utilizable energy, of the kind in which the central solar receiver is mounted on top of a solar tower.

As shown, a heliostats field **1** comprising a plurality of mirrors **2** which may for example be in the form of parabolic mirrors, reflects concentrated solar radiation to a solar receiver **3** mounted in the focal region of the heliostats field **1** on top of a tower **4**. As a rule, the solar receiver **3** is associated with a secondary concentrator and with equipment for the extraction of the utilizable heat generated in the receiver or for other use of the concentrator light.

Attention is now directed to FIG. **2** which shows one embodiment of a solar plant according to the invention. As shown, a heliostats field **6** consisting of a plurality of concentrating reflectors **7** such as, for example, parabolic mirrors, is mounted on a base plane **8**. The focal point of the heliostats field is indicated at **9**.

A solar receiver **11** is mounted slightly above the base plane **8** underneath the focal point **9** so that its axis coincides with the axis of symmetry **10** of the plant. Above receiver **11** and somewhat underneath the focal point **9** there is mounted an additional reflector **12**. Preferably, the ratio of a distance between additional reflector **12** and the focal point **9** to the focal length of the heliostats field, is from 1:5 to 1:10.

The additional reflector **12** is preferably in the form of a convex mirror, particularly a hyperbolic mirror with a diameter about 10% and an area of about 1% of the heliostats field. Alternatively, additional reflector **12** may be mounted behind the focal point **9** and be concave. The additional reflector may be made in one piece or be segmented. It may also be of the Fresnel type.

As shown, the oncoming solar radiation **13** is concentrated by the heliostats field **6** in the direction of the focal point **9** and is reflected by additional reflector **12** so as to be redirected onto the solar receiver **11**.

As described later in detail, the additional reflector, according to the present invention, is in the form of a dielectric mirror designed so that its absorption of the radiation is negligible, enabling the reflector to be exposed to the highly concentrated light reflected by the heliostats field.

The embodiment of FIG. **3** is similar to that of FIG. **2** and it again comprises a heliostats field **14** mounted on a base plane **15** and comprising a plurality of concentrating mirrors **16**, e.g. parabolic mirrors.

The heliostats field **14** has a focal point **17** located on the axis of symmetry **18**.

Slightly above the base plane **15** there is located an assembly **19** comprising a secondary concentrator **20** and a solar receiver **21**. Intermediary between the secondary concentrator **20** and the focal point **17** and close to the latter there is mounted an additional reflector **22** which redirects the concentrated solar radiation arriving from the heliostats field **14** onto the secondary concentrator **20** which in turn directs the further concentrated solar radiation onto the solar receiver **21**. The incident solar radiation is indicated at **23**.

It should be noted that the heliostats field may be installed on a base plane inclined towards the incident solar radiation so as to reduce the angle that the latter forms with a normal to the base plane. Furthermore, in case of an inclined base plane, the inclinations of the individual heliostats themselves may be decreased whereby shadowing and aberrations are reduced.

In the embodiments of FIGS. **2** and **3**, the additional reflector and solar receiver and in the case of FIG. **3** also the secondary concentrator, are mounted symmetrically with respect to the heliostats field. A different embodiment in which the additional reflector and the receiver are mounted asymmetrically, is illustrated schematically in FIG. **4**. As shown, a heliostats field **25** comprising a plurality of concentrating mirrors **26**, e.g. of the parabolic dish type, is mounted on a base plane **27**, the design of the heliostats field being such that the focal point **28** is located off center in the manner shown and in consequence the solar receiver **31** is also off center. The additional reflector **30**, e.g. in form of an off-axis segment of a hyperboloid, is mounted in the manner shown off the vertical that leads from the focal point **28** to a secondary concentrator **29** and the associated solar receiver **31**.

The asymmetric arrangement of FIG. **4** has the advantage that it enables to mount mirrors **26** of the heliostats field **25** in such a way that the mirrors' axes are oriented towards the sun and the solar radiation incidents the mirrors essentially normal to the surface. The dimensions of the structure on which the secondary concentrator **29** and the solar receiver **31** are mounted are in this case increased as compared to those in the embodiments of FIGS. **2** and **3** because of an increase of the focal distances.

By way of example, the dimensions may be about as follows:

radius of heliostats field—100 m;

focal lengths—about 100 m;

radius of reflector **30**—10 m;

distance of reflector **30** from focal point **28**—9 m;

distance between reflector **30** and base plane **27**—66 m;

distance of secondary concentrator **29** from base plane—25 m.

The maximum size of the sun's image that would be produced by the heliostats field **25** around focal point **28** in the absence of additional reflector **30** would be 2.5 m., while the maximum size of the image actually afforded by additional reflector **30** is 5.2 m., i.e. more than double the size. By means of the secondary concentrator **29** this image is then reduced to the size of about 1 m.

If desired, the solar energy plant in accordance with the present invention may have dimensions much larger than that in the above example. Thus, the radius of the additional reflector may even be about 25 m. However, when such a large mirror is installed on the high solar tower (100 m and more) it will undoubtedly be exposed to very strong wind loads which may cause a severe sway thereof leading to significant displacements of the mirror with respect to the heliostats field. To avoid deterioration of concentration and light losses, the solar energy plant is provided with means for monitoring and measuring these displacements and for dynamic adjustment of aiming point of the heliostats so as to achieve a substantial compensation of the displacements. The monitoring means may be in the form of a laser scanner or TV imaging system.

In the embodiment of FIG. **5**, the solar receiver **32** is significantly distanced from the heliostats field **33**, and the additional reflector **34** is tilted so as to redirect light to said distant receiver **32**. This embodiment may be particularly useful when the plant associated with the receiver **32** is to be located remote the place where the energy is used.

It has already been mentioned regarding the additional reflector, such as **12** in FIG. **2**, **22** in FIG. **3**, **30** in FIG. **4** and **34** in FIG. **5**, that, in accordance with the present invention, it is in the form of a dielectric mirror. Generally, this mirror is designed so that the radiation which is not reflected by the reflector is transmitted therethrough. By a proper choice of material, thickness, number and sequence of the layers, which is usually done by a computer means, the reflector can be provided with a required extent of reflection and a variety of specific properties. Thus, the reflector is, preferably, in the form of a substrate made of a transparent material (such as glass or quartz) coated with a plurality of transparent thin layers constituting highly reflective interference coating. In this case, the mirror functions as a beam-splitter. Heat from radiation transmitted through the additional reflector may be extracted and utilized to warm a working fluid. In this case the part of the collected radiation which passes through the additional reflector can be used for processes utilizing low concentrated light. Alternatively, the additional reflector may be essentially reflective so that all the losses will be transmission losses or it may comprise a highly reflective metallic back coating with the reflectivity enhanced by a combination of the dielectric layers, in which case a necessity of forced cooling is avoided and natural air convection can be sufficient.

The dielectric mirror may be fitted with special features so as to be able to serve several purposes at the same time. If desired, the mirror may be made selective and designed to reflect for example, only short wavelength or alternatively only long wavelength radiation. The short wavelength radiation may be used for quantum conversion processes, and the long wavelength radiation may be used for thermal conversion processes. In cases, where light is converted directly into utilizable energy, it is preferable to utilize for such conversion only that fraction of the solar spectrum which is efficient for said conversion and remove or rather to utilize the rest of light for other purposes. Typical examples of such direct conversion are photovoltaic systems for direct production of electricity, solar pumped lasers for direct production of laser beam, photochemical reactors, etc.

To optimize conversion efficiency it is in many cases preferable to use a bandpass-type color selective additional reflector, i.e. capable of selecting out of the concentrated solar radiation specific spectral bands which may be chosen so as to increase the efficiency of the solar radiation conversion. For example, in photovoltaic systems the conversion efficiency to above 30% may be achieved by selecting out of the concentrated solar light the bandpass in a range of 0.4–0.9μ. By way of a further example, where the concentrated solar light is used for optical pumping of laser devices, it is preferable to select out of the solar spectrum a bandpass which corresponds to the absorption wavelength, which in case of a Nd:YAG laser 0.7–0.9μ.

If desired, more than one receiver may be used in the plant in accordance with the present invention. In case of the additional reflector being of the beam splitter type, an additional secondary concentrator and/or receiver may be installed at the focal point region of the heliostats field behind a beam splitter with means for converting the transmitted part of the concentrated radiation into utilizable heat, electricity, heat storage systems, etc.

Supplementary reflectors may be placed between the additional reflector and any of the receivers so as to provide a multistage beam-splitting, spectral bands selection, etc., which may be particularly useful with a large heliostats field.

It should be noted that the light distribution of the image obtained in the focal point of the system is not homogenous, having its maximum at the center of the image and being slowly reduced towards the edges. This phenomenon can be used in thermodynamic cycles where a working fluid is gradually heated from a low temperature to a maximal temperature. In this case, the secondary concentrator, such as **20** in FIG. **3** and **29** in FIG. **4**, may comprise a plurality of non-imaging concentrators arranged in concentric zones. In this case, the receiver **11**, **21** or **31** has a plurality of apertures or rather is formed as an assembly of a plurality of receivers, each having one aperture. Each concentrator is connected to a respective aperture. The working fluid is gradually heated by flowing from the outermost zones with the lowest temperature to the innermost zones with the highest temperature.

The invention can be used for efficient delivery of high power fluxes separately or simultaneously to various receivers such as lasers, photovoltaic systems, semiconductor devices, fluorescent devices, chemical reactors, heat exchangers, heat engines, etc.

The present invention is specifically advantageous for use with heat storage systems which, by their very nature, must be installed at ground level. In this case, the receiver of the solar energy plant is attached directly to the heat storage system avoiding any need for heat transfer arrangements.

We claim:

1. A solar energy plant for the conversion of solar radiation into utilizable energy, comprising:

a Fresnel reflector including a plurality of radiation concentrating mirrors installed on a base plane, said Fresnel reflector being in the form of a heliostats field in which said concentrating mirrors track the sun and having a focal point removed from the heliostats field by a focal length;

at least one solar receiver placed close to said base plane; and

an additional reflector mounted above said heliostats field close to said focal point so that concentrated solar radiation reflected by the heliostats field is redirected onto said at least one solar receiver; and

wherein said additional reflector is in the form of a dielectric mirror, whereby an overheating of the additional reflector is avoided.

2. A solar energy plant according to claim **1**, characterized in that the additional reflector is in the form of a mirror having a curved shape so as to ensure that a distribution of angles of incidence of the radiation is substantially limited.

3. A solar energy plant according to claim **2**, characterized in that the additional reflector is a convex mirror mounted in front of the focal point.

4. A solar energy plant according to claim **2**, characterized in that the additional reflector is a concave mirror mounted behind the focal point.

5. A solar energy plant according to claim **4**, characterized in that the dielectric mirror is of the beam-splitter type so that all the non-reflected radiation is transmitted.

6. A solar energy plant according to claim **5**, characterized in that the dielectric mirror is highly reflective so that all the losses of the reflector are transmission losses.

7. A solar energy plant according to claim **4**, characterized in that the dielectric mirror is provided with a highly reflective metallic back coating and is adapted to enhance the reflectivity of said coating.

8. A solar energy plant according to claim **7**, characterized in that the dielectric mirror is fabricated so as to be color selective.

9. A solar energy plant according to claim **8**, characterized in that the color selective dielectric mirror is of a bandpass type.

10. A solar energy plant according to claim **9**, characterized in that the dielectric mirror is segmented.

11. A solar energy plant according to claim **10**, characterized in that the dielectric mirror is of the Fresnel type.

12. A solar energy plant according to claim **11**, comprising a secondary concentrator placed between said additional reflector and said at least one solar receiver.

13. A solar energy plant according to claim **12**, characterized in that said secondary concentrator is of the imaging type.

14. A solar energy plant according to claim **12**, characterized in that said secondary concentrator is of the non-imaging type.

15. A solar energy plant according to claim **14**, characterized in that said secondary concentrator is a compound parabolic concentrator.

16. A solar energy plant according to claim **14**, characterized in that said secondary concentrator is a tailored edge-ray concentrator.

17. A solar energy plant according to claim **16**, characterized in that the Fresnel reflector is located in a base plane that is inclined relative to the horizontal in a fashion that reduces the angle between incident solar radiation and a normal to the base plane.

18. A solar energy plant according to claim **17**, characterized in that said at least one receiver is distanced from said Fresnel reflector and said additional reflector is tilted so as to redirect radiation onto said receiver.

19. A solar energy plant according to claim **18**, comprising means for extracting utilizable energy from said additional reflector.

20. A solar energy plant according to claim **19**, characterized in that said at least one solar receiver is associated with a heat engine and electric generator.

21. A solar energy plant according to claim **19**, characterized in that said at least one solar receiver is a light pumped laser device.

22. A solar energy plant according to claim **19**, characterized in that said al least one solar receiver is a chemical reactor.

23. A solar energy plant according to claim **22**, characterized in that said at least one solar receiver is a photochemical reactor.

24. A solar energy plant according to claim **19**, characterized in that said at least one solar receiver is a photovoltaic system.

25. A solar energy plant according to claim **19**, characterized in that said at least one solar receiver is associated with means for the extraction of utilizable heat.

26. A solar energy plant according to claim **19**, characterized in that said at least one solar receiver is associated with an energy storage system.

27. A solar energy plant according to claim **19**, characterized in that said at least one solar receiver is a heat storage tank.

28. A solar energy plant according to claim **27**, characterized in that the ratio between the distance of the additional reflector from said focal point and the focal length of the heliostats field is within the range of from about 1:5 to about 1:10.

29. A solar energy plant according to claim **28**, characterized in that the ratio between the diameter of the additional reflector and the heliostats field is about 1:10.

30. A solar energy plant according to claim **29**, characterized in that it comprises at least two solar receivers.

31. A solar energy plant according to claim **30**, characterized in that at least one of said solar receivers is placed in the focal region of said heliostats field.

32. A solar energy plant according to claim **31**, comprising at least one supplementary reflector placed between said additional reflector and at least one of said solar receivers.

33. A solar energy plant according to claims **30**, comprising at least one supplementary reflector placed between said additional reflector and at least one of said solar receivers.

34. A solar energy plant according to claim **33**, characterized in that said at least one supplementary reflector is of the dielectric mirror type.

35. A solar energy plant according to claim **33**, characterized in that said at least one supplementary reflector is of the beam-splitter type.

36. A solar energy plant according to claim **35**, characterized in that said at least one supplementary reflector is fabricated so as to be color selective.

37. A solar energy plant according to claim **36**, characterized in that said at least one supplementary color selective reflector is of the bandpass type.

38. A solar energy plant according to claim **37**, characterized in that said at least one supplementary color selective reflector has different bandpasses for different solar receivers.

39. A solar energy plant according to claim **38**, characterized in that said at least one receiver holds a working fluid for a withdrawal of absorbed heat and the plant comprises intermediary between said additional reflector and said receiver, a plurality of non-imaging secondary concentrators arranged in concentric zones, each secondary concentrator associated with a dedicated aperture in said receiver, whereby concentric zone of different temperature are formed inside the receiver and the working fluid is gradually heated when passing from the outermost zone with the lowest temperature to the innermost zone with the highest temperature.

40. A solar energy plant according to claim **39**, characterized in that the receiver comprises a plurality of receiver units each having one aperture.

41. A solar energy plant according to claim **39**, characterized in that the receiver comprises one single receiver unit with a plurality of apertures.

42. A solar energy plant according to claim **41**, characterized in that the plant comprises means for monitoring a displacement of said additional reflector and means for dynamic adjustment of the heliostats so as to track the displacement of the reflector whereby any impairment of the performance of the plant in consequence of reflector displacement is avoided.

43. A solar energy plant according claim **42**, characterized in that said monitoring means is a laser device.

44. A solar energy plant according claim **42**, characterized in that said monitoring means is a TV imaging system.

45. A solar energy plant according to claim **1**, wherein said additional reflector is disposed at an altitude at which intensive cooling of the reflector is not practical.

46. A solar energy plant for conversion of solar radiation of the kind that comprises a working fluid for the withdrawal of absorbed heat, comprising a Fresnel reflector consisting of a plurality of concentrating mirrors installed on a base plane and having a focal point above said base plane removed from the Fresnel reflector by a focal length, at least one solar receiver assembly placed close to said base plane and holding said working fluid and an additional reflector mounted above said Fresnel reflector close to said focal point whereby concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver assembly, characterized in that the plant comprises intermediary between said additional reflector and said at least one solar receiver, a plurality of non-imaging secondary concentrators arranged in concentric zones, each secondary concentrator associated with a dedicated aperture in said receiver assembly, whereby concentric zones of different temperature are formed inside the receiver and the working fluid is gradually heated when passing from the outermost zone with the lowest temperature to the innermost zone with the highest temperature.

47. A solar energy plant according to claim **46**, characterized in that the receiver assembly comprises a plurality of receiver units each having one aperture.

48. A solar energy plant according to claim **46**, characterized in that the receiver assembly comprises one single receiver unit with a plurality of apertures.

49. A solar energy plant of the kind comprising a Fresnel reflector consisting of a plurality of concentrating mirrors installed on a base plane and having a focal point above said base plane removed from the Fresnel reflector by a focal length, at least one solar receiver placed close to said base plane and an additional reflector mounted on a tower close to said focal point whereby concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver, characterized in that the plant comprises means for monitoring a displacement of said additional reflector, which monitoring means may be in the form of laser scanning device or TV imaging system, and means for dynamic adjustment of the heliostats so as to track the displacement of the reflector whereby any impairment of the performance of the plant in consequence of reflector displacement is avoided.

50. A solar energy plant according to claim **49**, characterized in that said monitoring means is a laser scanning device.

51. A solar energy plant according to claim **48**, characterized in that said monitoring means is a TV imaging system.

52. A solar energy plant for conversion of solar radiation into heat, comprising:

a Fresnel reflector including a plurality of radiation concentrating mirrors installed on a base plane and having a focal point above said base plane removed from the Fresnel reflector by a focal length;

at least one solar receiver placed close to said base plane; and

an additional reflector mounted above said Fresnel reflector close to said focal point so that concentrated solar radiation reflected by the Fresnel reflector is redirected onto said at least one solar receiver;

wherein said at least one solar receiver is in the form of a heat storage system and said additional reflector comprises a dielectric mirror, whereby an overheating of the additional reflector is avoided.

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(54) **ARRAY MODULE OF PARABOLIC SOLAR ENERGY RECEIVERS**

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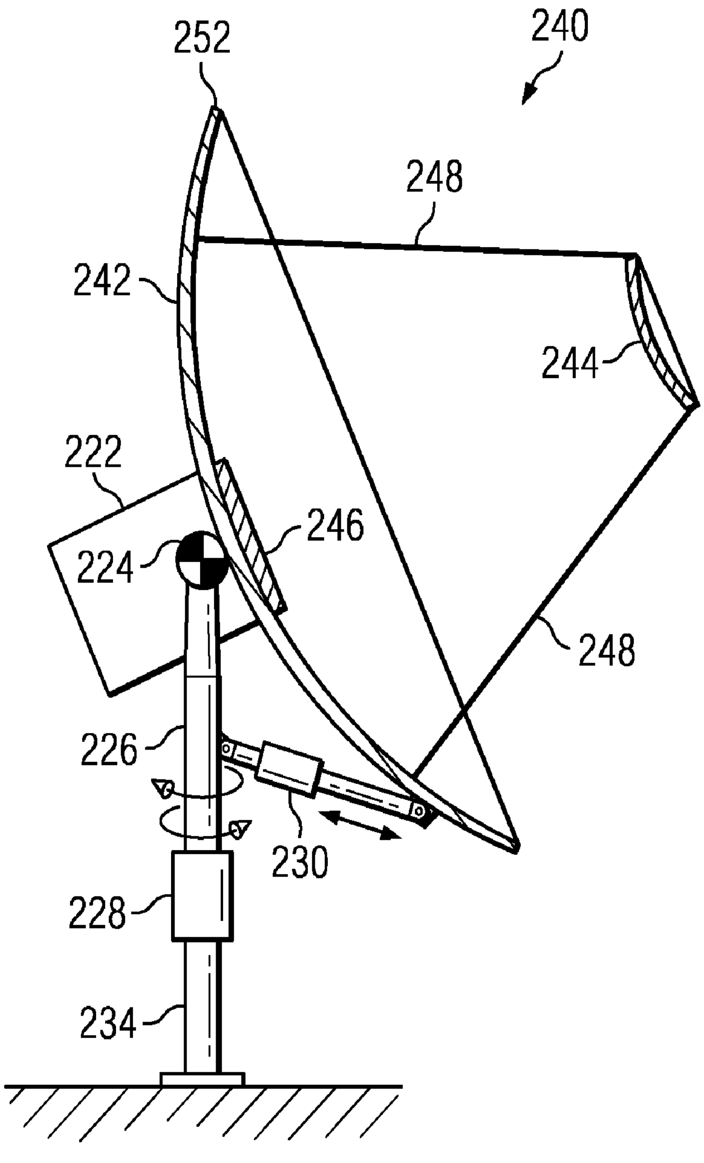
(52) **U.S. Cl.** **136/246**; 136/259

(57) **ABSTRACT**

A solar energy receiver array comprises a plurality of solar energy receivers arranged in an X by Y array. A protected housing includes a plurality of sides defining an opening therein. The plurality of solar energy receivers are arranged in the X by Y array may be lowered into the opening within the protective housing to protect the plurality of solar energy receivers arranged in the X by Y array from external winds.



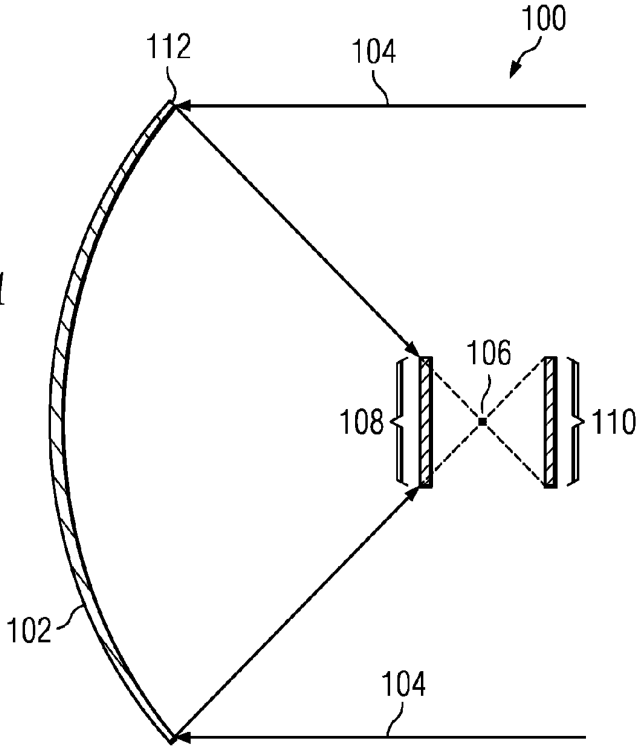


FIG. 1A

100
112
104
106
108
110
102
104

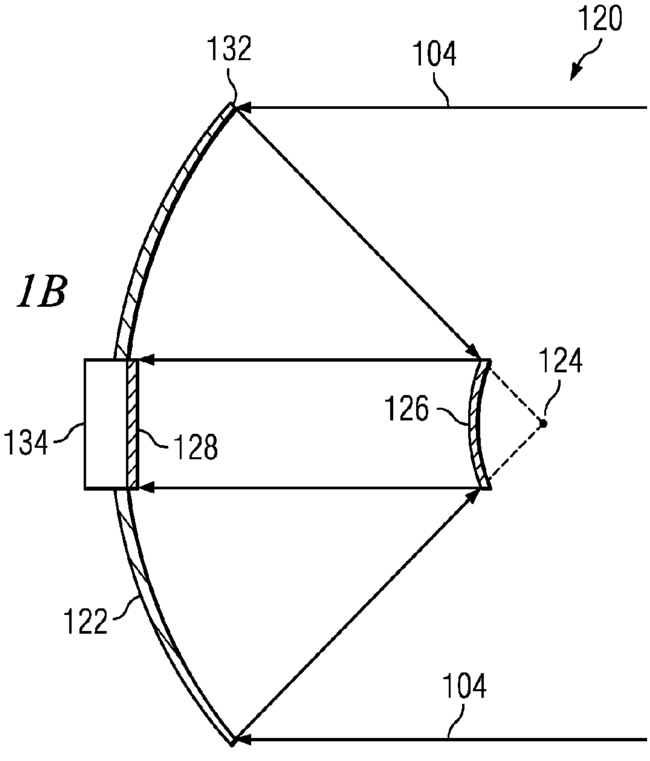


FIG. 1B

120
132
104
124
126
134
128
122
104

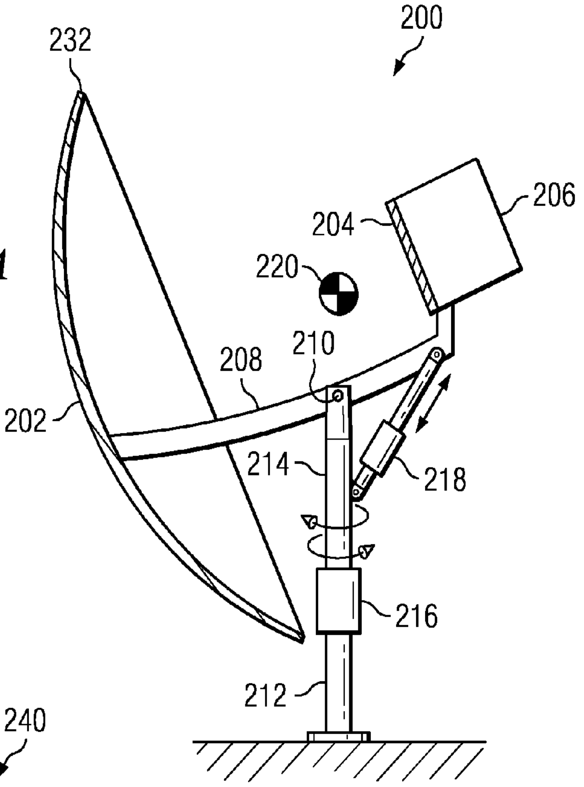

200
232
206
204
220
210
208
202
214
218
216
212

FIG. 2A

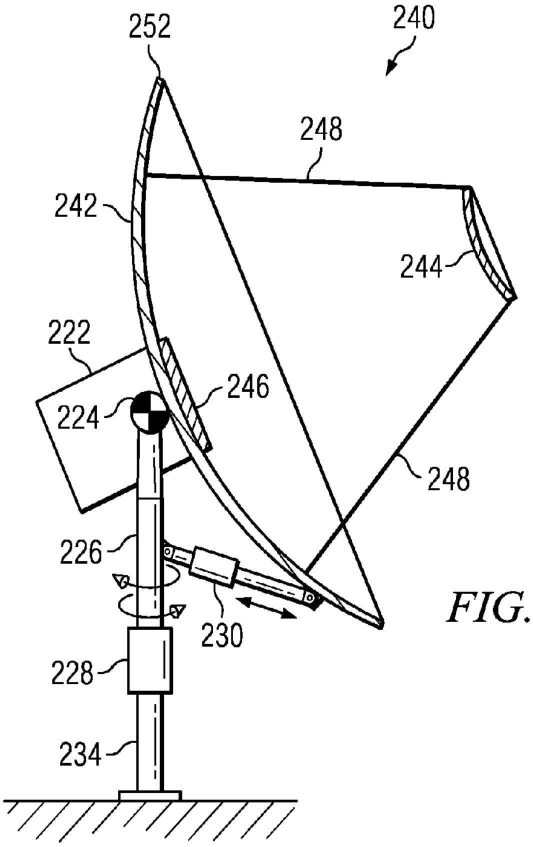

240
252
248
242
244
222
246
224
248
226
230
228
234

FIG. 2B

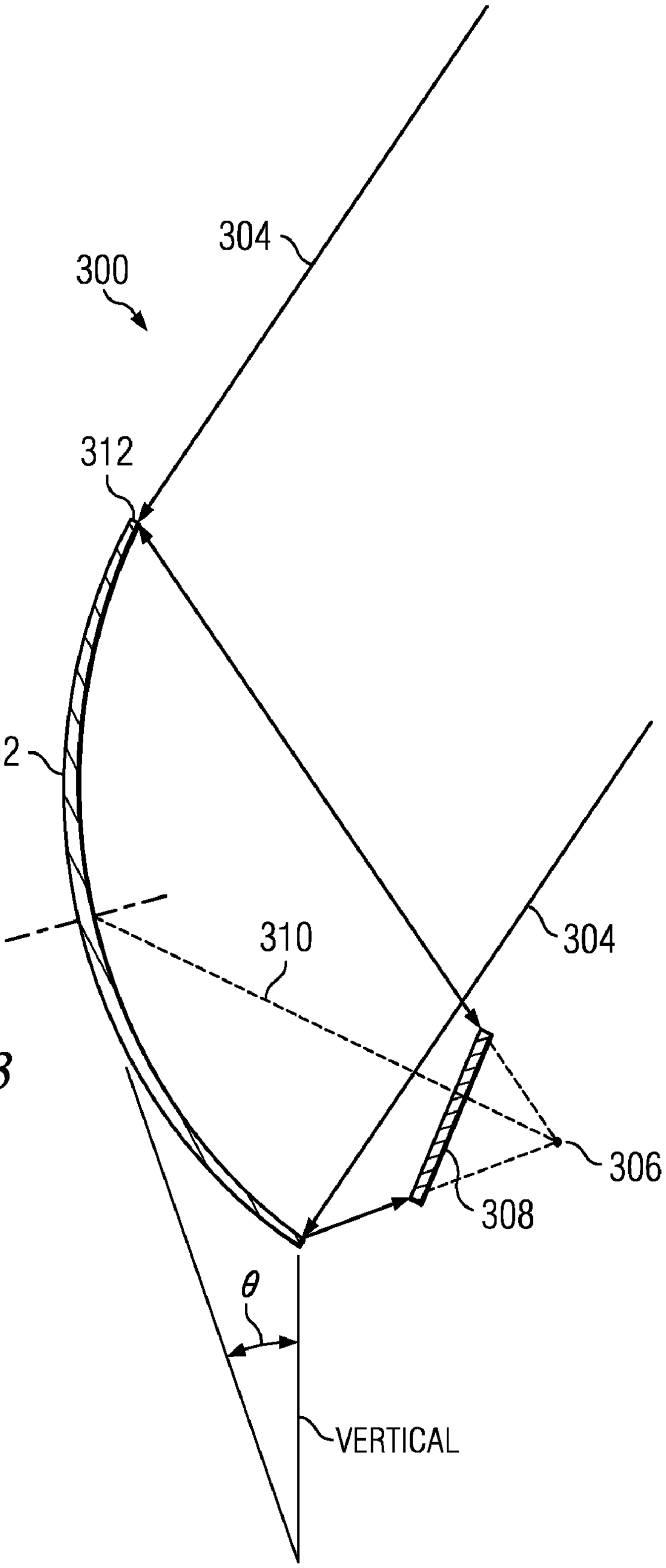


FIG. 3

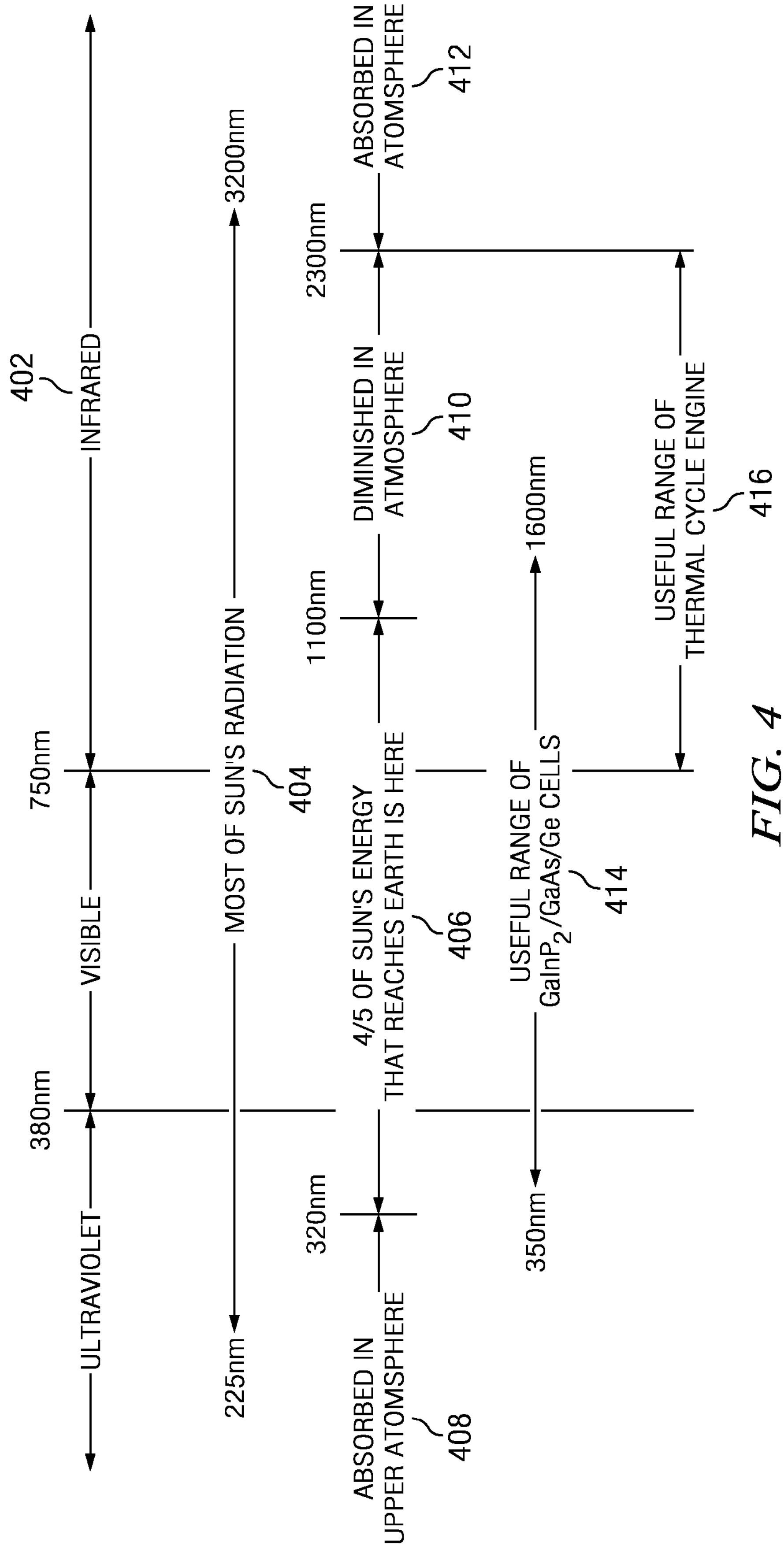

ULTRAVIOLET
380nm
VISIBLE
750nm
INFRARED
402
225nm
MOST OF SUN'S RADIATION
404
3200nm
ABSORBED IN UPPER ATOMSPHERE
408
320nm
4/5 OF SUN'S ENERGY THAT REACHES EARTH IS HERE
406
1100nm
DIMINISHED IN ATMOSPHERE
410
2300nm
ABSORBED IN ATOMSPHERE
412
350nm
USEFUL RANGE OF $GaInP_2$/GaAs/Ge CELLS
414
1600nm
USEFUL RANGE OF THERMAL CYCLE ENGINE
416

FIG. 4

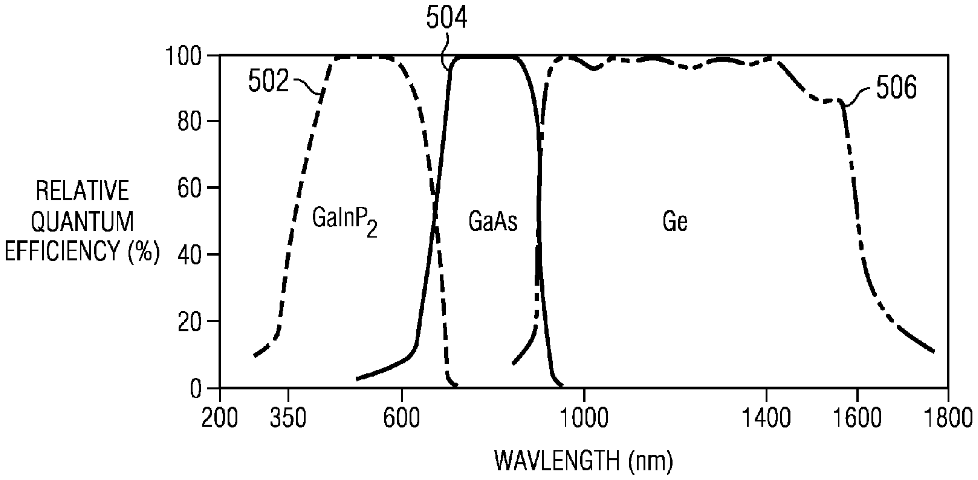

504
502
506
100
80
60
40
20
0
RELATIVE QUANTUM EFFICIENCY (%)
GaInP$_2$
GaAs
Ge
200
350
600
1000
1400
1600
1800
WAVLENGTH (nm)

FIG. 5

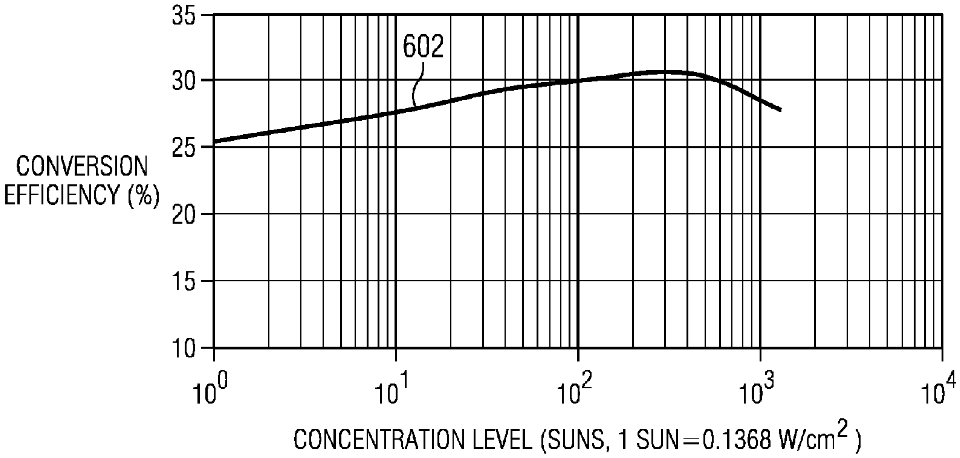

35
30
25
20
15
10
602
CONVERSION EFFICIENCY (%)
10^0
10^1
10^2
10^3
10^4
CONCENTRATION LEVEL (SUNS, 1 SUN=0.1368 W/cm^2)

FIG. 6

FIG. 7A

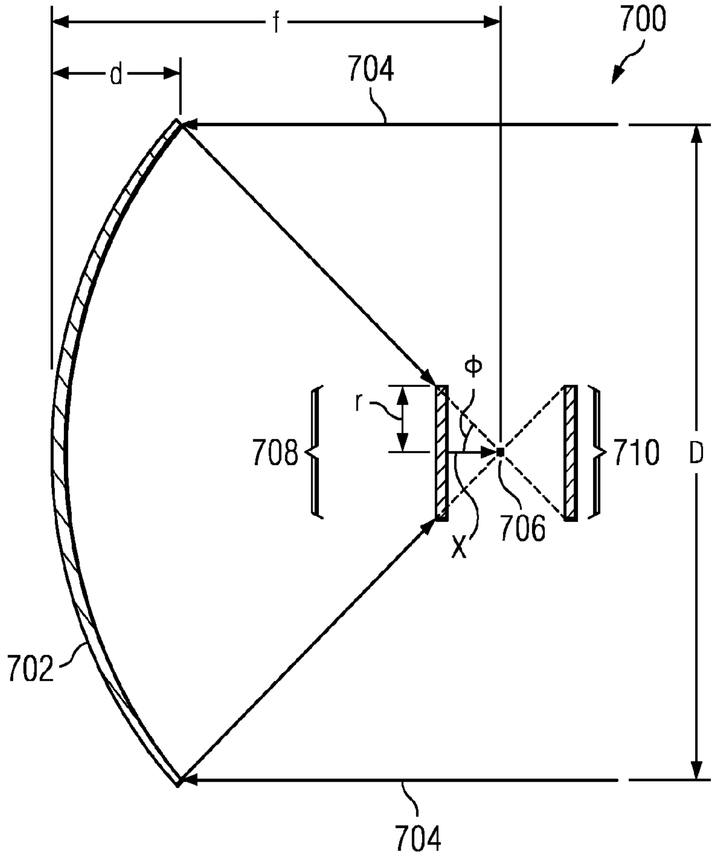
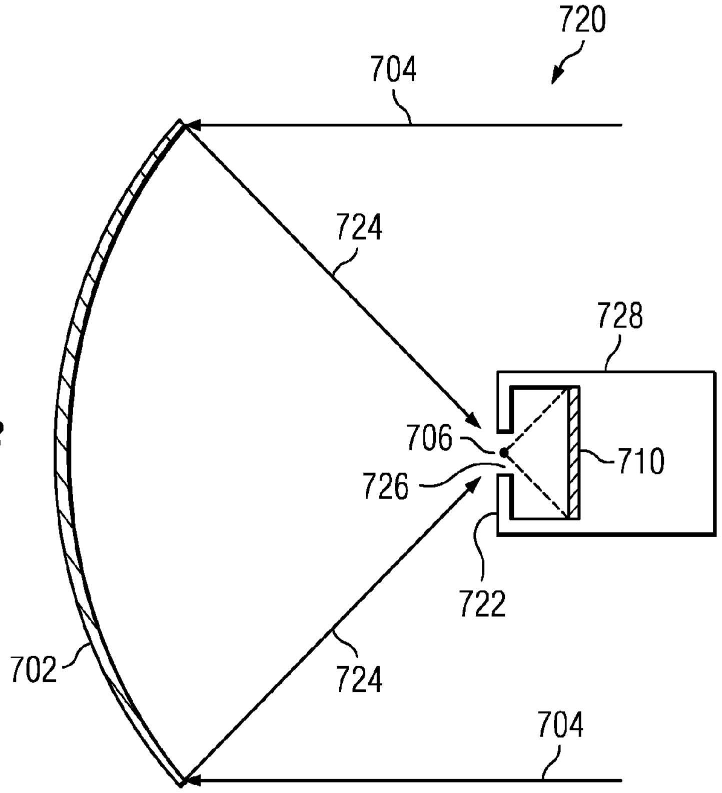

700
f
d
704
Φ
r
708
710
D
706
X
702
704

FIG. 7B


720
704
724
728
706
710
726
722
702
724
704

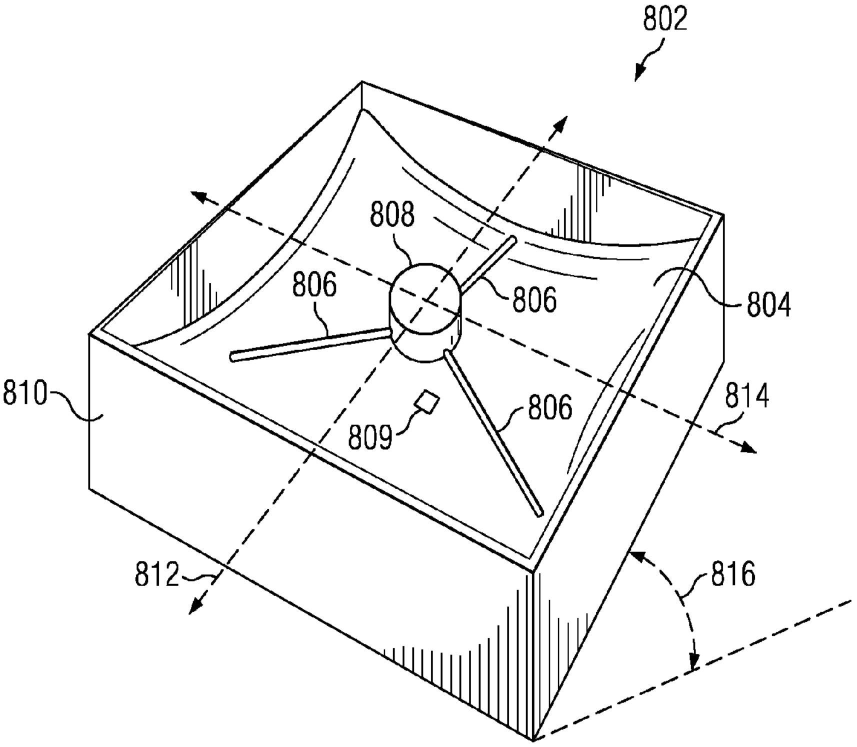


FIG. 8

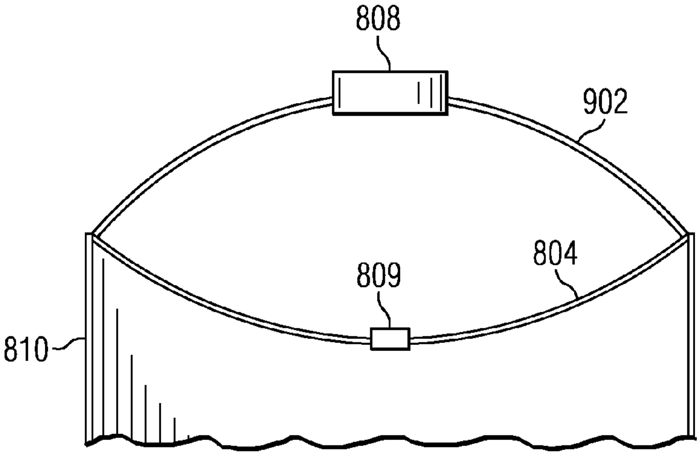


FIG. 9

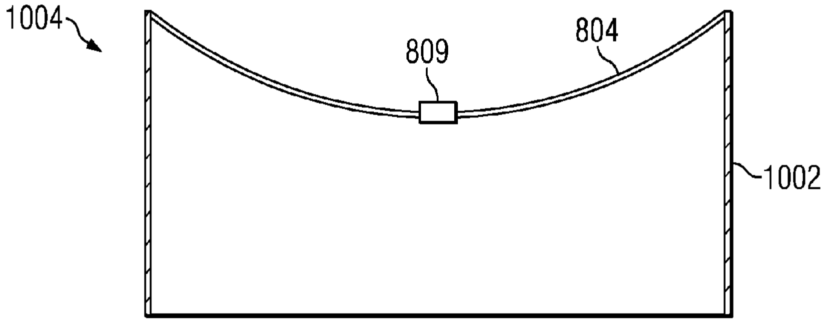

1004
809
804
1002

FIG. 10

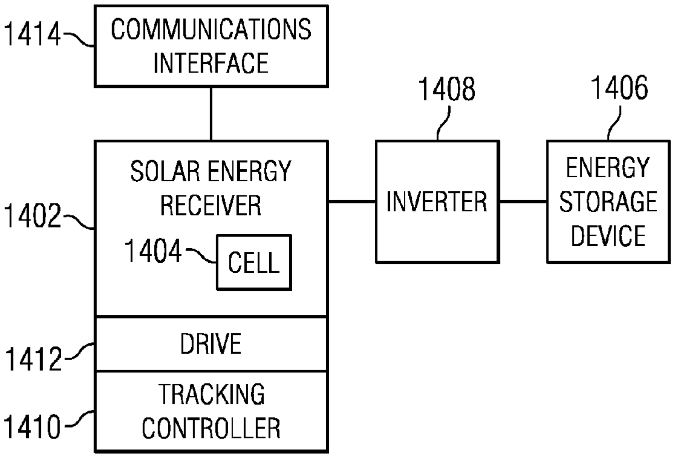

1414
COMMUNICATIONS INTERFACE
1408
1406
1402
SOLAR ENERGY RECEIVER
1404
CELL
INVERTER
ENERGY STORAGE DEVICE
1412
DRIVE
1410
TRACKING CONTROLLER

FIG. 14

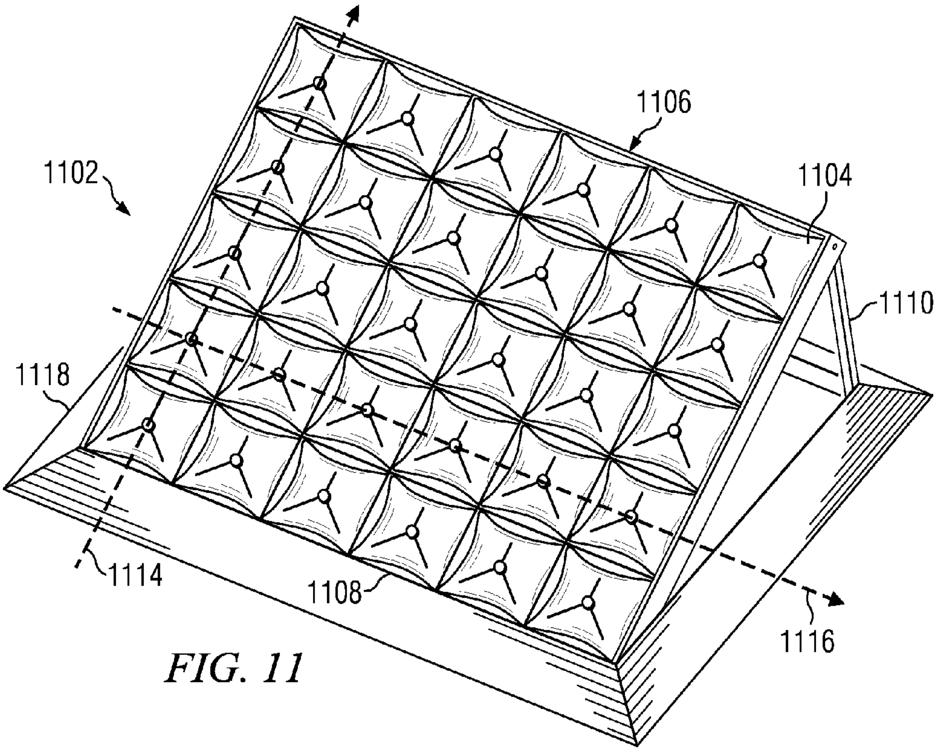


FIG. 11

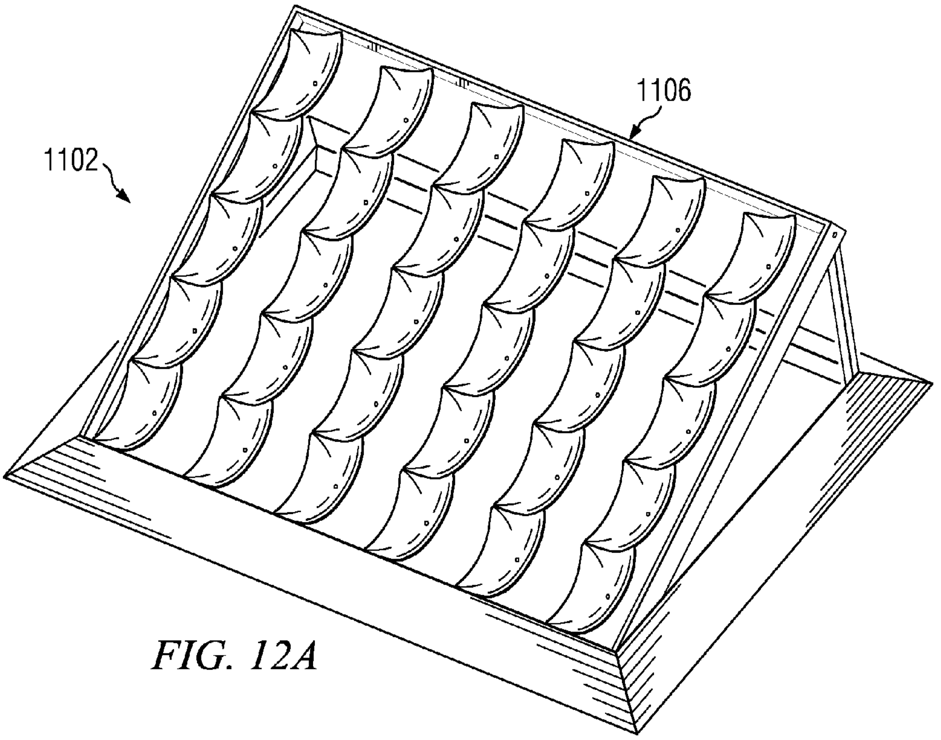


FIG. 12A

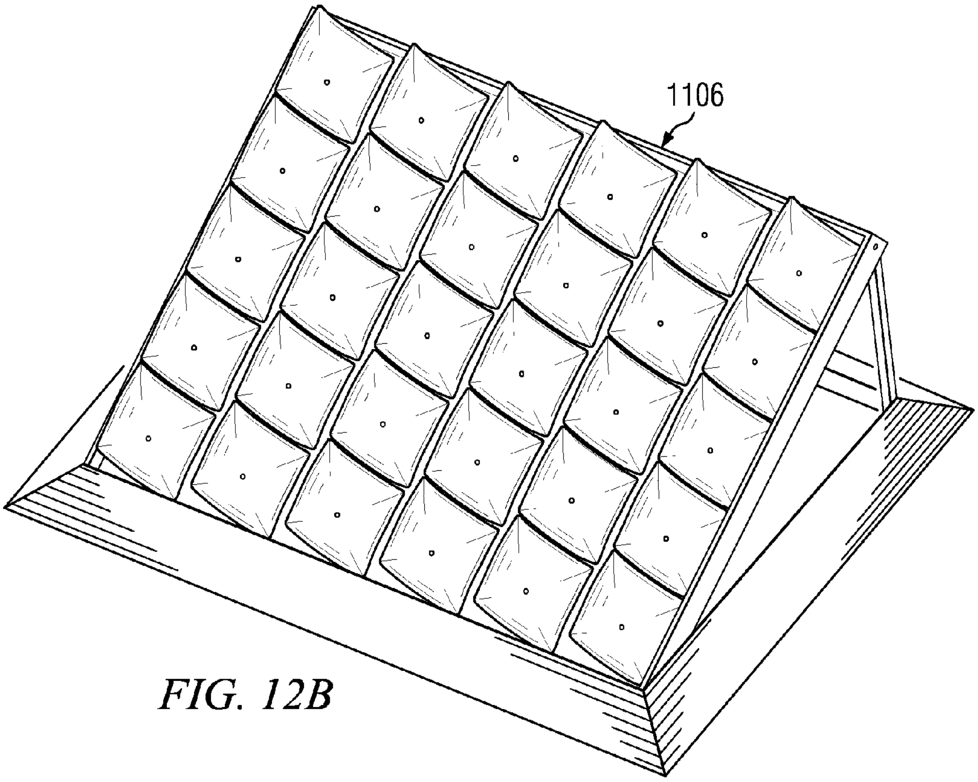


FIG. 12B

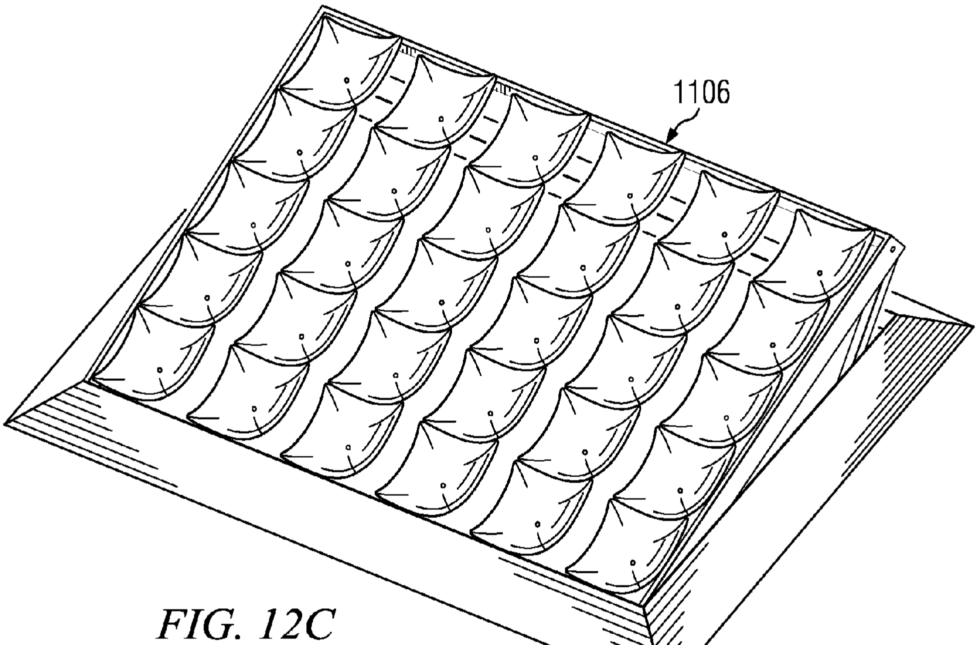


FIG. 12C

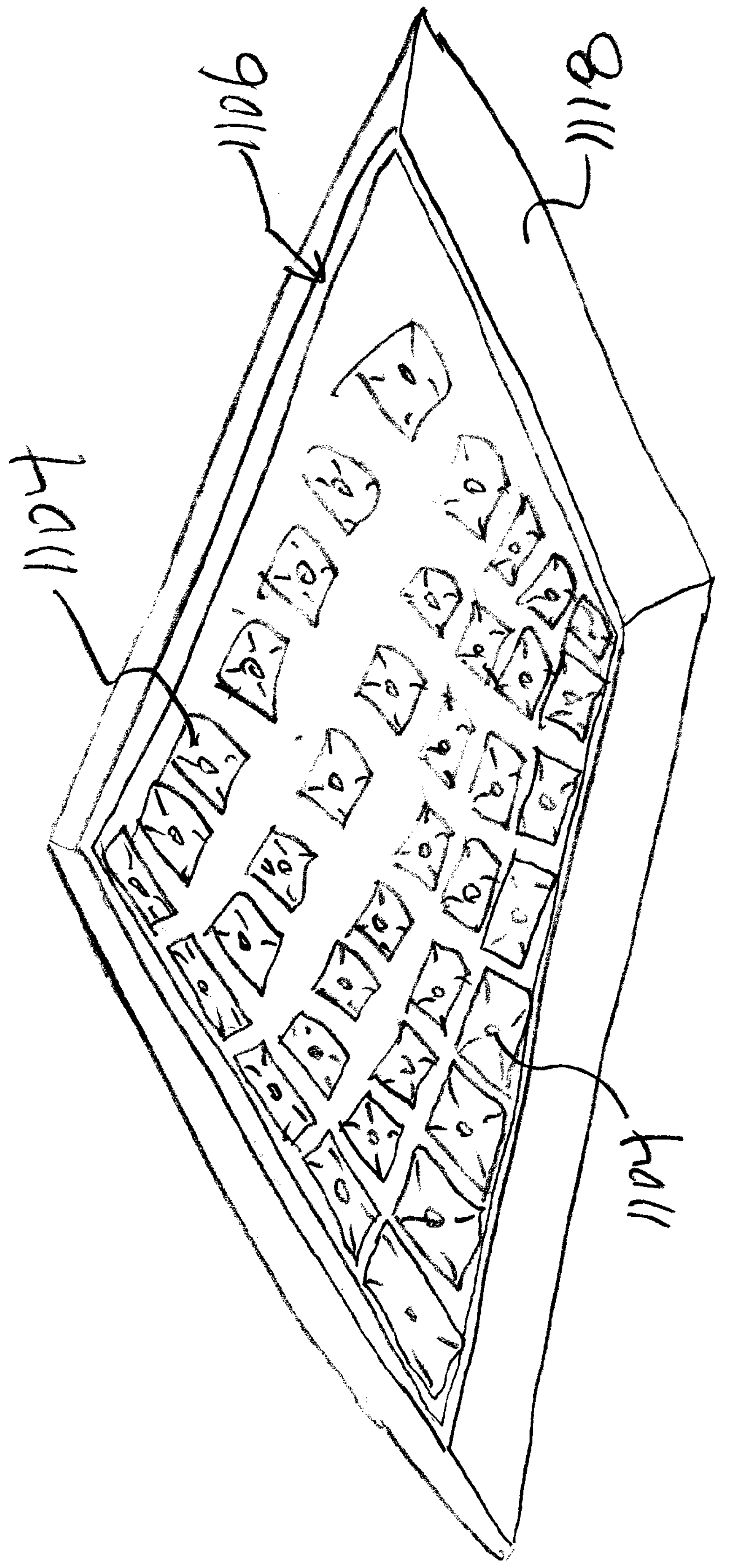


Fig 12D

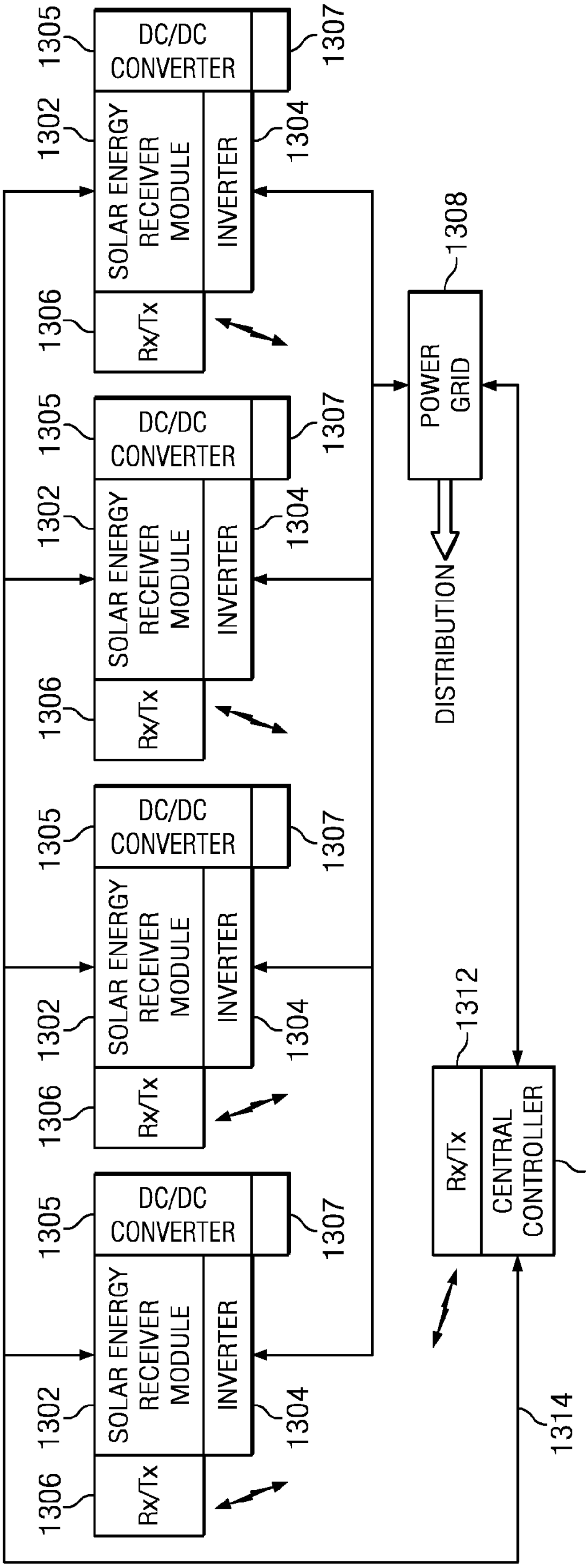

1306
Rx/Tx
1302
SOLAR ENERGY RECEIVER MODULE
1304
INVERTER
1305
DC/DC CONVERTER
1307
1306
Rx/Tx
1302
SOLAR ENERGY RECEIVER MODULE
1304
INVERTER
1305
DC/DC CONVERTER
1307
1306
Rx/Tx
1302
SOLAR ENERGY RECEIVER MODULE
1304
INVERTER
1305
DC/DC CONVERTER
1307
1306
Rx/Tx
1302
SOLAR ENERGY RECEIVER MODULE
1304
INVERTER
1305
DC/DC CONVERTER
1307
1314
Rx/Tx
1312
CENTRAL CONTROLLER
1310
DISTRIBUTION
POWER GRID
1308

FIG. 13

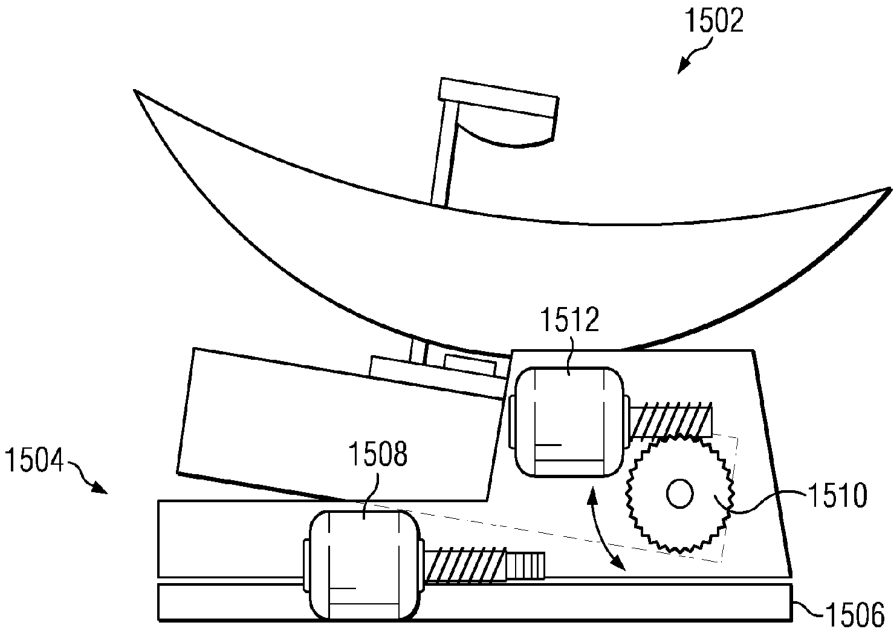


FIG. 15

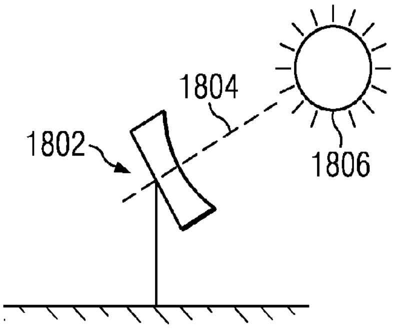


FIG. 18a

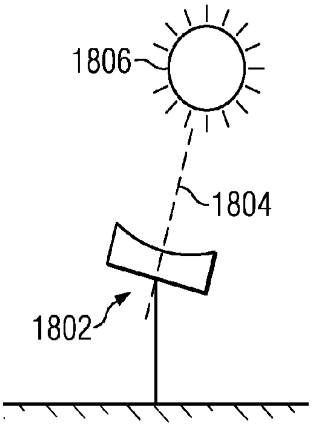


FIG. 18b

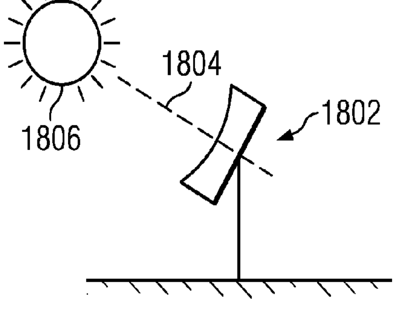


FIG. 18c

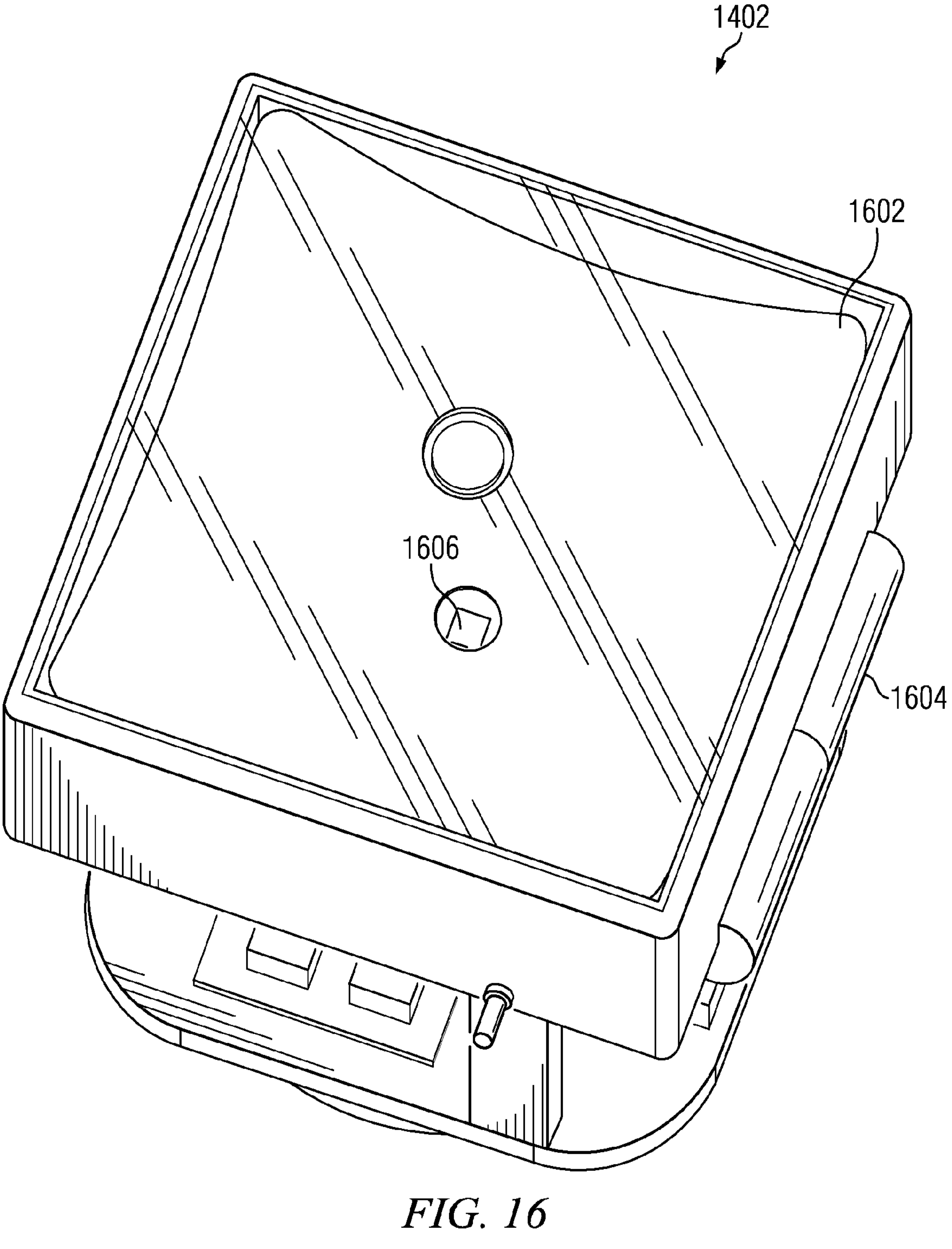


FIG. 16

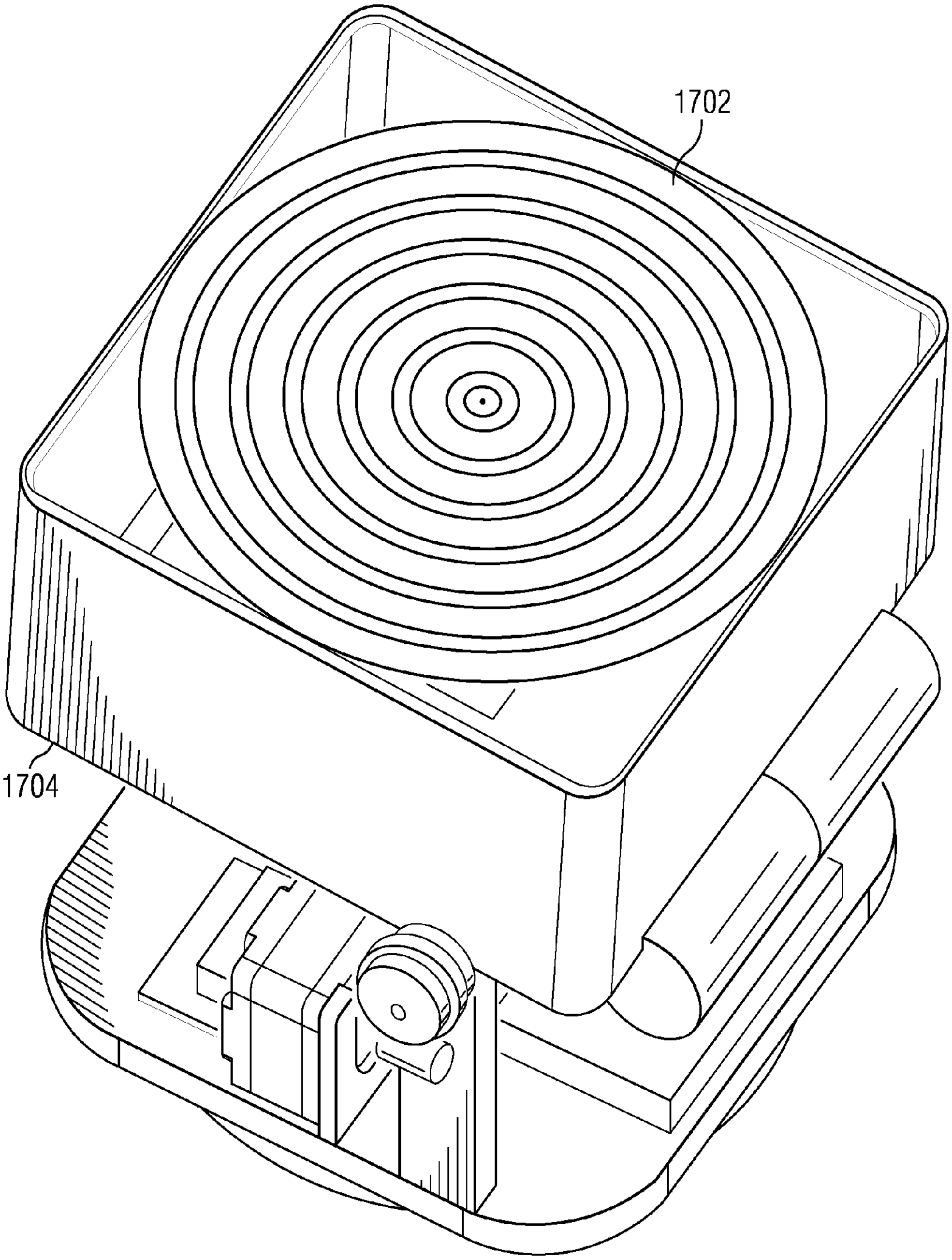


FIG. 17

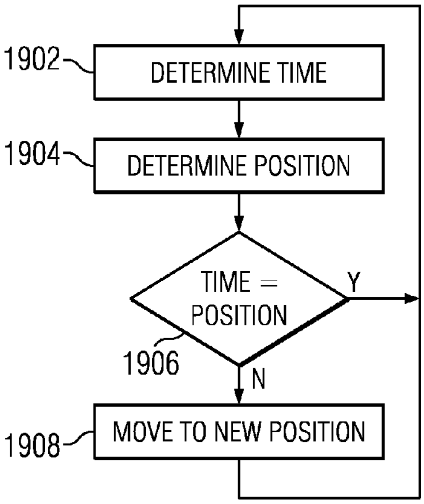


FIG. 19

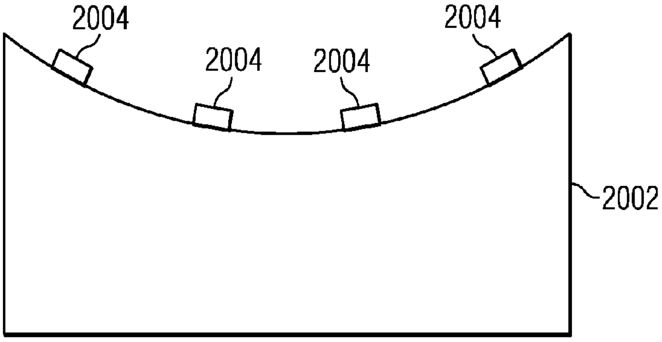


FIG. 20

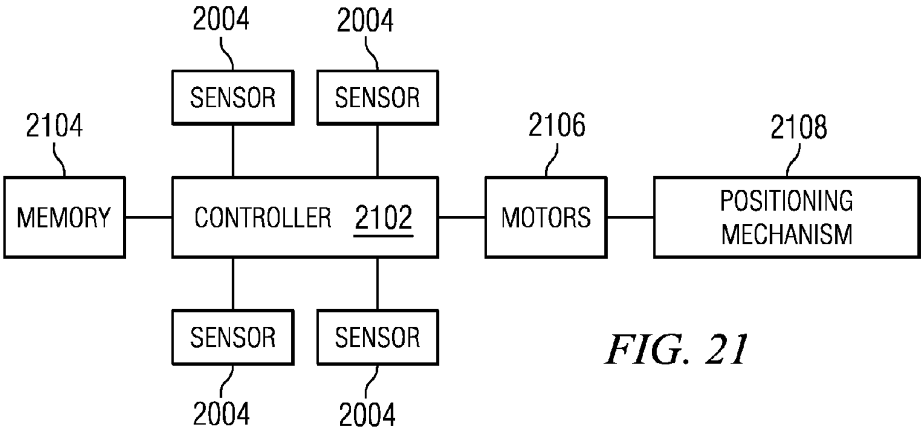


FIG. 21

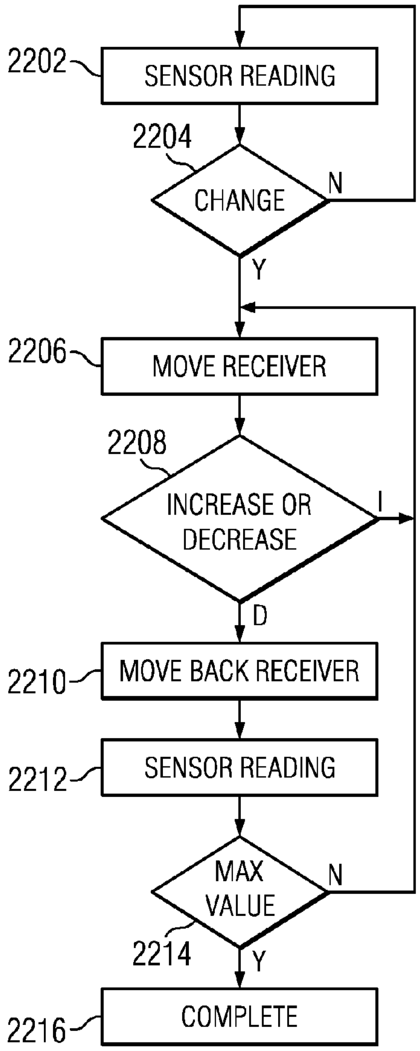

2202
SENSOR READING
2204
CHANGE
N
Y
2206
MOVE RECEIVER
2208
INCREASE OR DECREASE
I
D
2210
MOVE BACK RECEIVER
2212
SENSOR READING
MAX VALUE
N
2214
Y
2216
COMPLETE

FIG. 22

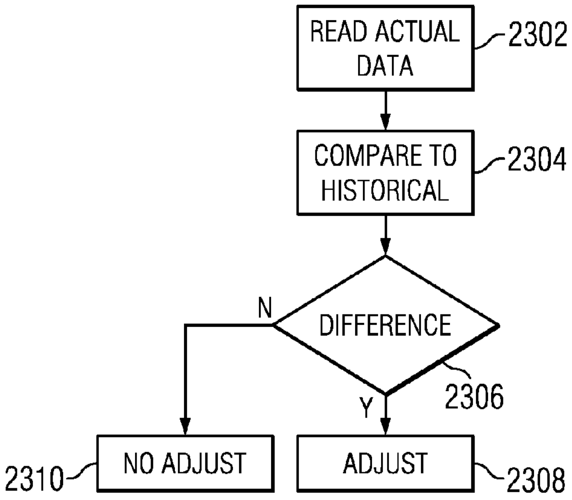
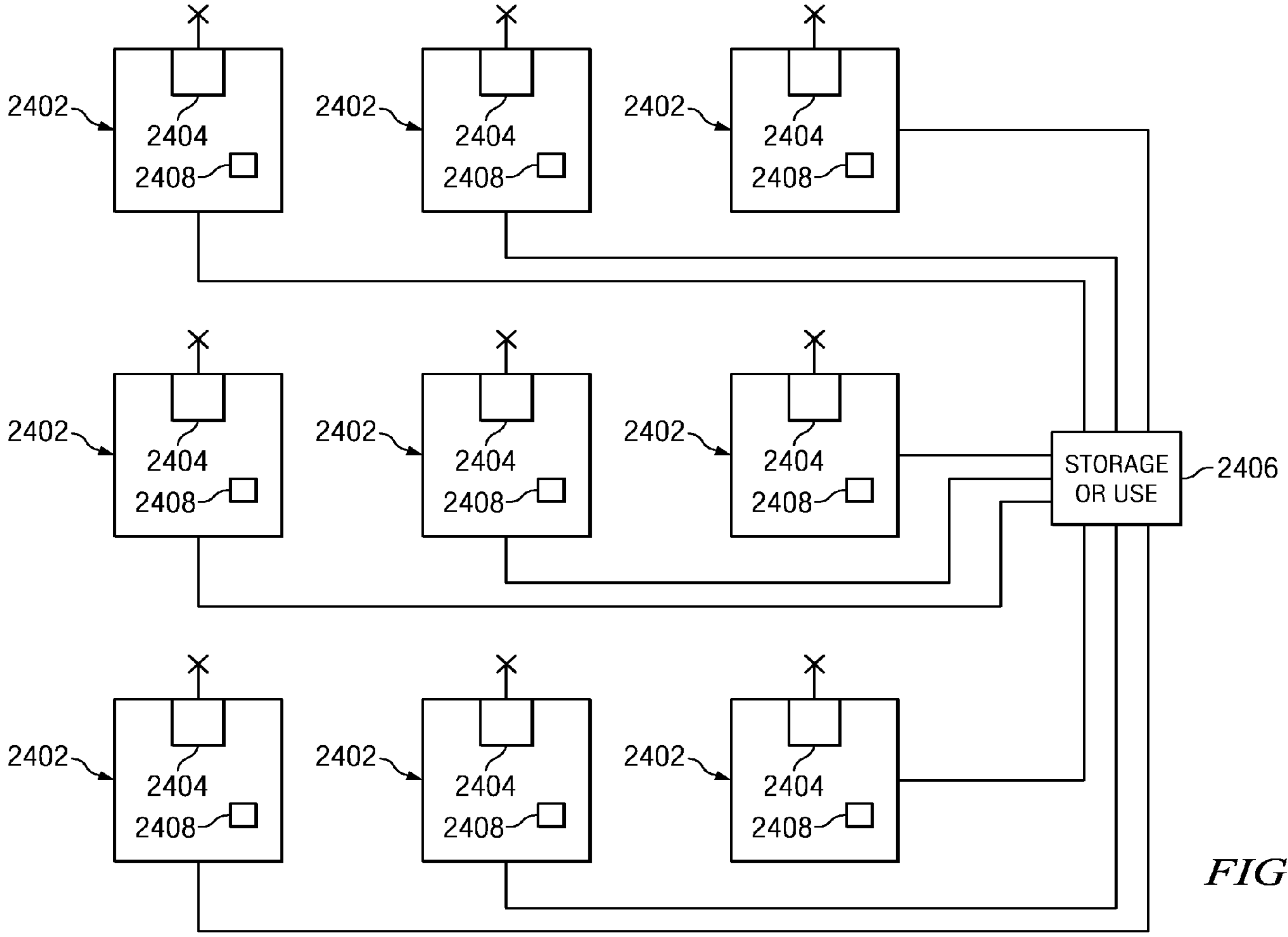

READ ACTUAL DATA
2302
COMPARE TO HISTORICAL
2304
N
DIFFERENCE
2306
Y
2310
NO ADJUST
ADJUST
2308

FIG. 23


2402
2404
2408
2402
2404
2408
2402
2404
2408
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2408
2402
2404
2408
2402
2404
2408
2402
2404
2408
2402
2404
2408
2402
2404
2408
STORAGE OR USE
2406

FIG. 24

ARRAY MODULE OF PARABOLIC SOLAR ENERGY RECEIVERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 61/295,488, filed Jan. 15, 2010, and entitled "SELF-TRACKING ARRAY OF CPV PARABOLIC SOLAR ENERGY RECEIVERS WHICH EMBODIES 3 AXES OF ORIENTATION," the specification of which is incorporated herein by reference. This application also claims the benefit of U.S. Provisional Application Ser. No. 61/389,593, filed Oct. 4, 2010, and entitled "ARRAY MODULE OF PARABOLIC SOLAR ENERGY RECEIVERS WITH MICRO-POD DEVICE," the specification of which is incorporated herein by reference. This application is related to U.S. Pat. No. 6,818,818, which issued on Nov. 16, 2004 and is entitled "CONCENTRATING SOLAR ENERGY RECEIVER," the specification of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to solar energy conversion, and more particularly, to arrays of self-tracking concentrating solar energy receivers.

BACKGROUND

[0003] Devices for solar energy collection and conversion can be classified into concentrating types and non-concentrating types. Non-concentrating types intercept parallel unconcentrated rays of the sun with an array of detection or receiving devices such as a solar panel of photovoltaic cells or hot water pipes, for example. The output is a direct function of the receiving area of the rays. A concentrating type of solar energy collector focuses the energy rays using, e.g., a parabolic reflector or lens assembly to concentrate the rays, creating a more intense beam of energy. The beam is concentrated to improve the efficiency of conversion of solar radiation to electricity or to increase the amount of heat energy collected from the solar radiation to provide for heating of water and so forth. In a conventional concentrating solar energy receiver, the incident solar radiation is typically focused at a point from a circular reflector (e.g., a dish reflector) or along a focal line from a cylindrical shaped reflector. In another prior art example, a flat portion in the center of a round, parabolic primary reflector provided by flattening the center portion of the reflector radiates to a predetermined diameter before the parabolic curve glances outward to the rim of the reflector. In this device, the reflected solar energy is focused at a ring corresponding to the outer diameter of the flat central portion of the reflector.

[0004] However, even conventional concentrating solar energy receivers require improvements for two reasons. First, the solar energy conversion module in conventional systems is located directly at the focal point or focal line which have to deposit a very small volume, this small volume causes a high concentration of heat that must be dissipated in the region of the focal point. Secondly, a large portion of the infrared portion of the radiant solar energy spectrum cannot be efficiently converted to electricity by currently available low mass conversion devices such as solar cells. Instead, this excess infrared energy is collected by the reflector and contributes to heating a conversion device which can impair the conversion efficiency of the solar cells.

[0005] Additionally, there is a need to group whichever type of concentrating solar energy receivers are utilized in a configuration array such that the aggregate affect of the energy created by each individual solar energy receiver may be utilized. Alternatively, with array configurations there may be the danger of damages due to external environmental conditions such as high velocity winds. Thus, there is a need for some manner for protecting the solar energy receivers in addition to improving their energy collection and distribution characteristics.

SUMMARY

[0006] The present invention, as disclosed and described herein, in one aspect thereof, comprises a solar energy receiver. The solar energy receiver comprises a plurality of solar energy receivers arranged in an X by Y array. A protective housing includes a plurality of sides defining an opening therein. The plurality of solar energy receivers may be lowered into the opening within the protective housing to protect the plurality of solar energy receivers from external winds.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

[0008] FIG. **1**A illustrates one embodiment of a concentrating solar energy receiver;

[0009] FIG. **1**B illustrates an alternative embodiment of the concentrating solar energy receiver having both a primary reflector and a secondary reflector;

[0010] FIG. **2**A is a pictorial drawing of the embodiment of FIG. **1**A showing the supporting structure for the primary reflector and a corresponding solar to electrical energy conversion module;

[0011] FIG. **2**B is a pictorial drawing illustrating an alternative embodiment of FIG. **1**B showing the supporting structure for the primary and secondary reflectors and the corresponding solar to electrical energy conversion modules;

[0012] FIG. **3** illustrates another alternative embodiment of the concentrating solar energy receiver of FIG. **1**A wherein the focal area is positioned away from the principal axis of the primary reflector;

[0013] FIG. **4** is a graph illustrating the various components and wavelengths of the solar radiation spectrum as compared with the effects of the atmosphere thereon in the conversion and path of several currently available solar energy conversion devices;

[0014] FIG. **5** is a graph showing the typical relative quantum efficiency versus the active wavelength range of a triple junction $GaInP_2/GaAs/Ge$ solar cell;

[0015] FIG. **6** is a graph showing the typical conversion efficiency performance versus the solar energy radiation level for a triple junction solar cell as shown in FIG. **5**;

[0016] FIG. **7**A illustrates a design example for a concentrating solar energy receiver according to the present disclosure;

[0017] FIG. **7**B illustrates an alternative embodiment of FIG. **2**A using a film recycle engine in a solar to electrical energy conversion module;

[0018] FIG. **8** illustrates a solar energy receiver pod;

[0019] FIG. **9** illustrates a transparent cover of a solar energy receiver pod including an integrated secondary reflector;

[0020] FIG. **10** illustrates a side view of an integrated primary reflector and heat sink of a solar energy receiver pod;

[0021] FIG. **11** illustrates a ganged array of solar energy receiver pods utilizing a single common sun tracking mechanism;

[0022] FIGS. **12**A-**12**D illustrates the array of solar energy receiver pods within various positions;

[0023] FIG. **13** is a functional block diagram illustrating the connection of multiple solar energy receiver modules to a power grid and centralized controller;

[0024] FIG. **14** illustrates a further embodiment of a solar energy receiver module;

[0025] FIG. **15** illustrates a side view of a self-tracking solar energy receiver ("pod") rotatable about three different axis;

[0026] FIG. **16** illustrates a two axis implementation of a solar energy receiver using a parabolic dish;

[0027] FIG. **17** illustrates an implementation of a solar energy receiver using a Fresnal lens;

[0028] FIGS. **18**A-C illustrate a solar energy receiver controlled via a tracking algorithm;

[0029] FIG. **19** is a flow diagram describing one possible control algorithm for positioning a solar energy receiver;

[0030] FIG. **20** illustrates a solar energy receiver including light sensors for providing a self-tracking ability;

[0031] FIG. **21** illustrates a block diagram of a control mechanism for controlling tracking of a solar energy receiver via light sensors;

[0032] FIG. **22** is a flow diagram illustrating a control method for a solar energy receiver using light sensors;

[0033] FIG. **23** is a flow diagram describing a method for accounting for misalignment within a tracking algorithm; and

[0034] FIG. **24** illustrates an array of solar energy receivers communicating via wireless communications.

DETAILED DESCRIPTION

[0035] Referring now to the drawings, wherein like reference numbers are used herein to designate like elements throughout, the various views and embodiments of an array module of parabolic solar energy receivers are illustrated and described, and other possible embodiments are described. The figures are not necessarily drawn to scale, and in some instances the drawings have been exaggerated and/or simplified in places for illustrative purposes only. One of ordinary skill in the art will appreciate the many possible applications and variations based on the following examples of possible embodiments.

[0036] Referring now to FIG. **1**A, there is illustrated one embodiment of a concentrating solar energy receiver according to the present disclosure. The concentrating solar energy receiver **100** includes a primary parabolic reflector **102** shown in cross-section, which intercepts solar energy radiation in the form of a plurality of incident rays **104** being reflected from a highly reflective concave side of the primary parabolic reflector **102** toward a focal point **106**. It will be appreciated that the focal point **106** lies along the first or principle focal axis of the primary parabolic reflector **102** and passes through the center of the reflector **102** and substantially perpendicular to a plane tangent to the center of the reflector **102**. This focal axis is not shown in the diagram for clarity, but will be understood to be present as described unless otherwise stated. As is well-known, incident rays **104** from the sun falling within the outer rim **112** of the primary parabolic reflector **102** will be reflected through the focal point **106**. Also shown in FIG. **1**A are a near focal area **108** and a far focal area **110**. These focal areas, which each define a planar region disposed substantially at right angles to the principle focal axis passing through the focal point **106**, are offset or displaced along the principle axis by a predetermined distance either toward the primary parabolic reflector **102** or away from the primary parabolic reflector **102**. The area of a focal area is approximately the same, or slightly larger than, the cross-sectional area of the reflected radiation pattern at the location of the focal plane along the principle axis.

[0037] A focal area in this disclosure is defined as a planar region representing the desired position of a sensor for receiving solar energy for the purpose of converting it to another form. Such focal area regions may also be referred to herein as reception areas or reception surfaces. Reception or solar sensor surfaces are the energy-incident portions of a conversion device or module which receive the incident energy and transfer it to structures in the conversion device or module which convert the incident solar energy to an electrical, mechanical or thermal form. It will be readily appreciated by those skilled in the art that a solar energy sensor having a plane area approximately the size of focal area **108**, or alternatively, focal area **110**, is in a position to intercept all of the reflected incident rays being directed through the focal point **106**. In addition, the reflected solar energy is uniformly distributed at a lower average intensity throughout that focal area. Thus, the solar energy sensor located at a focal area intercepts all of the radiation but intercepts the energy at a uniform, lower intensity which, in practical terms, means that the solar energy sensor is less subject to intensity peaks and can more readily dissipate heat energy that is outside the conversion bandpass of the conversion module. This is because the heat energy contained in the solar radiation is intercepted over a larger area than would exist at the more concentrated focal point. By distributing the received energy evenly over a larger surface, the useful operating life of the conversion module is increased significantly. Thus, a concentrating solar energy receiver configured as shown in FIG. **1**A can be built in a wider variety of sizes with much less severe constraints placed upon the heat dissipation capability of the solar energy conversion module that is utilized in the concentrating solar energy receiver of the present disclosure. It will be apparent from the description which follows that some of the parameters which may be adjusted to provide various output levels are the size of the primary reflector, the size of the solar sensor, the position or offset of the solar sensor from the focal point, the way in which heat dissipation is provided, etc.

[0038] Continuing with FIG. **1**A, the primary parabolic reflector **102** shown in FIG. **1**A in cross section may in general be of circular shape, that is, the rim **112** when viewed looking toward the concave surface of the primary parabolic reflector **102** appears as a circle. As is well known, this is an efficient shape for receiving incident solar energy radiation. However, the concentrating solar energy receiver **100** of the present disclosure is not limited to a circular primary reflector **102** but could be other geometric shapes such as an ellipse, an oval, a rectangle (i.e., a cylindrical reflector), a polygon or an array of regular polygons or any other closed plane figure with a parabolic surface. Such an array of panel segments could be a composite of contiguous shapes placed edge-to edge or a composite of reflecting elements arranged in proximity to one another or a composite of reflecting elements arranged in predetermined positions though not necessarily close together. Further, the individual panel segments may have a flat or curved surface. The primary reflector may be constructed of any material in which the desired parabolic shape may be maintained. Some examples of suitable materials include metals, such as polished aluminum, steel with nickel or chromium plating; glass, with or without a silvered coating (as in a mirror); ceramics or other composites such as fiberglass, graphite, polymers or plastics having a reflective coating or plating; or any other material that meets the structural and reflective properties required of a parabolic reflector. In some applications, a reflective sheet or membrane having sufficient support to maintain a parabolic shape may be used as a reflector. However, it will be appreciated by persons skilled in the art that a lightweight metal such as aluminum offers a number of advantages such as high strength-to-weight ratio, ease of manufacture, ability to provide a polished, highly reflective finish and the ability to conduct heat away from any structure that is mounted thereon. Some of the various construction variations will be described in detail hereinbelow.

[0039] Continuing with FIG. **1**A, the solar energy conversion module, which may be used with the primary parabolic reflector **102** and which has a planar solar energy sensor to be positioned within one or the other of the focal areas **108**, **110**, may be of several basic types. These may include, illustratively, an array of one or more photovoltaic solar cells or a thermal cycle engine coupled to an electric generator, for example. In this description, an electric generator may refer to any device which converts solar or mechanical or thermal energy to direct or alternating current electricity. Further, an electric generator includes an alternator. The specific solar energy conversion module that may be used in the embodiment of FIG. **1**A is not shown therein for clarity, the purpose of FIG. **1**A being to illustrate the principle of positioning the solar sensor portion of the conversion module at a predetermined distance from the actual focal point of the primary parabolic reflector **102**. As will become apparent hereinbelow, the choice of which focal area **108** or **110** is selected for a particular application will become clear as various embodiments of the concentrating solar energy receiver **100** are further described.

[0040] In a preferred embodiment of the concentrating solar energy receiver shown in FIG. **1**A, a photovoltaic solar cell conversion module includes one or more triple junction solar cells, specifically triple junction $GaInP_2/GaAs/Ge$ solar cells. Such solar cells currently available are capable of operating with intensities of solar radiation of up to several hundred suns, where one sun equals 0.1368 watts per centimeter squared (W/cm^2). Solar cells suitable for use in the concentrating solar energy receiver of the present disclosure include devices manufactured by EMCORE Photovoltaics of Albuquerque, N. Mex. or Spectrolab, Inc., a division of the Boeing Company located in Sylmar, Calif. The solar energy sensor for a conversion device will typically be made up of an array of solar cells of the type described in the foregoing, arranged in a planar array to be positioned in the plane of the focal area chosen. It is essential to ensure that the solar sensor be carefully positioned so that the sunlight reflected from the primary reflector is uniformly distributed throughout the focal area and is uniformly distributed upon the surface of the solar cell array. Failure to ensure a uniform distribution of reflected energy can result in damage to the conversion module.

[0041] Generally speaking, the focal area **108** is preferred for the location of the solar sensor of the conversion module. However, the focal area **110** is preferable when a thermal cycle engine is selected as the conversion device because that location enables the conversion device, that is the thermal cycle engine, to be fully enclosed within a housing having an aperture positioned to surround the focal point **106**. This configuration, which is illustrated in FIG. **7**B, permits the entry of all of the reflected incident rays into the housing surrounding the thermal cycle engine. This housing may be fully insulated and configured to contain any heat energy that might otherwise escape from the heat engine to the surroundings. Thus, the amount of heat energy presented to the input of the thermal cycle engine may be maximized for optimum efficiency of the concentrating solar energy receiver that employs a thermal cycle engine. In applications where it is desired to utilize a thermal cycle engine, one suitable choice is a Stirling engine which, as is well known in the art, is a closed cycle regenerative heat engine which alternately stores energy in a working fluid. In another portion of the cycle the energy is released from the working fluid as the heat input to the thermal cycle engine is converted to mechanical motion—e.g., rotary or reciprocating—and used to drive a generator to produce electricity. Stirling engines may be readily built using construction information that is widely available and so will not be described further herein.

[0042] Referring now to FIG. **1**B, there is illustrated an alternate embodiment of a concentrating solar energy receiver **120** showing, in cross section, a primary parabolic reflector **122** which intercepts the incident rays of solar radiation **104** falling within the outer rim **132** and reflects them toward a focal point **124** which is located on a principle axis passing through the center of the primary parabolic reflector **122**. In FIG. **1**B, the principle axis passing through the center of the primary reflector **122** is not shown for clarity, it being understood where it is located. The characteristics of the primary parabolic reflector **122** are the same as described for the primary parabolic reflector **102** of FIG. **1**A. A focal area is also defined for the embodiment shown in FIG. **1**B. However, in the focal area **126** of FIG. **1**B, there is positioned a secondary parabolic reflector **126**, which has characteristics (except for size) generally to same as or similar to the primary parabolic reflector **122**. The secondary parabolic reflector **126** may be constructed in the same way as the primary parabolic reflector **122**. In this embodiment, the secondary parabolic reflector is disposed to intercept and reflect all incident rays **104** reflected from the primary parabolic reflector **122** from a convex surface of the secondary parabolic reflector **126** back toward the central portion of the primary parabolic reflector **122**. As will be appreciated, the convex parabolic surface of the secondary parabolic reflector **126** enables the reflection of the rays incident thereon in a direction that is parallel to the original incoming incident rays **104** from the sun. Thus, the rays reflected from the secondary parabolic reflector are substantially parallel and will illuminate the center portion of the primary parabolic reflector. This centrally-located focal area, now defined in the center of the primary parabolic reflector, may also be called a reception surface **128**. The reception surface **128** is part of a conversion module **134**. The secondary parabolic reflector **126** is offset by a predetermined distance from the focal point **124** toward the primary parabolic reflector **122**. Again, to control the cross-sectional area of the incident solar radiation beam so as to correspond with the overall cross-sectional area of the solar sensor utilized in a conversion module, the reception area is sized and placed so that the solar sensor region is substantially in the plane of the primary parabolic reflector. This embodiment presents several advantages for maximizing the efficiency of a concentrating solar energy receiver according to the present disclosure as will be described more fully hereinbelow.

[0043] Continuing with FIG. **1**B, the concentrating solar energy receiver **120** shown therein has three advantages over the embodiment illustrated in FIG. **1**A. First, locating the focal area **128**, or alternatively the reception surface **128**, at the central portion of the primary parabolic reflector **122** permits the conversion module **134** to transfer excess heat produced by the incident radiation within the heat dissipating qualities of the material used for the primary parabolic reflector **122**. Thus, for example, if the primary reflector is constructed of aluminum and the conversion module having a solar sensor in the plane of the central portion of the primary reflector **122**, is placed in contact with the primary reflector **122** it may transfer the heat from the conversion module **134** to the metal shell forming the primary reflector **122**.

[0044] Second, by locating the conversion module **134** at the center part of the primary reflector **122**, the center of gravity of the entire concentrating solar energy receiver may be more closely positioned to the supporting structure of the primary parabolic reflector **122**. Thus, the largest single unit of the concentrating solar energy receiver **120** in combination with the conversion module **134** permits smaller and more efficient structures for moving and positioning the assembly with respect to the direction of the sun, etc.

[0045] Third, the positioning of a secondary reflector at the focal area **126** not only facilitates the two advantages described above, but it also permits the use of a filter element (not shown in FIG. **1**B) to be placed on or in front of the secondary parabolic reflector **126** for the purpose of filtering solar radiation components which lie outside the conversion bandpass of the solar sensor and conversion module **134** that is utilized for the concentrating solar energy receiver **120**. For example, a filtering material can be laminated or attached to the secondary parabolic reflector **126** to permit only solar energy which is within the conversion bandpass of the solar sensor and conversion module **134**, thus limiting the amount of unconvertible energy reaching the surface of the solar sensor portion of the conversion module **134** and reducing thereby the heat dissipation requirements of the conversion module **134** itself. To say it another way, the use of a filter in conjunction with the secondary parabolic reflector **126** controls the admittance bandpass of the concentrating solar energy receiver so that it corresponds substantially to the conversion bandpass of the solar energy conversion module **134** that is utilized with the concentrating solar energy receiver **120** of FIG. **1**B.

[0046] Continuing further with FIG. **1**B, the reflective properties of the secondary parabolic reflector **126** may be altered in a number of ways to provide the filtering effect described hereinabove. For example, a number of processes in manufacturing are suitable. These may include laminating or applying a chemical coating or covering or depositing a film of suitable material on the surface of the secondary parabolic reflector **126**. The use of a specialized material positioned next to the surface of the secondary reflector itself may also be utilized to provide the required filtering. Other processes useable to achieve the desired reflective properties may include chemical plating or doping of the reflector surface material and the like. In one alternative embodiment a secondary parabolic reflector may be may of a glass or plastic material that is transparent to some wavelengths of solar radiation (which are not useful for conversion by present conversion devices) and reflective to other wavelengths which are useful for conversion of solar energy to electrical energy or to other useful forms. As an example, glass is a versatile material that may be coated to provide a variety of properties including reflection, absorption or filtering of specified wavelengths. The techniques and processes for achieving such properties are well known and will not be further described herein. Excess energy in the form of spectral solar radiation components that are not needed by the conversion device may be absorbed, passed-through or dissipated over the surface area of the secondary parabolic reflector **126** and radiated to the environment through a suitable heat sinking or conducted to a heat exchanger configured for the purpose. It will also be appreciated that a filter element may be used with, applied to or incorporated with the primary parabolic reflector, either to supplement the filtering associated with the secondary parabolic reflector or in the embodiment wherein a secondary parabolic reflector is not used. Such a primary parabolic reflector could be constructed as outlined previously in this paragraph. Details of the solar energy radiation spectrum and the bandpass aspects of various structures of the concentrating solar energy receiver of the present disclosure will be described further in conjunction with FIGS. **4**, **5** and **6**.

[0047] Referring now to FIG. **2**A, there is illustrated an embodiment of a concentrating solar energy receiver shown in pictorial form to illustrate a mounting structure for a concentrating solar energy receiver according to the present disclosure. The concentrating solar energy receiver **200** of FIG. **2**A includes a primary parabolic reflector **202** shown in cross section and having a circular shape and a rim **232** which defines the circular outer perimeter of the primary parabolic reflector **202**. Also shown in FIG. **2**A is a focal area **204** (or reception surface **204**) which represents the solar sensing surface of a conversion module **206**. The primary parabolic reflector **202** is as previously described in conjunction with FIG. **1**A. The focal area **204** is as previously described in FIG. **1**A wherein the focal area **204** is offset with respect to the focal point of the primary parabolic reflector as the near focal area **108** appears in FIG. **1**A. In FIG. **2**A, the focal area **204** represents the solar sensing portion of a conversion module **206**. The conversion module **206** may illustratively be a solar cell array as previously described hereinabove or it may also be a combination of a thermal cycle engine and an electric generator unit as also previously described.

[0048] Continuing with FIG. **2**A, the primary parabolic reflector **202** and the conversion module **206**, which includes the reception surface **204**, are held in a fixed relationship by a first frame member **208**. The first frame member **208** is connected to the primary parabolic reflector **202** near its center and extends therefrom to connect with and support the conversion module **206** along the principle axis of the primary parabolic reflector **202**. The solar sensor in the reception surface **204** is thus positioned to directly face the center portion of the primary parabolic reflector **202** such that it receives all of the solar energy radiation being reflected from the primary parabolic reflector **202**. The first frame member **208** is connected to a rotatable vertical post **214** at a pivoting joint **210** which permits the first frame member **208** to rock in a vertical plane about a horizontal axis so that the primary parabolic reflector **202** may be positioned at any required elevation angle while pivoting about the axis of the pivoting joint **210**. The rocking motion of the first frame member **208** is provided by a vertical control actuator **218** which consists of a variable length strut whose length may be varied under the action of a motor or linear actuator in the longitudinal axis of the vertical control actuator **218**. The rotating post **214** is rotatably secured to a horizontal control motor **216** which in turn is supported by a vertically oriented stationary base **212** anchored upon the ground, a building or other structure. The vertical control actuator **218** provides for adjusting the elevation of the concentrating solar energy receiver assembly **200** of the present disclosure. The horizontal control motor permits the adjustment of the azimuth of the concentrating solar energy conversion receiver **200** of the present disclosure. Thus the primary parabolic reflector **202** of a concentrating solar energy receiver **200** may be aimed directly at the sun and enabled to track the sun as it proceeds across the sky during daylight hours.

[0049] One property of the concentrating solar energy receiver **200** illustrated in FIG. 2A is that the center of gravity **220** of the movable portion of the system is located approximately between the primary parabolic reflector **202** and the conversion module **206** near the principle axis of the primary parabolic reflector **202** and approximately above the upward end of the rotating vertical post **214** coupled to the first frame supporting member **208**. The embodiment of FIG. 2A would be suitable for use with the solar cell type of conversion module with the solar sensing portion positioned in the region of the near focal area as shown in the near focal area **108** of FIG. **1**A. However, the embodiment of FIG. 2A may also be adapted to use with a thermal cycle engine type of conversion module by locating the solar sensing portion of the thermal cycle engine in the region of the far focal area **110** of FIG. **1**A. In this position, the conversion module **206** that utilizes a thermal cycle engine can be enclosed in a housing having an aperture located surrounding the focal point (see, e.g., FIG. 7B), the housing being utilized to contain the heat energy within a near field of the solar energy portion of the thermal cycle engine to maximize the amount of heat applied to the input of the thermal cycle engine.

[0050] Continuing with FIG. 2A, while the embodiment illustrated therein applies one of the principles of the present disclosure, that is in utilizing an offset focal area, this embodiment is somewhat awkward mechanically. It is more expensive and less efficient to implement because of the attachment of the first frame member **208** to the concave side of the primary reflector **202** and because of the location of the center of gravity **220** away from the structures of the concentrating solar energy receiver **200** having the most mass. For example, in order for the primary reflector **202** to be aimed at the sun when the sun is directly overhead, a large cut-out region or slot must be cut into the primary reflector **202** to permit it to move past the base **212**, vertical support **214** and control motor **216**. Further, a greater amount of structural components are required to support the primary reflector **202** and the conversion module **206** in the correct relationship as shown in FIG. 2A. The cutout region in the primary reflector **202** creates additional complexity in the mechanical support to maintain the parabolic shape of the primary reflector **202** as well as reduces the available reflective surface area for use in receiving sunlight.

[0051] Referring now to FIG. 2B, there is illustrated an alternate and preferred embodiment of a concentrating solar energy receiver **240** according to the principles of the present disclosure. In this embodiment, the primary parabolic reflector **242**, shown in cross section and having a circular rim **252** includes a secondary parabolic reflector **244** disposed along the principle focal axis of the primary reflector and at the near focal area for reflecting radiant energy toward a focal area **246** (or reception surface **246**) on the surface of the center portion of the primary parabolic reflector **242**. Also located in the center portion of the primary parabolic reflector **242** is the conversion module **222** which includes the solar sensing reception surface **246** mounted in the center portion of the primary parabolic reflector **242**. The secondary parabolic reflector **244** is shown supported on struts **248** which may be attached to the rim **252** or, as shown in FIG. 2B, to the concave side of the primary parabolic reflector **242**. It will be appreciated that the focal axis of the secondary reflector **244** lies along the focal axis of the primary reflector in the embodiment of FIG. 2B, that is, their principle axes are coincident.

[0052] With the distribution of masses of the various components of the concentrating solar energy receiver **240** as shown in FIG. 2B, the center of gravity is located approximately at the center of and just behind the primary parabolic reflector **242**. This location of the center of gravity **224** considerably simplifies the supporting structure needed to support the concentrating solar energy receiver **240** and provide for its movement in both the elevation and azimuth directions. The concentrating solar energy receiver **240** is supported at the top of a rotating vertical post **226**. Rotating vertical post **226** is controlled by a horizontal control motor **228** which is supported at the upper end of a vertically oriented stationary base **234**. The stationary base **234** may be mounted upon the ground, a building or other structure. Also attached to the rotating vertical post **226** is a vertical control motor **230**, which is a variable length strut controlled by a linear actuator or motor disposed along the longitudinal axis of the variable length strut and is provided to control the elevation of the concentrating solar energy receiver **240**. The azimuth orientation of the concentrating solar energy receiver **240** is controlled by the horizontal control motor **228**. It will be appreciated that in both FIGS. 2A and 2B, the respective control motors for the vertical (elevation) and horizontal (azimuth) may be controlled by suitable electronics which are not shown in the diagrams, but are readily available and known to persons skilled in the art.

[0053] Continuing with FIG. 2B, it is apparent that locating the most massive components together positions the center of gravity in such away that the responsiveness of the control system is maximized and the size of the actuating units and motors is minimized, thus increasing performance and reducing the cost of the assemblies required. Further, the use of the secondary parabolic reflector **244** more readily permits the use of filtering elements as described hereinabove so that the admittance bandpass of the reflecting portions of the concentrating solar energy receiver **240** is well matched to the conversion bandpass of the conversion module **222** utilized therein. This advantage is especially realized when the conversion module **222** employs a solar cell array of the triple junction solar cells previously described. Matching of the light reflecting filtering and absorption properties of the secondary reflector **244** can be accomplished using any of several processes in manufacturing including, but not limited to, chemical coating or plating or deposition of other materials on the surface of the secondary parabolic reflector **244**, or use of specialized materials in the reflector construction, or the use of chemical doping of the reflective material, or lamination of filtering materials upon the reflective surface of the secondary parabolic reflector **244**. Excess heat which is rejected by the filtering element or otherwise absorbed by the secondary parabolic reflector **244** may be dissipated over the surface area of the secondary parabolic reflector **244**. Further, the secondary reflector may be mounted on a heat sink structure to improve the dissipation of heat therefrom. Alternatively a filtering element or function may be applied to the primary parabolic reflector **242** or to the reception surface **246**, with excess heat energy dissipated through contact with adjacent structures in the primary parabolic reflector **242**. In typical applications, filtering maybe applied to one or more of the three structures: the primary reflector **242**, secondary reflector **244** and the reception surface **246**. In an alternate embodiment the secondary parabolic reflector may be fabricated of glass or other similar transmissive material that reflects wavelengths to be applied to the solar energy reception surface and passes through those wavelengths which will not be received and utilized.

[0054] Referring now to FIG. **3**, there is illustrated an alternate embodiment of the concentrating solar energy receiver of the present disclosure. It will be recalled from the description of FIGS. **1**A, **1**B, **2**A and **2**B that the focal areas or solar sensors or solar cells or secondary reflectors have been located on the principle axis of the primary reflector. These embodiments are known as prime focus reflectors because of the location of the sensing or reflecting elements along the principle axis of the primary reflector. An alternate embodiment as shown in FIG. **3** offsets the focal point from the principle axis in order to maintain the primary reflector **302** at a steeper angle θ with respect to the earth's surface. This orientation prevents the accumulation of debris and other precipitants or particulates. It also allows moisture and contaminants to drain from the reflective surface while the primary reflector **302** is collecting incident solar radiation from relatively high elevation angles. The primary parabolic reflector **302** of FIG. **3** is also shown in cross section and in a shape having a rim **312**. Solar radiation along incident rays **304** is reflected toward the focal point **306** located along an offset focal axis which also passes through the center of the primary parabolic reflector **302**. As before, the focal area **308**, which represents the potential position of the solar sensor portion of a conversion module or secondary reflector, may typically be oriented perpendicular to the focal axis **310**, but may in some applications be oriented at angles other than perpendicular to the focal axis **310**. However, in the embodiment shown in FIG. **3** the solar sensor is shown positioned at the near focal area **308** and approximately perpendicular to the focal axis **310**. As thus positioned, the primary parabolic reflector **302** will tend not to accumulate atmospheric precipitation such as rain, snow or other contaminants (such as dust or other particulates) all of which may damage the reflector or tend to reduce the operating efficiency of the concentrating solar energy receiver of the present disclosure. The principle components of the concentrating solar energy receiver **300** as shown in FIG. **3** may be supported by similar structures as described previously in conjunction with FIGS. **2**A and **2**B.

[0055] Referring now to FIG. **4**, there is shown a series of graphs representing the spectrum components of electromagnetic radiation along axis **402**. These categories include wavelengths shorter than 380 nanometers, the ultraviolet spectrum, between 380 nanometers and 750 nanometers, the visible light spectrum, and for wavelengths longer than 750 nanometers, the infrared radiation spectrum. On another axis **404** is represented the range of solar radiation extending from 225 nanometers to 3200 nanometers which overlaps the three categories of electromagnetic radiation described above. On a third axis is represented the destination of the solar radiation as it travels from the sun toward the earth. The range of 320 nanometers to 1100 nanometers along axis **406**, which straddles the visible light spectrum as well as a portion of the ultraviolet and infrared spectrums, includes approximately ⅘ of the sun's energy that reaches the earth Ultraviolet wavelengths shorter than 320 nanometers are absorbed in the upper atmosphere as represented on axis **408**. For infrared wavelengths longer than 1100 nanometers, axis **410** shows that this energy is diminished or attenuated as it passes through the earth's atmosphere. The very long infrared wavelengths greater than 2300 nanometers in length are absorbed in the atmosphere as represented along axis **412** and do not reach the surface of the earth.

[0056] Continuing with FIG. **4**, an axis **414** represents the useful range or conversion bandpass of the triple junction solar cells contemplated for application in several of the embodiments of the present disclosure. This conversion bandpass of the triple junction $GaInP_2$/GaAs/Ge solar cells extends from 350 nanometers in the near ultraviolet spectrum through the visible light spectrum to the near infrared spectrum at approximately of 1600 nanometers. As can be seen from FIG. **4**, this conversion bandpass covers essentially the entire range wherein ⅘ of sun's energy reaches the earth's surface. Thus, a conversion module which uses a triple junction solar cell as described herein is able to capture approximately ⅘ of the radiation from the sun for conversion to electricity or other uses. Also shown in FIG. **4** is the approximate useful range of a typical thermal cycle engine which is shown along line **416** to extend from approximately 750 nanometers through the infrared spectrum range to at least 2300 nanometers. It will be appreciated that the solar energy reaching the surface of the earth lies between the wavelengths of 320 nanometers and 2300 nanometers and is greater than the range of wavelengths of conversion of the presently available triple junction cells employed in the preferred embodiments. It may also be appreciated that, wide as the conversion bandpass of presently available triple junction solar cells is, further advances in technology may extend this range beyond the present limits so that conversion of energy in the wavelengths shorter than approximately 350 nm and/or longer than approximately 1600 nm would permit useful conversion applications in locations at the earth's surface or above the earth's atmosphere such as in space stations, satellites and the like.

[0057] The energy of the spectrum which lies outside the range of the triple junction cells, that is, having wavelengths smaller than 350 nanometers or greater than 1600 nanometers, represents unuseable or excess energy. This excess energy may cause a decrease in the efficiency of the triple junction cells and thus represents energy that must be reduced, diverted or otherwise dissipated. As described previously hereinabove, one way to reduce this excess energy is to filter it. For example, a filter element may be used in conjunction with a secondary parabolic reflector. The filter element may be a coating applied to the surface of the reflector or it may be an integral property of the reflector as described hereinabove. Filtering may also be applied at the primary parabolic reflector or disposed as a separate element of the concentrating solar energy receiver disclosed herein.

[0058] Referring now to FIG. **5**, there is illustrated a graph of the relative quantum efficiency in percent versus the wavelength in nanometers of the distinct semiconductor portions of the triple junction solar cell suggested for use in the preferred embodiments of the present disclosure. The three semiconductor materials include a compound of gallium, indium and phosphorous, designated as $GaInP_2$, gallium arsenide, designated by GaAs and the element germanium, Ge. The useful relative quantum efficiency range of the gallium indium phosphorous compound shown by the dashed line **502** extends approximately from 350 to 650 nanometers. The useful relative quantum efficiency range of the gallium arsenide semiconductor material extends from approximately 650 nanometers to approximately 900 nanometers as shown by the solid line **504**. The useful relative quantum efficiency range of the germanium semiconductor material, as shown by the dotted line **506**, extends from approximately 900 nanometers to approximately 1600 nanometers. Thus, it can be seen that the approximate composite conversion bandwidth for the triple junction solar cell described in FIG. **5** extends from approximately 350 nanometers to 1600 nanometers which is in agreement with the illustration in FIG. **4**.

[0059] Referring now to FIG. **6**, there is illustrated a graph of the overall conversion efficiency of the triple junction solar cells described hereinabove in percent versus the concentration level of the solar radiation in units of suns, wherein one sun equals 0.1368 watts per centimeter squared (W/cm^2). This level corresponds to the intensity of the direct solar energy radiation at the earth's surface of approximately 1 kW/m^2. It can be seen from the solid line **602** in the graph of FIG. **6** that the conversion efficiency of the triple junction solar cells covers a broad range of solar energy concentration level exceeding 25% from a concentration level of one sun to greater than 1000 suns with the peak occurring between approximately 100 and 600 suns.

[0060] Referring now to FIG. **7**A, there is illustrated a cross sectional view of a concentrating solar energy receiver **702** similar to that illustrated in FIG. **1**A. Some of the calculations for designing a typical concentrating solar energy receiver of the present disclosure will now be described. A primary parabolic reflector **702** is shown in cross section which reflects incident rays **704** to focal point **706**. These reflected rays may pass through either near focal area **708** or far focal area **710**. Also shown in FIG. **7**A are symbols representing various dimensions which will be used in the calculations. The symbol D represents the aperture or diameter of the primary parabolic reflector. The symbol d represents the depth of a primary parabolic reflector. The symbol f represents the distance from the primary parabolic reflector center to the focal point along a principle axis. A symbol r represents of the radius of the circular focal area. It will be appreciated that, as this embodiment is shown in cross-section, both the primary parabolic reflector and the focal area will be circular shapes as previously described hereinabove. The symbol x represents the distance from the focal point to the focal area in either direction along the principle axis. The variables r and x are related by the equation:

[0061] Further, the "shallowness" of a parabolic reflector is given by the ratio f/D. In practice, this ratio would need to be between approximately 0.25 and 1.0 in order to preserve the ease of manufacturing. Moreover, as a practical matter, it is much easier to fabricate, finish, and transport shallow (that is, low f/D ratio) prime focus parabolic reflectors. The radius r is determined from the amount of surface area of the reception area part of the conversion module i.e., the diameter of the solar cell array, that is required to provide the desired electrical output.

[0062] To determine the approximate primary parabolic reflector diameter, it is noted that solar insolation, that is the power of the incoming sunlight per unit area, reaching the surface of the earth is approximately 1 kilowatt per square meter (1 kW/m^2) or 100 miliwatts per square centimeter (100 mW/cm^2). The efficiency of the solar to electrical conversion element is also a primary determining factor in the diameter of the reflector required. In this example, the efficiency is taken from FIG. **6** as will be described. The diameter of the primary parabolic reflector can be calculated from the following relationship:

[0063] where:

[0064] P is the electrical power output required in kilowatts; I is the approximate value for solar insolation, that is approximately 1 kW/m^2; S is the area of the shadow cast by the conversion module;

[0065] D is the diameter of the primary parabolic reflector; and E is the conversion efficiency of the conversion module.

[0066] In the next step, it will be determined what focal area is required for triple junction solar cells used as a conversion module. The focal area and its radius r can be determined by noting the technical specification for triple junction solar cells. For example, from the manufacturer's data, maximum efficient output can be obtained with an intensity range of 200 to 500 suns and operating the cells with a safety margin at 450 suns would produce an output of approximately 14 W/cm^2 of area of the solar cell array. Then, to generate an electrical output of 1.36 kilowatts for example, dividing 1,360 watts by 14 W/cm^2 yields a result of 97 square centimeters. Thus, 97 cells, each having an area of 1 cm^2 would be required and would take up an area of approximately 97 square centimeters. Because the cells are square and must be fit into a roughly circular area, the overall focal area required for illumination of the cell array will be slightly larger or approximately 100 square centimeters (11.28 cm diameter). This arises from the fact that in practice, geometric incongruities caused by fitting a plurality of square, triple junction cells into an array forming a circular area will require a circle having an area slightly larger than 97 square centimeters.

[0067] We have previously observed from FIG. **6** that the typical conversion efficiency of a triple junction solar cell array in the presence of 400 to 500 suns of insolation is slightly above 30%. Moreover, the shadow that the conversion module will cast will be approximately 100 cm^2. Plugging these values into equation (2), the diameter of the primary parabolic reflector will then be: D=2.4 meters. To determine where to position the focal area for a shallowness ratio, f/D of 0.75, we multiply the f/D ratio of 0.75 times 2.4 meters and find that the focal point is 1.8 meters from the center of the primary reflector along the principle axis. At this location it can be determined that the angle θ in FIG. **7**A is 45°. Then, it can be determined from equation 1 that the value x, the distance of the focal area from the focal point, is 5.64 centimeters. Thus, in this design example, a triple junction solar cell in a circular array having an area of 100 square centimeters for use with a primary parabolic reflector having an overall diameter of 2.4 meters is located approximately 5.64 centimeters toward the primary reflector from the focal point. In the alternative embodiment, using a conversion module located at the center of the primary parabolic reflector, this is also the correct position of a secondary parabolic reflector having a diameter of approximately 11.28 centimeters.

[0068] Referring now to FIG. **7**B, there is illustrated a cross-sectional diagram of a concentrating solar energy receiver **720** according to the present disclosure that is a variation of the embodiment illustrated in FIG. **1**A wherein the conversion module to be used employs a solar sensor panel in the location of the far focal area. A primary parabolic reflector is shown at **702** for receiving solar radiation along incident ray **704** which is reflected along the path indicated by **724** through the focal point **706** and further along the dashed lines to a solar sensor panel **710** located at the position of focal area **726** which is also known from the description hereinabove as the far focal area. Coupled with the solar sensor **710** is a thermal cycle engine enclosed within a housing **728**. The housing includes extensions **722** which extend beyond the reception surface of the solar sensor **710** and enclose the space between the solar sensor **710** and the plane containing the focal point which is at right angles to the principle axis of the primary reflector **702**. The housing extension includes an aperture **706** which is just large enough for the reflected rays from the parabolic reflector **702** to pass through the aperture into the space within the housing in front of the solar sensor **710**. It will be observed that the heat energy contained in the radiation that enters the housing area will tend to be contained therein and contribute to the incidence of solar energy into the input heat exchanger of the thermal cycle engine within the housing **728**. As was mentioned hereinabove, the thermal cycle engine includes a mechanical coupling from the output of the thermal cycle engine to an electric generator.

[0069] Other features may be incorporated in the specific implementation of the concentrating solar energy receiver of the present disclosure. For example, the primary reflector, or some other portion of the structure may include one or more lightning rod or arresting devices to prevent lightning damage to the receiver. The reflectors and the reception surfaces may include a protective coating to retard oxidation or deterioration of the reflective surfaces or solar sensing surfaces. The reflectors may be protected from moisture precipitation, particulates, debris or other contaminants by a covering or from hail and other objects by a screen that may be fixed or movable. Accessory panels or deflectors may be utilized to minimize the disturbance of the receiver components by wind. In other examples, solar energy may be collected in a concentrating solar energy receiver of the present disclosure for application to other uses or conversion to other forms. One advantageous implementation may collect heat energy for heating water or other liquids, gases or plasmas. Heat transferred to such materials may be readily transported to other locations or structures. As solar sensing and energy storage technologies develop, selective portions of the solar radiation spectrum may be collected and converted, processed or stored for a variety of applications. For example, the ultraviolet wavelengths, those wavelengths shorter than 380 nanometers may be received, collected and applied to industrial or scientific processes. Or, variations of the basic principles of the present disclosure may be adapted to reception of solar radiation at locations above the earth's atmosphere where wavelengths above and below the visible spectrum of solar radiation are unaffected by absorption or other attenuation of their intensities.

[0070] Referring now to FIG. **8**, there is illustrated an alternative embodiment of a solar energy receiver comprised of a solar energy receiver pod **802**. The solar energy receiver pod **802** consists of the primary reflector **804**, as described previously herein with respect to FIG. **1**A. Mounted above the primary reflector **804** on three support members **806** is the secondary reflector **808**. Of course, other types and numbers of support members may be used. The operation of the primary reflector **804** and the secondary reflector **808** is in the same manner described previously hereinabove. However, the primary reflector **804** rather than being the circular shape described previously with respect to FIG. **1**A, is configured in a square configuration with a parabolic surface wherein each side of the primary reflector **804** is of equal size to each of the other sides. This enables the primary reflector **804** to be fitted within a square housing **810** comprising a four-sided square box. The assembled primary reflector **804**, secondary reflector **808** within the housing **810** comprises the solar energy receiver pod **802** (the tracking mechanism is not shown for simplicity).

[0071] When assembled with other solar energy receiver pods **802**, the solar energy receiver pod **802** may move in a number of different directions. The solar energy receiver pod **802** may rotate along a columnar axis **812**. Additionally, the pod **802** may be configured to rotate along a row axis **814** perpendicular to the columnar axis **812**. Finally, the entire pod **802** may rotate up on its edge along an arc **816**. This would provide the ability for the pod **802** to track the sun making the operation of the solar energy receiver pods **802** more effective.

[0072] The secondary reflector **808** focuses the received solar energy on the solar sensor and conversion device **809**. While the solar energy receiver pod **802** of FIG. **8** illustrates that the secondary reflector **808** is supported above the primary reflector **804** using a series of support members **806**, in an alternative embodiment, as illustrated in FIG. **9**, the secondary reflector **808** may be suspended above the primary reflector **804** within a transparent covering **902**. In this embodiment, a transparent covering **902** encloses the pod assembly **802** and extends to each edge of the housing **810** in order to protect the primary reflector **804** from debris and external environmental conditions. Since the transparent covering **902** covers the entire opening of the housing **810**, the secondary reflector **808** may be integrated within the transparent covering **902** such that when the transparent covering **902** is in position, the secondary reflector **808** is suspended in the appropriate position above the primary reflector **804**. This eliminates the need for the supporting members **806**. The transparent covering **902** comprises a glass or highly transparent material. The glass or transparent material may be coated with a material that allows a range of light spectrum to pass through while the glass or transparent material serves to protect the solar sensor and conversion module **809** and surface of the primary reflector **804** from dust or other interfering contamination. Such spectrum filtering may be accomplished by coating the transparent material or glass with an optical filter material such as that described hereinabove.

[0073] Referring now to FIG. **10**, there is illustrated an integrated primary reflector **804** and heat sink **1002**. As discussed previously, a heat sink **1002** may be included with the primary reflector **804** to remove heat generated by the solar radiation that is being collected by the solar energy receiver. Rather than utilizing a separate heat sink that is connected to the primary reflector **804** via some type of thermally conductive adhesive, the primary reflector **804** as well as the heat sink portion **1002** may be configured in a single assembly **1004**.

The assembly **1004** may be made of a single block of metal or other material which may be extruded. One portion of the assembly **184** is reamed or formed to create the parabolic dish that forms the primary reflector **804** on one side that is polished to create a highly reflective surface or is coated with a highly reflective film that reflects a certain spectrum of light while being transparent to other energy spectrum. This allows pass through light to be absorbed by the primary reflector **804** and dissipated in the surrounding air and to any thermally conductive device that may be attached to the primary reflector **804** such as the heat sink **1002**. The heat sink **1002** conveys heat away from the conversion device **809** to limit damages to the device. This combined assembly **1004** would then be placed within the housing **810** as described previously.

[0074] Referring now to FIG. **11**, there is more fully illustrated a solar receiver module **1102**. The solar receiver module **1102** comprises a 5×6 array of solar energy receiver pods **1104** without an individual tracking mechanism. Each of the solar energy receiver pods **1104** are configured the same as the receiver pods described previously herein with respect to FIGS. **8-10**. The solar energy receiver pods **1104** are arrayed together such that the entire pod array assembly **1106** may be raised and lowered along an edge **1108** using an elevating mechanism **1110**. While FIG. **11** illustrates that the elevating mechanism **1110** comprises a mechanical arm for raising and lowering the array assembly **1106** along its bottom edge **1108**, it should be realized that other types of mechanisms that are hydraulic, electric, mechanical, etc., may be used for raising and lowering the array assembly **1106** along its bottom edge **1108** or any other edge. Additionally, it should be appreciated that while a 5×6 array of solar receiver pods **1104** is illustrated with respect to FIG. **11**, arrays of any size and/or configuration may be utilized according to aspects of the present invention.

[0075] As described previously with respect to FIG. **8**, each of the solar energy receiver pods **1104** in addition to being raised and lowered via the elevating mechanism **1110** may also rotate about its columnar axis of rotation **1114** and additionally may be rotated along its row axis of rotation **1116**. In each case, the solar receiver pods **1104** in a particular column are each chained together such that each pod **1104** within the column will rotate the same amount about the columnar axis of rotation **1114**. Similarly, each of the solar energy receiver pods **1104** are chained together within a separate row such that they may rotate the same amount about the row axis **1116**. While the present description describes that each of the pods are chained with other pods in the same row and column, in alternative configurations, the solar receiver pods **1104** may be configured such that they are only chained with other pods in the same column or alternatively only with pods only in the same row. In yet another embodiment, each of the solar energy receiver pods **1104** may be configured such that each pod is individually controlled rather being controlled within similar pods in the same row or column in a staggered placement whereby an adjacent pod on a higher row is not shadowed from the sun by the adjacent pod below it.

[0076] The module assembly **1102** may be lowered via the elevating mechanism **1110** down into a protective enclosure **1118**. The protective enclosure **1118** in the illustration of FIG. **11** includes slanted or aerodynamically shaped sides. Each of the four sides of the protected enclosure **1118** defines within the center a space into which the module assembly **1106** may be lowered. When lowered into the protective enclosure **1118**, the module assembly **1106** will lie below the top edge of the protective enclosure **1118**. The slanted or aerodynamically shaped sides of the protective enclosure **1118** provide for aerodynamic airflow over and around the protective enclosure **118** while protecting the module assembly **1106** lying down therein when the pods are retracted/lowered into the enclosure. The individual pods **1104** may be locked down to prevent dislodgment under heavy wind conditions. In additional configurations, the aerodynamic shape of the sides of the protective enclosures **1118** may be configured in such a manner such that a slight vacuum is created within the area above the protective enclosure and above the surface of the pod assembly **1106**. In this case, dust, dirt or other particulate matter that would lie on the surface of the individual pods **1104** of the pod assembly **1106** would be pulled off of the solar energy receiver pods **1104** by the slight vacuum as wind passes over the protective enclosure **1118**. Other aerodynamic shapes are possible that enable the generation of wind eddy currents that causes changes in the flow of the wind or channels the wind such as to function as a cooling medium or to provide for secondary energy conversion such as from mechanical energy to electrical energy.

[0077] Referring now to FIGS. **12**A-**12**D, there are illustrated the pod assembly **1106** in various positions and configurations within the module assembly **1102**. In the case of FIG. **12**A, the pod assembly **1106** is in a raised position and each of the individual pods **1104** are rotated about their columnar axis **1114** such that the primary reflectors are focused in a direction generally to the left of the figure. In this case, there is no change of the orientation with respect to the rows and each of the solar receiver pods **1104** are chained with other solar receiver pods **1104** in its same column. Each pod is enclosed by a protective cover.

[0078] Referring now to FIG. **12**B, the pod assembly **1106** is still in the same raised position as described with respect to FIG. **12**A; however, each of the individual pods **1104** are rotated about its columnar axis **1114** such that the focus of each of the primary reflectors is in a direction generally to the right of the figure. With respect to FIG. **12**C, the pod assembly **1106** is now in a lower position between a maximum extended position and a fully lowered position. Additionally, each of the individual solar receiver pods **1104** are configured in a direction such that they rotate about the columnar axis **1112** to point the focus of the primary reflector generally perpendicularly to the plane of the pod assembly **1106**. Finally, in FIG. **12**D, the pod assembly **1106** has been completely lowered within the protective enclosure **118**. When lowered within the protective enclosure **1118**, each of the individual pods **1104** are protected by each side of the protective enclosure **1118** as described previously.

[0079] Referring now to FIG. **13**, there is illustrated the manner in which the solar energy receiver module **1302** may be interconnected with other modules and controlled. Each solar energy receiver module **1302** includes an inverter **1304** and transceiver circuitry **1306**. The solar energy receiver module **1302** comprises the structure described previously with respect to FIGS. **11** and **12**. The inverter **1304** turns the DC energy generated by the solar energy receiver module **1302** into AC electrical energy that may be utilized within an associated power grid **1308**. Each of the inverters **1304** associated with a solar energy receiver module **1302** connects with the power grid **1308** such that all power may be distributed to needed areas. The solar energy receiver module additionally includes a DC/DC converter **1305** for turning the DC energy generated by the solar energy receiver module **1302**

into a regulated DC voltage. By incorporating individual inverters and converters with each solar energy receiver module **1305** such modules can be made to be portable as standalone units for personal use thereby providing portable AC and/or DC power to power personal electronic devices such as personal computers, personal data appliances ("PDA") and other popular personal consumer electronic products. Each unit can be equipped with appropriate universal power receptacles such as for a standard 3-pronged connector for AC or a USB outlet for 5V DC devices. In addition the components that make up such a portable unit can be made to be collapsible such as to occupy less space for travel or shipment and be reassembled when it is to be used.

[0080] The regulated DC voltage can be used locally for storage in a battery **1307** or powering devices or act as a power smoother and off hours power supply for the solar energy receiver module **1302**. The DC/DC converter **1305** also enables the solar energy receiver module **1302** to operate in a standalone mode where the module is powered by the converter **1305** or the battery **1307**. Additionally, the transceiver circuitry **1306** enables each of the solar energy receiver modules **1302** to be in wireless communication with a central controller **1310** that also includes transceiver circuitry **1312**. Through the wireless connection via the transceiver circuitry **1312**, the central controller **1310** may control the operation of the solar energy receiver modules **1302** and control the configuration of individual pods within the solar energy receiver module and control the manner in which the power grid **1308** is distributing power to buildings or areas associated with particular solar energy receiver modules. Additionally, the central controller **1310** can communicate with a solar energy receiver module **1302** via a wireline connection **1314** rather than the wireless connection via the transceiver circuitry **1312**.

[0081] The number of pods that are ganged together within a particular solar energy receiver module **1302** may be electrically configured or connected in numerous configurations to yield the desired power, voltage and current outputs. The ganged arrays may also be electrically connected and integrated with other physically separated ganged arrays or individual pods such as to generate a network or grid of solar generated electricity whereby the components of the electrical network (the pods and modules) are individually controlled and/or synchronized wirelessly for physical orientation and electricity generation and connectivity to the power grid **1308** via the central controller **1310**.

[0082] In one example, several solar energy receiver modules **1302** may be mounted upon the roofs of a number of different housing units. The individual solar energy receiver modules **1302** would be electrically connected to the power grid **1308** to supply electricity to the housing community in which the personal housing units associated with each of the solar energy receiver modules **1302** were associated. The configuration of FIG. **13** would enable the automatic switching of electricity flow from the solar energy receiver modules **1302** to the power grid **1308** whereby the modules **1302** generating electricity can be made available to other devices connected to the grid and alternatively the grid can provide electricity to the housing units when the solar energy receiver modules **1302** are not generating enough electricity.

[0083] The housing units associated with each of the solar energy receiver modules **1302** can be electrically grouped so that the electricity produced and/or consumed by the group can be isolated or connected to the power grid **1308** as a group as each module **1302** is wirelessly controlled from the central controller **1310** and thus each group of housing units may be ganged or integrated electrically to the power grid **1308**. Groups of housing units can also be electrically ganged as a higher aggregation of electricity generators or consumers with no foreseeable limits to the number of levels of aggregation. Thus, an entire community of hundred, thousand and more housing units may be controlled as to access to and from the grid **1308**.

[0084] By incorporating individual inverters and converters with each solar energy receiver module **1305** such modules can be made to be portable as standalone units for personal use thereby providing portable AC and/or DC power to power personal electronic devices such as personal computers, personal data appliances ("PDA") and other popular personal consumer electronic products. Each unit can be equipped with appropriate universal power receptacles such as for a standard 3-pronged connector for AC or a USB outlet for 5V DC devices. In addition the components that make up such a portable unit can be made to be collapsible such as to occupy less space for travel or shipment and be reassembled when it is to be used.

[0085] Referring now to FIG. **14**, there is illustrated a further embodiment of a solar energy receiver pod as depicted in FIGS. **8** to **10**. The solar energy receiver pod utilizes a solar energy receiver **1402** that utilizes a mechanism for magnifying the solar energy that is directed toward an associated CPV cell or cells. The mechanism may, in one example, comprise that disclosed in U.S. Pat. No. 6,818,818, which is incorporated herein by reference, or a retinal lens or other means of magnification for more specifically focusing solar energy on the photovoltaic cell such as the use of a Fresnel lens. The solar energy receiver **1402** is connected to an energy storage device **1406** through an inverter and/or battery charge controller **1408**. The energy created within the solar energy receiver **1402** is provided to the inverter **1408**, which converts the energy to a form able to be stored within the energy storage device **1406**. In one example, the energy storage device **1406** may comprise a rechargeable battery. The energy storage device **1406** may be used to provide energy to a tracking controller **1410** and drive mechanism **1412**. The tracking controller **1410** and driver mechanism **1412** enable the solar energy receiver **1402** to track the sun on one or more axis in order to position the CPV cells to face the sun and enable the generation of electricity and/or heat energy, which may be then provided to externally connected devices. The energy storage device **1406** may be enclosed together with the CPV receiver **1402** within a single enclosure or situated outside of the enclosure connected to externally connected devices.

[0086] The inverter **1408** or battery charge controller or other similar type of energy control device, may also be included within the enclosure with the receiver **1402** or connected outside of the enclosure by means of connecting cables or a heat exchanger in the case of heat storage. Thus, a single solar energy receiver **1402** may contain the full complement of devices necessary to track the sun in order to optimize the reception and magnification of the sun's energy onto the CPV cell **1404** to enable conversion of the sun's energy into electricity and other derivative energy for the powering of devices external to the solar energy receiver **1402**. The means of connecting these external devices may also be provided for or incorporated into the assembly housing the solar energy receiver such as via an electrical receptacle. Each receiver **1402** may also be equipped with a two-way communications interface **1414** in order for the receiver **1402** to be controlled remotely and/or communicate with external devices through the communications interface **1414**.

[0087] The assembly of FIG. **14** may be implemented in a stand-alone configuration and may comprise a "plug and play" configuration, wherein all of the necessary components to enable the receiver assembly to generate electricity or other forms of energy such as heat may be included within a single assembly. Such a solar energy receiver **1402** could also be fashioned as part of an overall grid, wherein the necessary electrical connections and mechanical receptacles are separately provided for the ready mating of the receptacle with the receiver assemblies. The receiver **1402** will be enclosed within a hermetically sealed container with all of the necessary connecting cables either embedded or protruding out of the receiver **1402** for connection to external devices. If a glass material or other light transparent material is used, the material itself would act as a mechanical support or holder for such components as a secondary lens as described herein.

[0088] The solar energy receiver **1402**, as mentioned hereinabove, may be configured to operate upon one or more axis in order to position the CPV cell **1404** with respect to the sun. Referring now to FIG. **15**, there is illustrated a side view of a solar energy receiver **1402** that may be rotated about three different axis, namely the X, Y and Z axis. The receiver structure **1402** is connected to a drive mechanism **1504** that contains a number of different parts providing movement of the solar energy receiver **1402** about the X, Y and Z axis. A base structure **1506** includes a drive gear **1508** that enables the entire solar energy receiver **1402** to be rotated about the Z axis. Gear **1510** enables the solar energy receiver **1402** to be rotated about the Y axis. Finally, a driver and worm gear **1512** enables the solar energy receiver **1402** to be rotated about the X axis. Thus, using the various drive and gear assemblies, the solar energy receiver **1402** can be rotated about three different sets of axes. This degree of movement would allow the receiver **1402** to track the movement of the sun.

[0089] Referring now also to FIG. **16**, there is illustrated a two axis implementation of a solar energy receiver **1402** using a parabolic dish **1602** for solar energy magnification. A drive mechanism **1604** orients the parabolic solar receiver which may be comprised of varying shapes and curvatures as described in U.S. Pat. No. 6,818, 818. The drive mechanism **1604** enables the solar energy receiver **1402** to face the sun to optimize and magnify the reception of solar energy by the CPV cell **1606**. The drive mechanism **1604** comprises any number of mechanical devices for rotating the parabolic dish **1602** illustrated in FIG. **16**. In one embodiment, the mechanism encompasses rollers for applying a frictional force to the convex surface (i.e., the backside) of the parabolic dish to move the parabolic dish into a position to receive solar energy. Additionally, a rail mechanism could be incorporated onto the convex side of the parabolic dish **1602** providing a guiding and traversing track that is coupled with some type of drive motor. A further implementation includes a pivot point of the dish enabling tilting of the dish **1602** to face one direction and additional pivot points may be used to tilt the dish **1602** in other directions.

[0090] Referring now also to FIG. **17**, alternative forms of solar energy magnification may be utilized rather than the parabolic dish illustrated in FIG. **16**. A Fresnel lens **1702** can be mounted within a housing **1704**. The housing **1704** is pivoted and/or rotated via associated drive gears and rollers that are interfaced with the housing **1704**. Driving of a Fresnel lens housing **1704** utilizes one or more of the components described hereinabove with respect to the manner for driving either of the implementations illustrated in FIGS. **15** and **16**. Additionally, the Fresnel lens **1702** could be included with the various other receiver components such as the inverter/controller and two way communications capability in order to optimize the magnification and reception of solar energy upon associated CPV cells and convert the sun's energy to electricity or derivative energy forms utilized to power or heat an external device.

[0091] A major challenge in the implementation of a self-tracking solar energy receiver is the process adopted for tracking and maintaining the accuracy of the tracking process with respect to the sun. The tracking of the sun's position may be achieved in a number of different ways. These include using a fixed algorithm that depends upon a known position of the sun during the course of a calendar year and varies based upon the natural rotation of the earth with respect to the sun or by measuring the relative strength of the sun incident upon a particular receiver using two or more light sensors.

[0092] Referring now to FIGS. **18**A-C, there is illustrated the use of a fixed algorithm implementation in a solar energy receiver. In a fixed algorithm implementation, the solar energy receiver **1802** may have its position manually set in relation to a known position of the rising sun such as that illustrated in FIG. **18**A, and the orientation of the solar energy receiver **1802** is adjusted automatically by the way of associated motors that rotate the receiver **1802** along one or more axis to correspond to the known path of the sun **1806** during the course of the day. Each morning, the receiver **1802** returns to a fixed initial orientation to begin its tracking cycle again. This initial position would of course change based upon the time of year.

[0093] In FIG. **18**A, the solar energy receiver **1802** is shown with its axis **1804** placed in a position to enable it to track the sun **1806** in the early morning shortly after sunrise. In this case, the axis **1804** is pointing low toward the eastern horizon responsive to the sun **1806** rising. The controlling algorithm would incorporate a known position on the horizon at which the sun would be rising based upon historical data stored within a memory of the solar energy receiver **1802**. As the day progresses, as illustrated in FIG. **18**B, the solar energy receiver **1802** is in a more upright position with the axis **1804** directed almost perpendicular to the ground. This is due to the fact that the sun **1806** has risen to almost a high noon position as the time of day has passed. Finally, as illustrated in FIG. **18**C, the solar energy receiver **1802** directs its axis **1804** low on the western horizon to track the sun **1806** as it begins to descend below the horizon in the west.

[0094] Referring now to FIG. **19**, there is illustrated a flow diagram describing the process by which the control algorithm controls the operation of the receiver **1802** during the course of a day. Initially, the time of day is determined at step **1902**. Next, the position of the solar energy receiver is determined at step **1904**. Inquiry step **1906** determines whether the present time and position of the solar energy receiver **1802** are correct with respect to each other. This could be achieved using a table that indexes the time of day to a particular directionality of the central axis **1804** of the solar energy receiver **1802**. If the time of day and position of the receiver correspond as they should, control passes back to step **1902** to continue to monitor the time of day and position of the receiver. If inquiry step **1906** determines that the time of day and position of the receiver are not properly indexed with each other, the drive assembly of the solar energy receiver **1802** is used to move at step **1908** the receiver to the new position as indicated by the positioning data stored in association with the algorithm. Control will then pass on to step **1902** to continue the position and time monitoring process.

[0095] Referring now to FIG. **20**, there is illustrated an alternative methodology for implementing a self-tracking solar energy receiver wherein the solar energy receiver **2002** includes a plurality of light sensors **2004** affixed to the surface thereof to enable the solar energy receiver **2002** to align the receiver with the sun. A typical methodology utilizes more than one sensor **2004** and provides a control mechanism wherein the sensor **2004** which detects a stronger light energy is determined to be the sensor that is pointed more directly toward the sun. A sensor **2004** experiencing less sunlight means that the sensor **2004** is not directly pointed at the sun. A control process orients the receiver **2002** by relative detection of the sunlight by the different sensors **2004**. Control motors are actuated to cause the receiver **2002** to rotate to a position to orient the receiver **2002** toward the detected sunlight.

[0096] Referring now to FIG. **21**, there is illustrated an implementation of one such control mechanism associated with the solar energy receiver **2002**. Each of the sensors **2004** provides sensor information to a central controller **2102**. In one embodiment, the sensors **2004** are equally spaced from each other but other configurations are also applicable. While the present description discloses the use of four sensors **2004** with respect to the solar energy receiver **2002**, any number of sensors or sensor arrays may be utilized in order to optimize the positioning capabilities of the solar energy receiver **2002**. The central controller **2102** utilizing the received sensor information and control information provided from a local memory **2104** determines a present position of the solar energy receiver **2002** with respect to the sun. Once a determination of the position of the solar energy receiver **2002** has been made by the controller **2102**, a new position to better orient the central axis of the solar energy receiver **2002** toward the sun is made by the controller **2102**. The controller **2102** sends actuation signals to various drive motors **2106** that are used to drive a positioning mechanism **2108** to orient the solar energy receiver **2002** into the new position as determined by the controller **2102**. The controller **2102** reacts to the information provided from the light sensors **2004** in a manner to reduce the rotational travel of the solar energy receiver **2002** such that only incremental positional changes are provided to the drive motors **2106** and positioning mechanism **2108** thus resulting in more accurate positioning of the receiver **2002**.

[0097] Often, there will be mismatches between the information provided from the various light sensors **2004** such that the light sensors provide different light strength information even when they are receiving the same amount of incident light. This will of course affect the tracking mechanism's accuracy. In order to improve tracking accuracy, an algorithm can be used within the controller **2102**, which detects changes of relative light intensity of different light sensors **2004** when the drive motors **2106** and positioning mechanism **2108** move the solar energy receiver **2002**. The controller **2102** determines accurate positioning with respect to the sun by monitoring the output of the light sensors and determining when a maximum light detection position is detected for each of the sensors. Comparisons of the output of the light sensors will be made to compensate for the light intensity changes of the sun during motor movement. Thus, the maximum light intensity reading for each of the sensors **2004** is used in determining a most likely direction of the sun rather than the absolute value detected by the sensors **2004**. By such an implementation of multiple sensor arbitration, the controller **2102** can be self-initiating in its initial positional orientation toward the sun, which is of great utility for an array consisting of more than one self-tracking solar energy receiver **2002**. This would remove the requirement for the solar energy receivers **2002** to be physically linked even if the solar energy pods in the array are physically linked through an inflexible frame. The solar energy receivers **2002** would not need to be preset on the frame, nor would they need to be aligned prior to shipment and installation, thus reducing the time and effort required in installation in the field. Thus, the self-tracking ability enables an array of solar energy receivers **2002** to be self-aligning.

[0098] However, self-alignment requires that the tracking sensors operate accurately, which may not be the case when one sensor loses sensitivity for one reason or another, such as becoming dirty or degrading in its operational capabilities. In order to avoid a creeping misalignment when the solar energy receiver initializes to face the sun, the initial daily starting position may be compared by the controller **2102** to a known reference coordinate such as the historical initial positioning of the solar energy receiver **2002** during the course of the calendar year. This type of information is stored within the memory **2104**. Alternatively, and/or simultaneously, the relative intensity of light sensed by a sensor **2004** with respect to another sensor may be compared to the historical relative strength of the subject sensors with this data also being stored within the memory **2104**. Such relative strength information is measured against more than one reference sensor thereby providing a means of arbitrating the true position of the malfunctioning sensor and generating correctional information responsive thereto.

[0099] Referring now to FIG. **22**, there is illustrated a flow diagram illustrating one manner in which the controller **2102** controls the operations of the solar energy receiver **2002**. Sensor readings are taken from the sensors **2004** at step **2202**. A determination is made by the controller **2102** as to whether there has been a change in the sensor readings since the last time the readings were taken. If not, the sensors are continuously monitored at steps **2202** and **2204**. If inquiry step **2204** determines a change in the sensor readings, the receiver **2002** is moved in a first direction at step **2206**. After the receiver **2002** is moved, inquiry step **2208** determines whether the light sensor readings have increased or decreased. If the light sensor values have increased, control passes back to step **2206** and the receiver **2002** is again moved in the first direction. If inquiry step **2208** determines that there has been a decrease in the detected light intensity, the receiver **2002** is moved in the reverse direction at step **2210**. New sensor readings are taken at step **2212** and inquiry step **2214** determines whether a maximum light intensity value has been detected. If so, the process is completed at step **2216**. If inquiry step **2214** determines that a maximum sensor value is not detected, the receiver **2002** is again moved in the second direction at step **2206**. The process continues until the maximum light intensity sensor value is detected and the process is completed at step **2216**.

[0100] Referring now to FIG. **23**, there is illustrated a flow diagram describing the manner in which the misalignment caused by loss of sensor sensitivity or other types of environmental conditions may be accounted for within the control system of the present disclosure. Initially, at step **2302**, the actual sensor data is read from the sensors **2004**. This sensor data is compared at step **2304** with the historical data that has been previously monitored from the sensor and stored within an associated memory **2104**. Inquiry step **2306** determines if there are drastic differences between the actually monitored data and the historical data. If changes are present, the position or calibration of the sensors is adjusted at step **2308** to correct for any drastic differences. If inquiry step **2306** detects no significant differences between the actual data and the historical data, no adjustments are necessary at step **2310**.

[0101] Referring now to FIG. **24**, there is illustrated an array of solar energy receivers **2402** that are able to communicate with each other via wireless communications connections **2404**. This allows each of the solar energy receivers **2402** to receive information concerning the location of the sun, control its tracking accordingly and aggregately provide information to a battery storage or use location **2406**. In the case of an array of solar energy receivers **2402**, by equipping each receiver **2402** with a communications interface **2404** which may be a wireless means as illustrated in FIG. **24**, or alternatively, could include other wireline communications capabilities, each receiver **2402** may communicate with other receivers within the arrays as well as with receivers in other arrays or with other arrays in the aggregate to receive and provide information regarding the position of the receiver **2402** with respect to the sun. By sharing this type of information in the aggregate, positional accuracy with respect to the sun may be increased by enabling each solar energy receiver **2402** to correct its position in the event of a malfunctioning sensor or otherwise based upon information from other sensors. Thus, if the sensors on any particular receiver **2402** were to fail, the solar energy receiver **2402** utilizes information received from adjacent or adjoining receivers **2402** in order to track the position of the sun. Each solar energy receiver **2402** could additionally include a reference positional device such as a GPS receiver **2408**. The GPS receiver **2408** is used for aligning the solar energy receiver **2402** with respect to the sun. A further benefit of the inter-receiver communications capability is the synchronization of orientation of the arrays within a field of arrays to maximize the positional reception of the sun's energy as receivers that are further away from the rising sun may not be able to detect the sun until it reaches a sufficient height in the sky. Such early detection of the sun by the solar energy receivers **2402** that are physically distant from the sun would increase the duty cycle of energy generation by each receiver or group of receivers and arrays if they would be focused on the sun at some point prior to the sun becoming visible over the horizon or terrain.

[0102] The communications interface **2404** additionally enables the receivers **2402** to be placed remotely from each other and still remain electronically connected to enable the aggregation of energy produced individually by the receivers **2402** at a central power storage/use location **2406**. The ability to self-track the sun would enable the solar energy receiver **2402** to be utilized in a stand-alone configuration to provide energy to one more devices such as in providing DC power to DC operating devices, wherein the DC-to-DC converter may be incorporated directly into the receiver or provided as a separately connected device. The same procedure would apply to a power inverter that would be used to convert DC power to AC power. An additional utility for a self standing solar energy receiver **2402** is the independent powering of electric vehicles such as an electric bicycle (e-bike), which may require several receivers to be electrically ganged together to provide the necessary voltage and current required.

[0103] Using the above-described solar energy receiver module, an array of solar energy receivers may be ganged together to produce electrical energy for use by the power grid. The ganged structure may allow the solar energy receivers to follow the sun at an optimal receiving angle and still place the individual receivers within a protective enclosure should environmental wind or other conditions potentially provide damaging operating conditions to the solar energy receivers.

[0104] It will be appreciated by those skilled in the art having the benefit of this disclosure that this array module of parabolic solar energy receivers provides an efficient manner of generating electricity while protecting the array from environmental conditions. It should be understood that the drawings and detailed description herein are to be regarded in an illustrative rather than a restrictive manner, and are not intended to be limiting to the particular forms and examples disclosed. On the contrary, included are any further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments apparent to those of ordinary skill in the art, without departing from the spirit and scope hereof, as defined by the following claims. Thus, it is intended that the following claims be interpreted to embrace all such further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments.

What is claimed is:

1. A solar energy receiver array, comprising:

a plurality of solar energy receivers arranged in an X by Y array;

a protective housing including a plurality of sides defining an opening therein; and

wherein the plurality of solar energy receivers arranged in the X by Y array may lowered into the opening within the protective housing to protect the plurality of solar energy receivers arranged in the X by Y from external winds.

2. The solar energy receiver array of claim **1**, wherein a first edge of the X by Y array may be raised from a first position within the protective housing to a second position outside of the protective housing and further wherein the X by Y array pivots on a second edge of the X by Y array as the first edge of the X by Y array moves from the first position to the second position.

3. The solar energy receiver array of claim **1**, wherein each of the plurality of solar energy receivers of the X by Y array rotate about a first columnar axis.

4. The solar energy receiver array of claim **3**, wherein each of the plurality of solar energy receivers of the X by Y array rotate about a second axis perpendicular to the first columnar axis.

5. The solar energy receiver array of claim **1**, wherein each of the plurality of sides of the protective enclosure directs an airflow over the plurality of solar energy receivers in the X by Y array.

6. The solar energy receiver of claim **1**, wherein each of the plurality of sides are configured to create a vacuum over the opening to remove particulates from the X by Y array responsive to airflow over the protective housing.

7. The solar energy receiver of claim **1**, wherein each of the plurality of solar energy receivers further comprises:

a primary reflector;
a secondary reflector suspended above the primary reflector;
a housing for containing the primary reflector; and
a solar cell mounted on the face of the primary reflector for receiving energy reflected from the secondary reflector.

8. The solar energy receiver array of claim **7**, wherein the primary reflector further comprises a heat sink, the primary reflector and the heat sink integrated into a single unit.

9. The solar energy receiver array of claim **7**, further including a transparent cover enclosing the primary reflector within the housing, wherein the transparent cover has mounted therein the secondary reflector to suspend the secondary reflector above the primary reflector.

10. The solar energy receiver array of claim **1**, further including at least one support arm for suspending the secondary reflector above the primary reflector.

11. The solar energy receiver array of claim **1**, further including an inverter for converting DC electricity generated by the plurality of solar energy receivers to AC electricity.

12. The solar energy receiver array of claim **1**, further including:
a transceiver for wirelessly connecting to a central controller;
wherein an orientation of the plurality of solar energy receivers may be configured by the central controller.

13. The solar energy receiver of claim **1**, further including a central controller for directing electrical energy generated by the solar energy receiver array to a selected location via a power grid.

14. The solar energy receiver of claim **1**, wherein each of the solar energy receivers comprises a self tracking solar energy receiver for detecting a position of a sun and aligning a pointing axis of the solar energy receiver with the sun.

15. The solar energy receiver of claim **14**, further including a tracking algorithm for controlling the position of the pointing axis of the solar energy receiver.

16. The solar energy receiver of claim **14**, further including:
a plurality of light sensors for sensing the position of the sun and generating control signals responsive thereto;
a controller for controlling the position of the pointing axis of the solar energy receiver responsive to the control signal.

17. The solar energy receiver of claim **16**, further including:
a memory for storing historical data relating to the position of the point axis of the solar energy receiver and the position of the sun;
wherein the control further uses the historical data for controlling the position of the pointing axis of the solar energy receiver.

18. The solar energy receiver of claim **16**, wherein the controller uses the historical data to adjust sensor readings of the plurality of light sensors to correct for errors in sensor reading measurements.

19. A solar energy receiver array, comprising:
a plurality of solar energy receivers arranged in an X by Y array, each of the solar energy receivers comprises a self tracking solar energy receiver for detecting a position of a sun and aligning a pointing axis of the solar energy receiver with the sun, wherein each of the plurality of solar energy receivers further comprises:
a primary reflector;
a secondary reflector suspended above the primary reflector;
a housing for containing the primary reflector;
a solar cell mounted on the face of the primary reflector for receiving energy reflected from the secondary reflector;
wherein a first edge of the X by Y array may be raised from a first position within the protective housing to a second position outside of the protective housing and further wherein the X by Y array pivots on a second edge of the X by Y array as the first edge of the X by Y array moves from the first position to the second position;
wherein each of the plurality of solar energy receivers of the X by Y array rotate about a first columnar axis;
a protective housing including a plurality of sides defining an opening therein; and
wherein the plurality of solar energy receivers arranged in the X by Y array may lowered into the opening within the protective housing to protect the plurality of solar energy receivers arranged in the X by Y from external winds.

20. The solar energy receiver array of claim **19**, wherein each of the plurality of solar energy receivers of the X by Y array rotate about a second axis perpendicular to the first columnar axis.

21. The solar energy receiver array of claim **19**, wherein each of the plurality of sides of the protective enclosure directs airflow over the plurality of solar energy receivers in the X by Y array.

22. The solar energy receiver of claim **19**, wherein each of the plurality of sides are configured to create a vacuum over the opening to remove particulates from the X by Y array responsive to airflow over the protective housing.

23. The solar energy receiver array of claim **19**, wherein the primary reflector further comprises a heat sink, the primary reflector and the heat sink integrated into a single unit.

24. The solar energy receiver array of claim **19**, further including a transparent cover enclosing the primary reflector within the housing, wherein the transparent cover has mounted therein the secondary reflector to suspend the secondary reflector above the primary reflector.

25. The solar energy receiver array of claim **19**, further including at least one support arm for suspending the secondary reflector above the primary reflector.

26. The solar energy receiver array of claim **19**, further including an inverter for converting DC electricity generated by the plurality of solar energy receivers to AC electricity.

27. The solar energy receiver array of claim **19**, further including:
a transceiver for wirelessly connecting to a central controller; and
wherein an orientation of the plurality of solar energy receivers may be configured by the central controller.

28. The solar energy receiver of claim **19**, further including a central controller for directing electrical energy generated by the solar energy receiver array to a selected location via a power grid.

29. The solar energy receiver of claim **19**, further including a tracking algorithm for controlling the position of the pointing axis of the solar energy receiver.

30. The solar energy receiver of claim **19**, further including:

a plurality of light sensors for sensing the position of the sun and generating control signals responsive thereto;

a controller for controlling the position of the pointing axis of the solar energy receiver responsive to the control signal.

31. The solar energy receiver of claim **30**, further including:

a memory for storing historical data relating to the position of the point axis of the solar energy receiver and the position of the sun;

wherein the control further uses the historical data for controlling the position of the pointing axis of the solar energy receiver.

32. The solar energy receiver of claim **30**, wherein the controller uses the historical data to adjust sensor readings of the plurality of light sensors to correct for errors in sensor reading measurements.

33. The solar energy receiver of claim **19**, further including:

a DC/DC converter associated with each of the plurality of solar energy receivers; and

a battery associated with each of the plurality of solar energy receivers.

* * * * *

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GERWING et al. (43) **Pub. Date: Nov. 13, 2008**

(54) **SOLAR COLLECTOR**

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(21) Appl. No.: **12/043,706**

(22) Filed: **Mar. 6, 2008**

Related U.S. Application Data

(60) Provisional application No. 60/893,275, filed on Mar. 6, 2007.

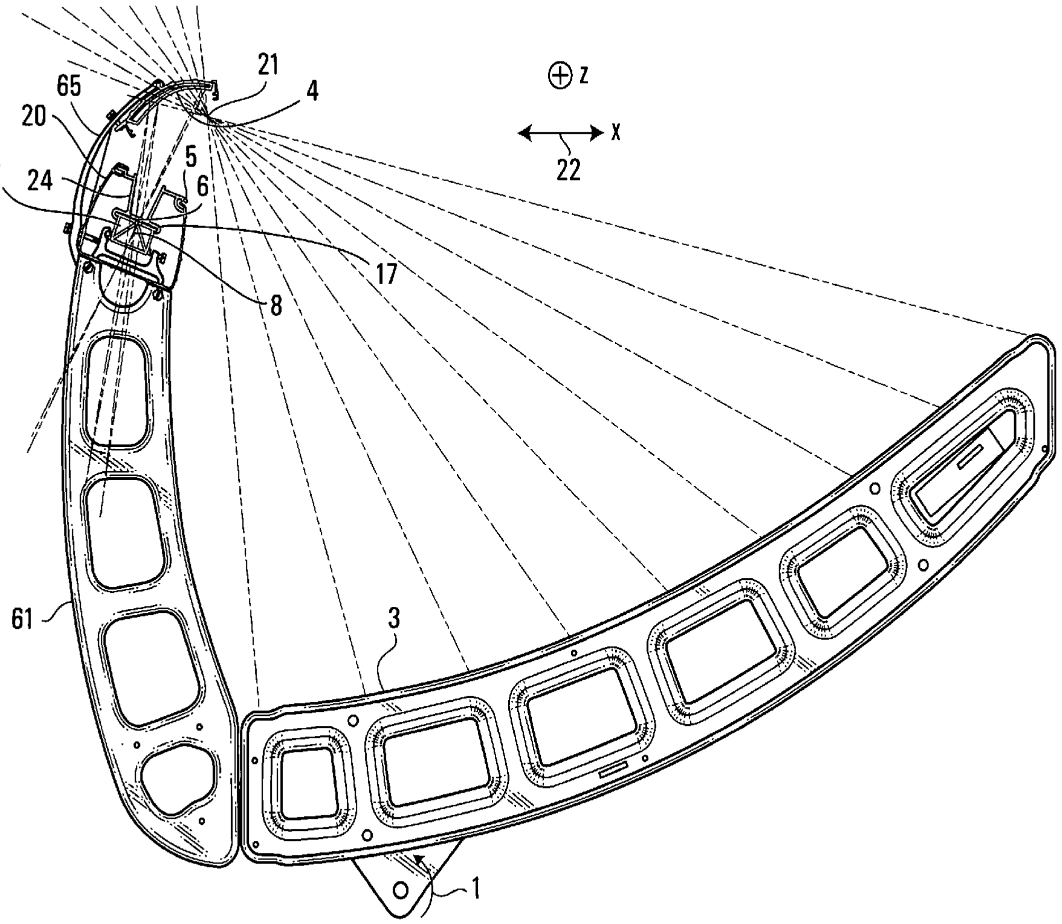
Publication Classification

(51) **Int. Cl.**
F24J 2/10 (2006.01)

(52) **U.S. Cl.** **126/634**; 126/684

(57) **ABSTRACT**

The invention provides a solar collector comprising a trough-like reflector for receiving solar rays and for concentrating the rays in a direction generally transverse to the length of the reflector between its ends. Concentrator means is provided for receiving the concentrated rays from the trough-like reflector and for concentrating the rays in one or more of a direction generally along said length and a direction generally transverse to said length.



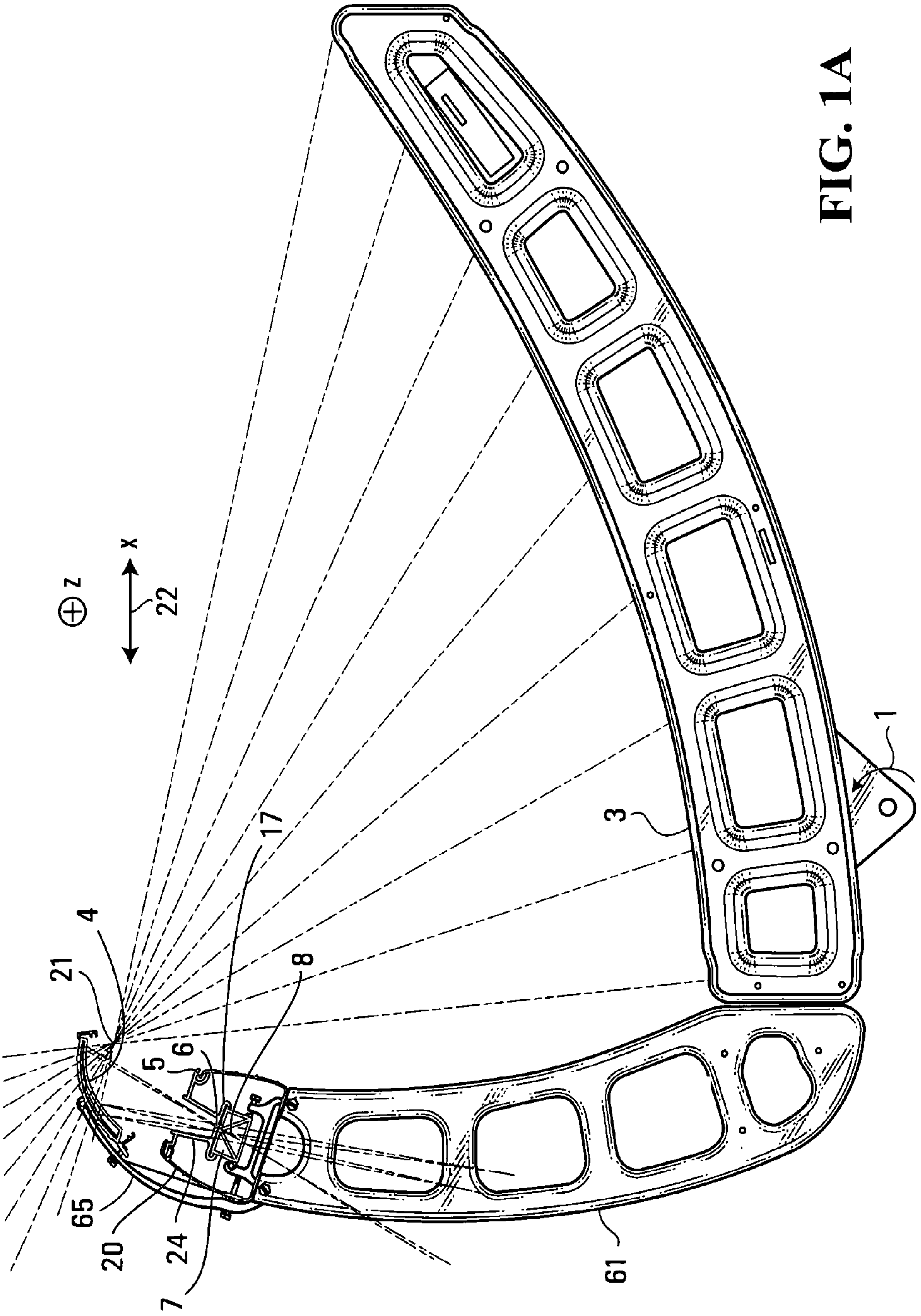
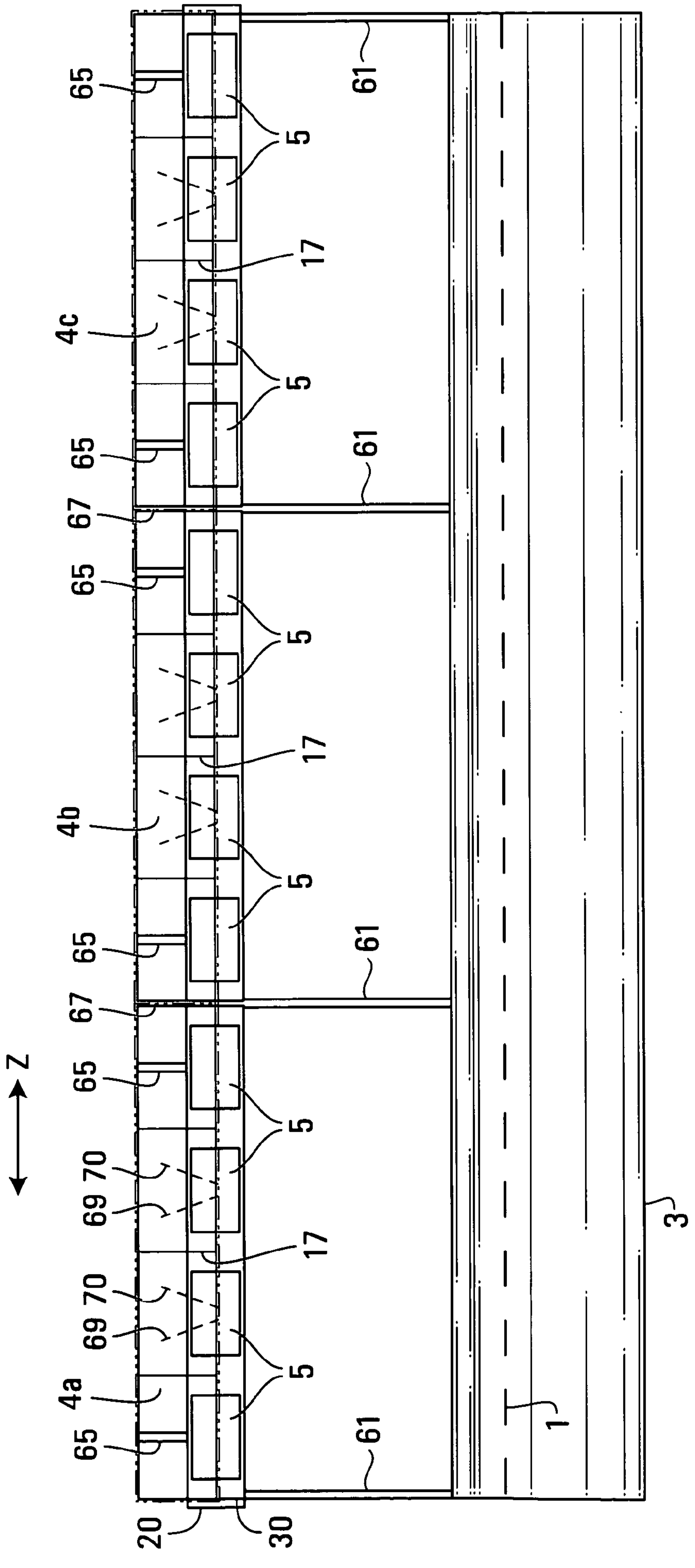


FIG. 1A


Z
65
4a
69
70
69
70
5
5
5
5
17
61
67
65
65
4b
5
5
17
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4c
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5
17
65
61
61
20
30
1
3

FIG. 1B

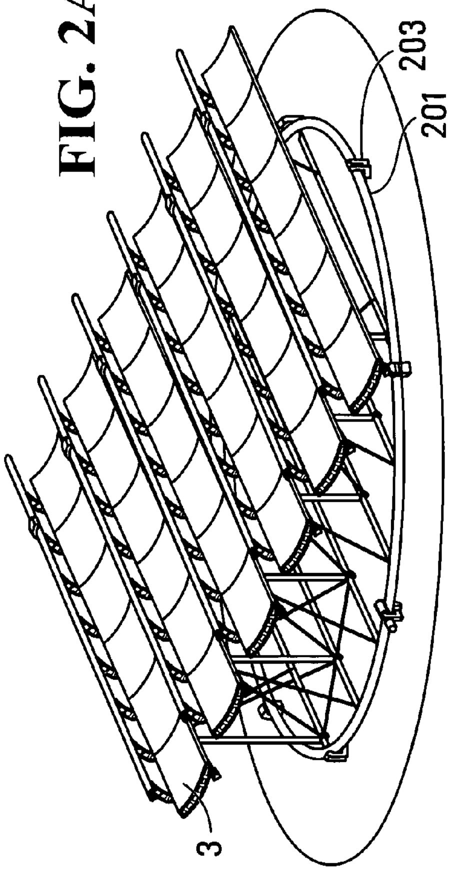

FIG. 2A

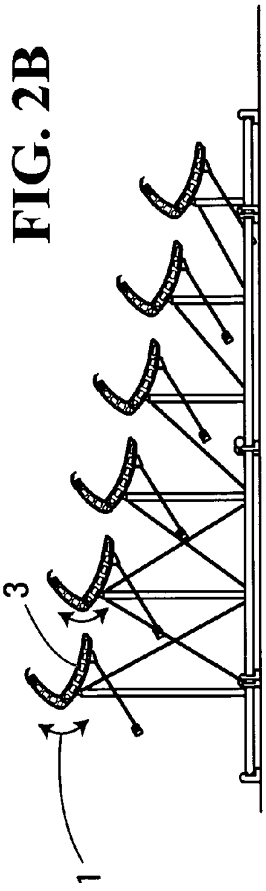

FIG. 2B

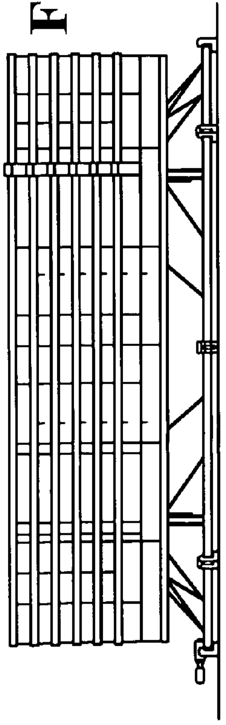

FIG. 2C

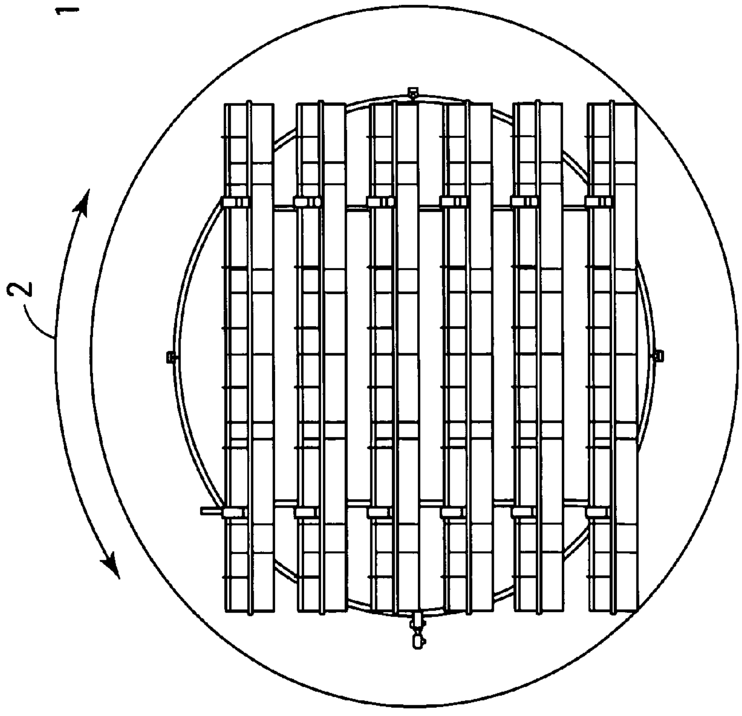

FIG. 2D

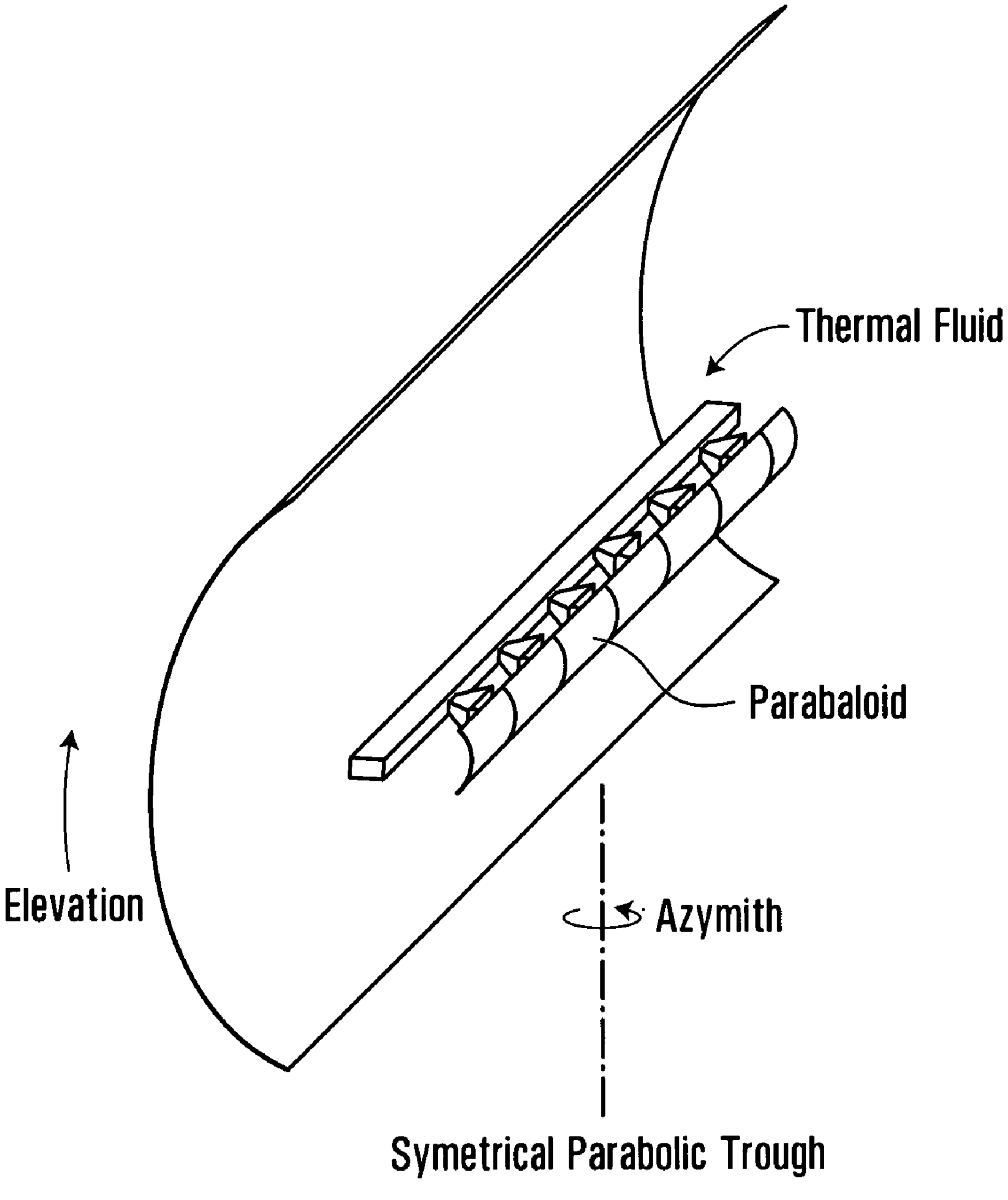
Thermal Fluid
Parabaloid
Elevation
Azymith
Symetrical Parabolic Trough

FIG. 3

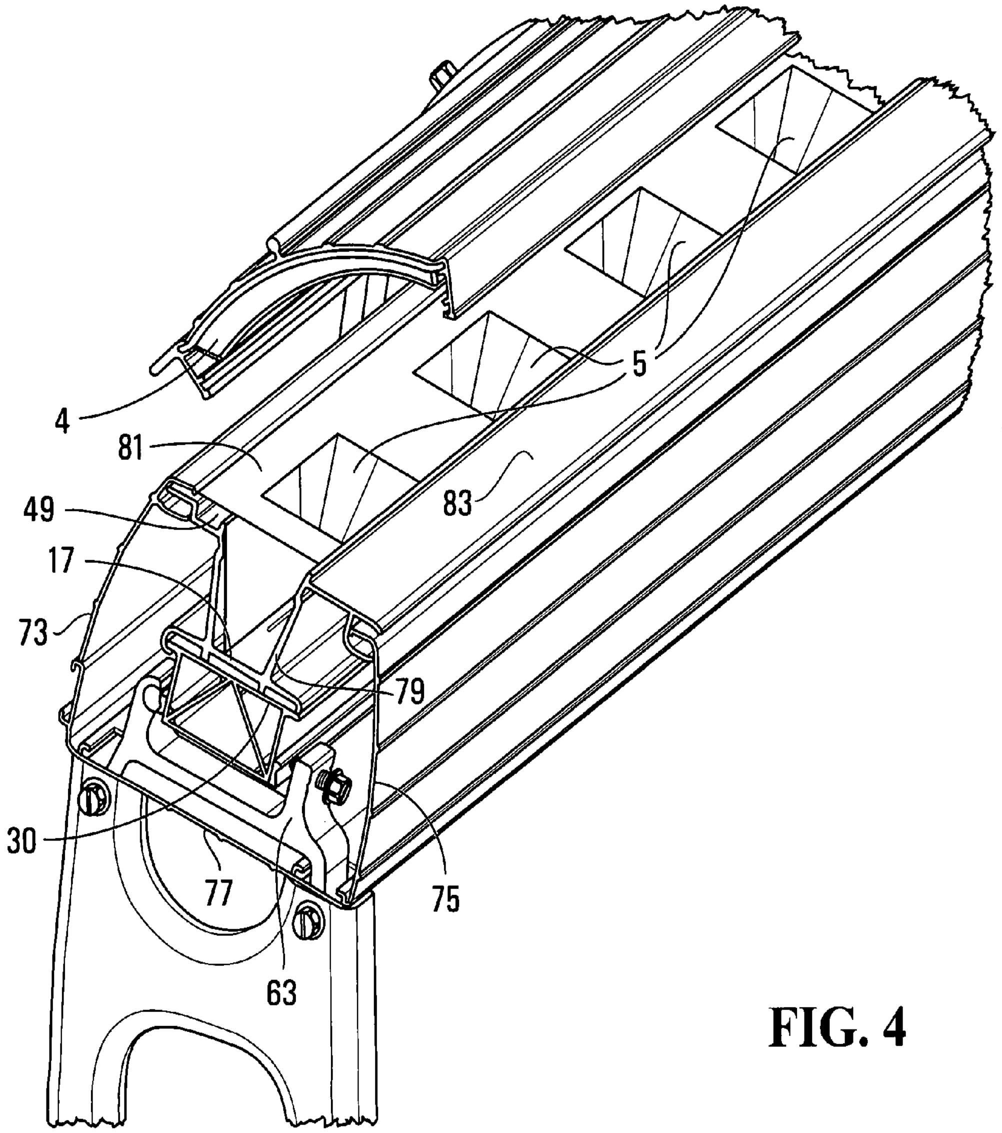

FIG. 4

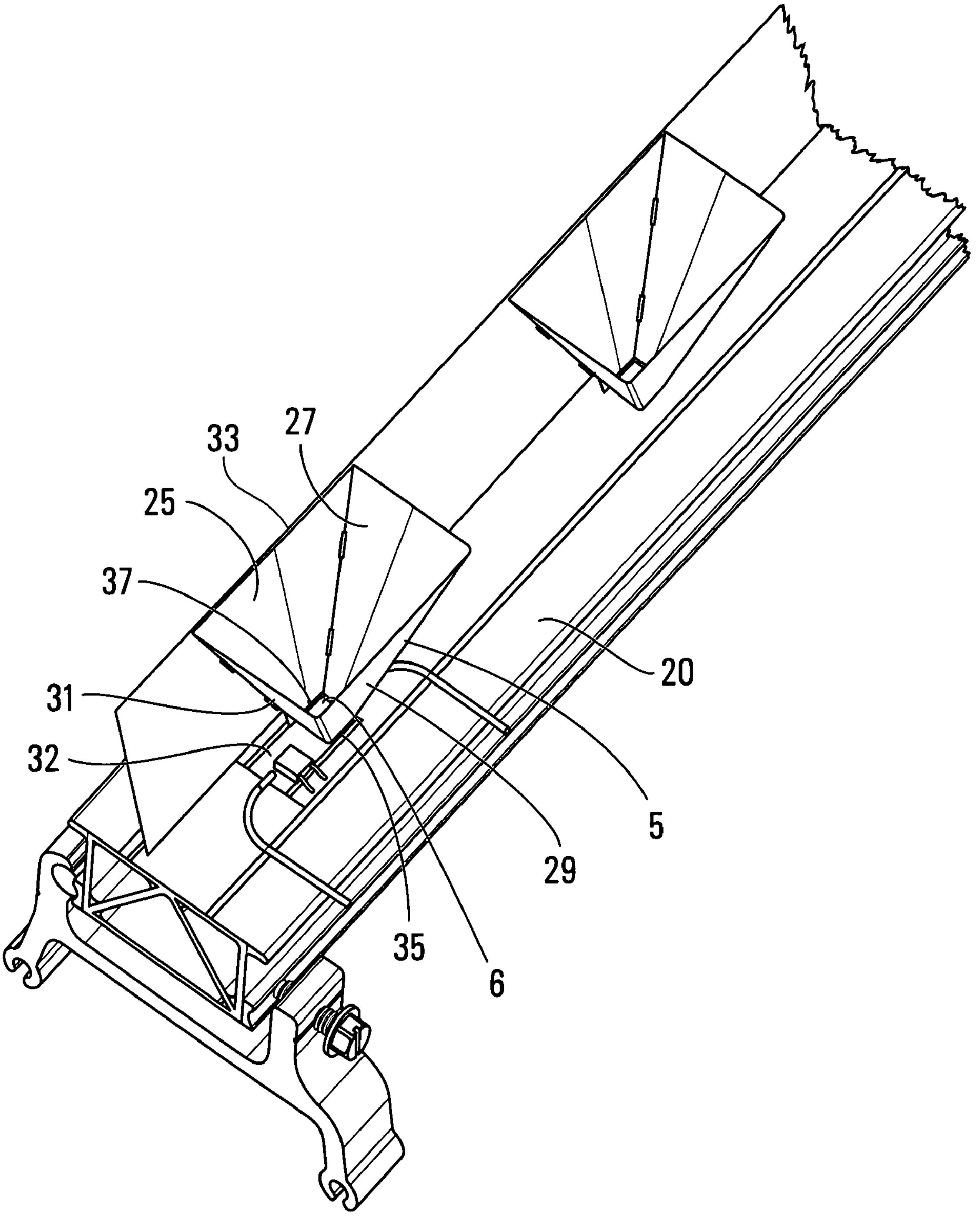

FIG. 5

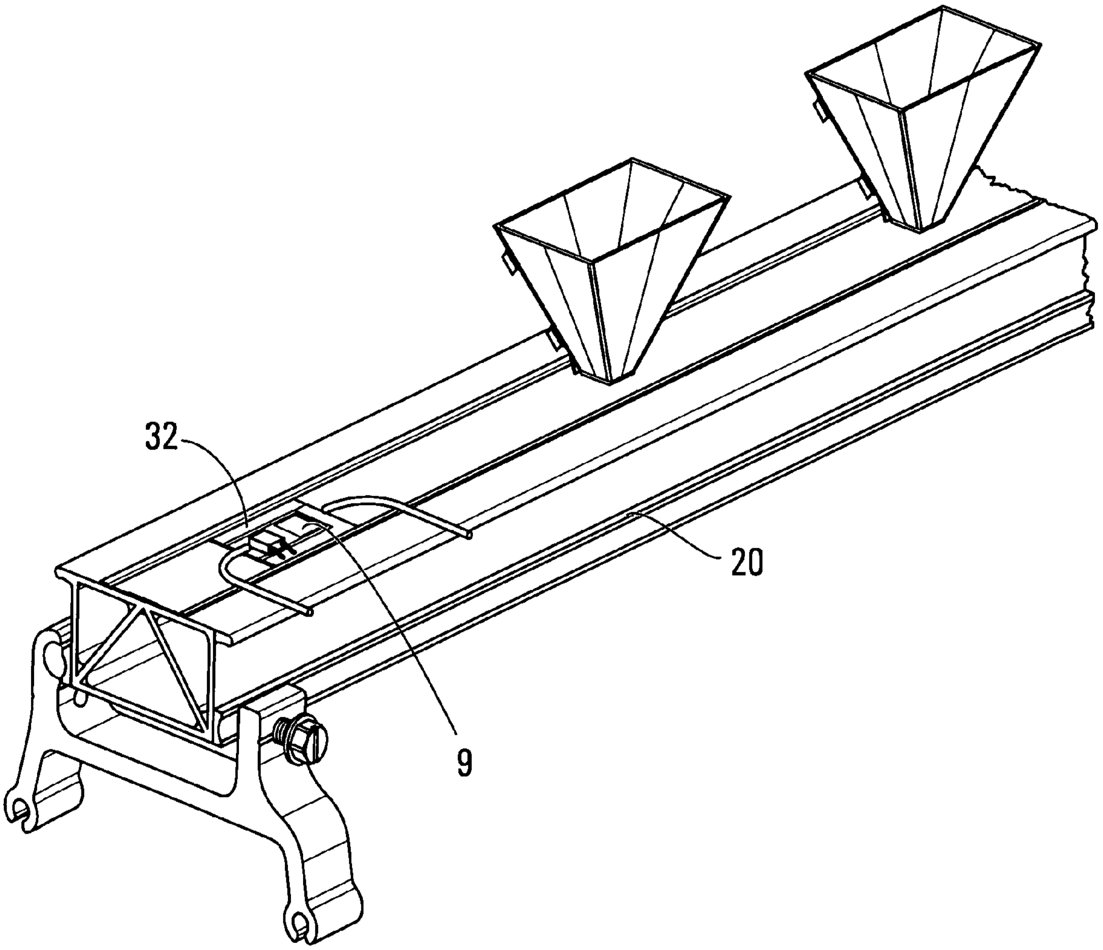

FIG. 6

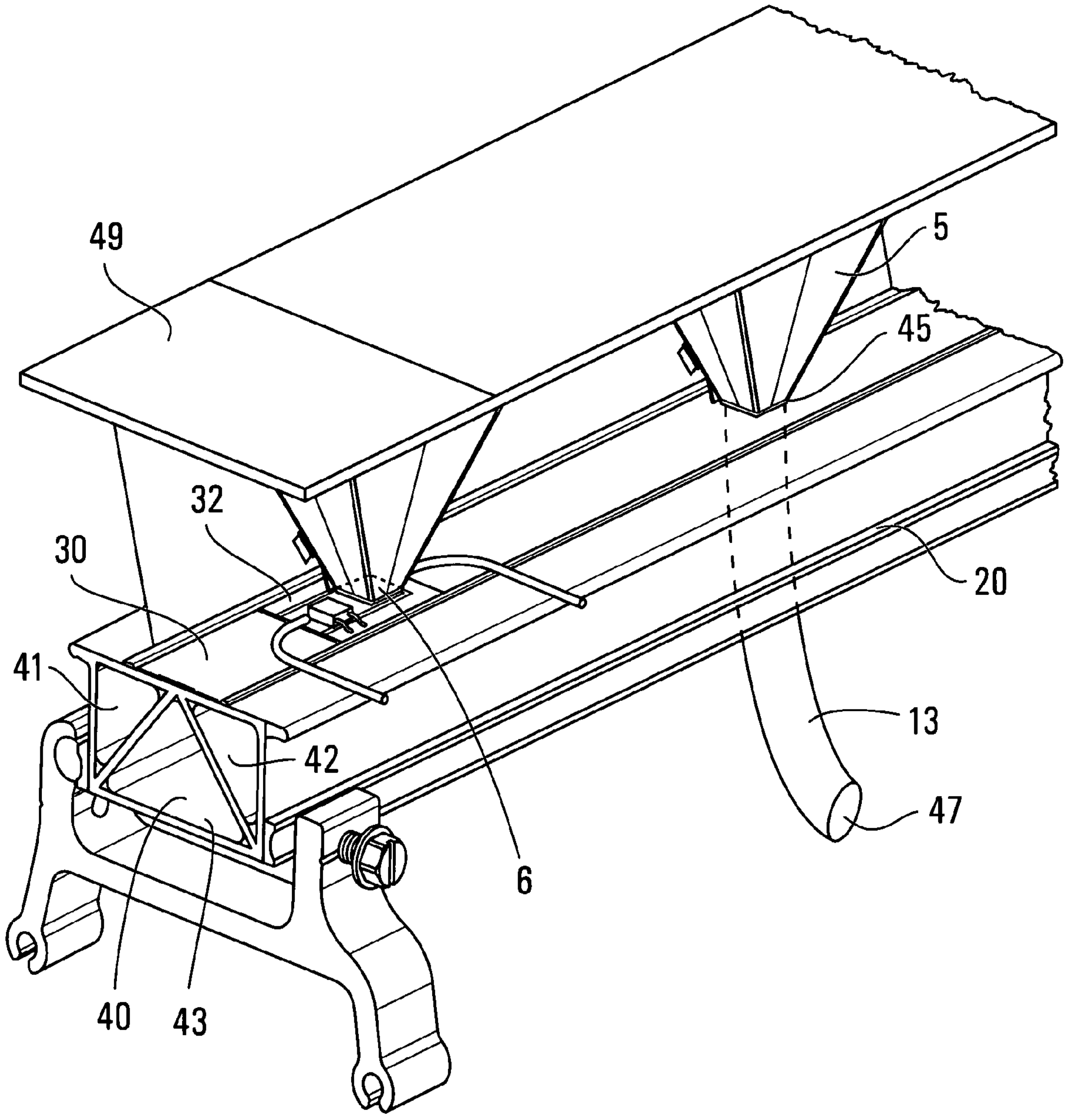

FIG. 7

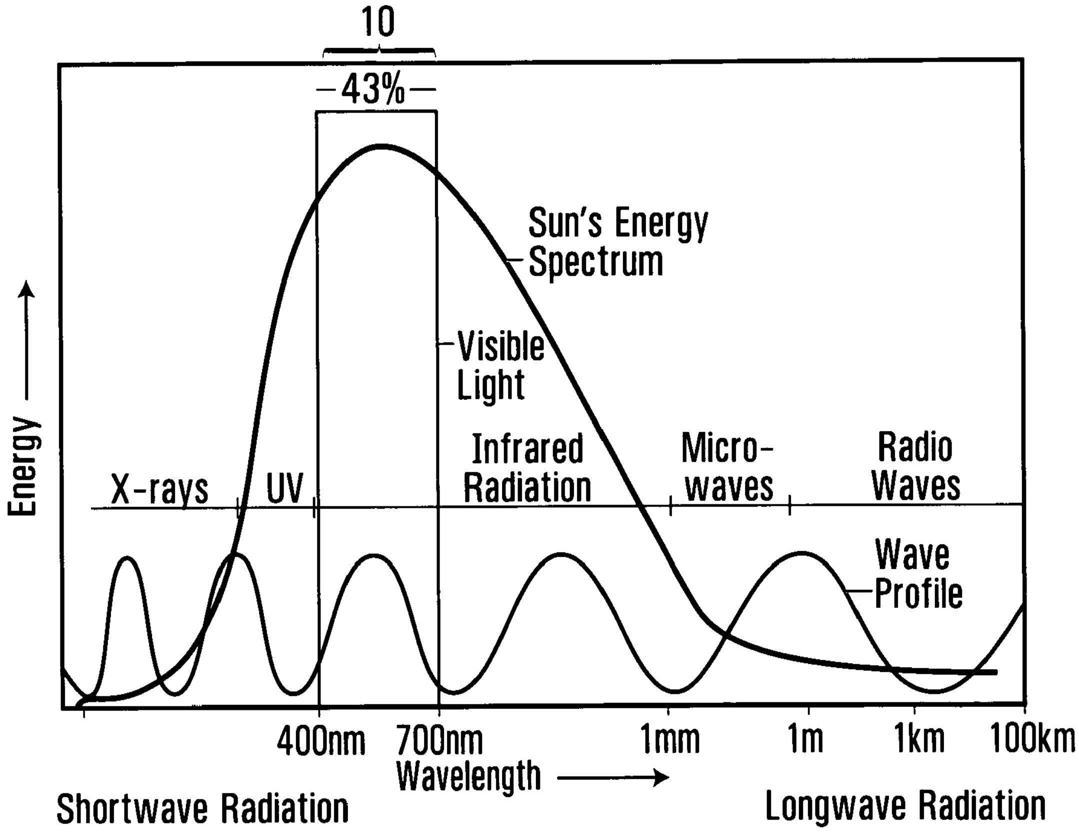
10
43%
Sun's Energy Spectrum
Visible Light
Energy
X-rays
UV
Infrared Radiation
Micro-waves
Radio Waves
Wave Profile
400nm
700nm
1mm
1m
1km
100km
Wavelength
Shortwave Radiation
Longwave Radiation

FIG. 8

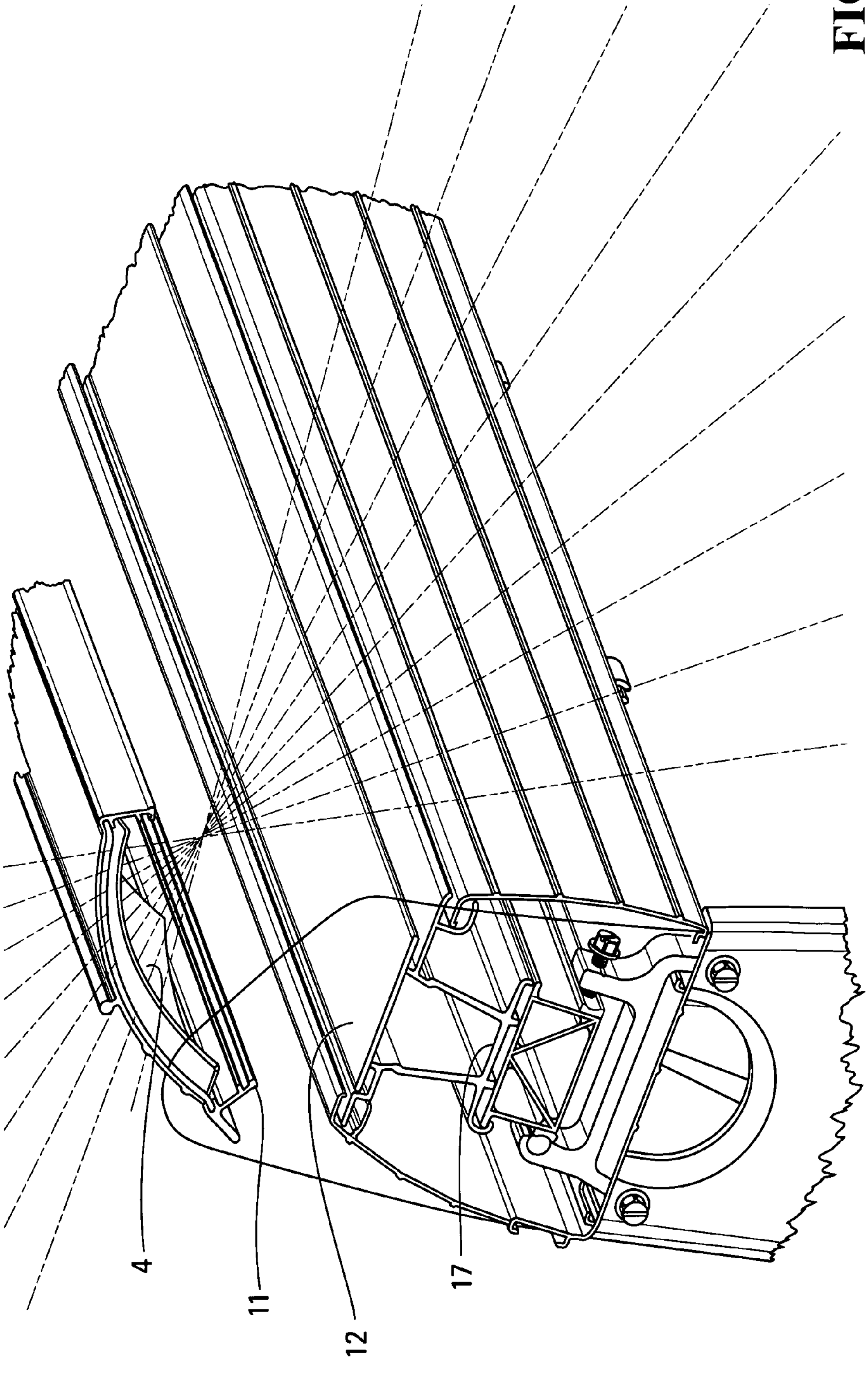

FIG. 9

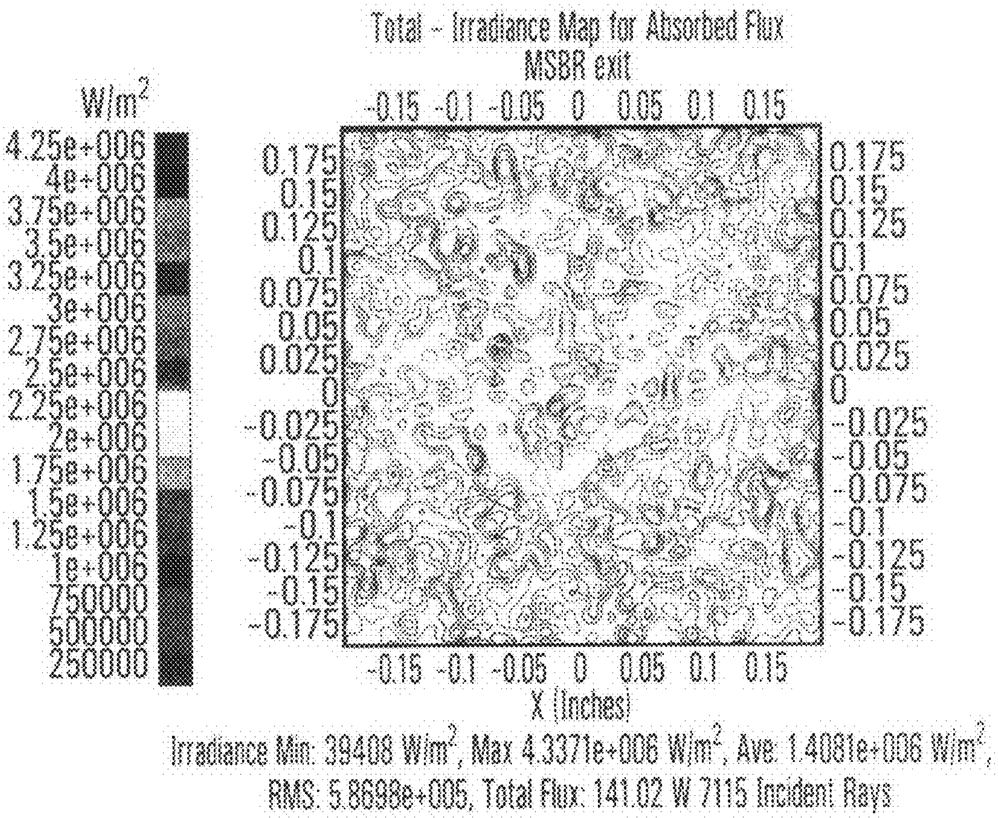

FIG. 10A

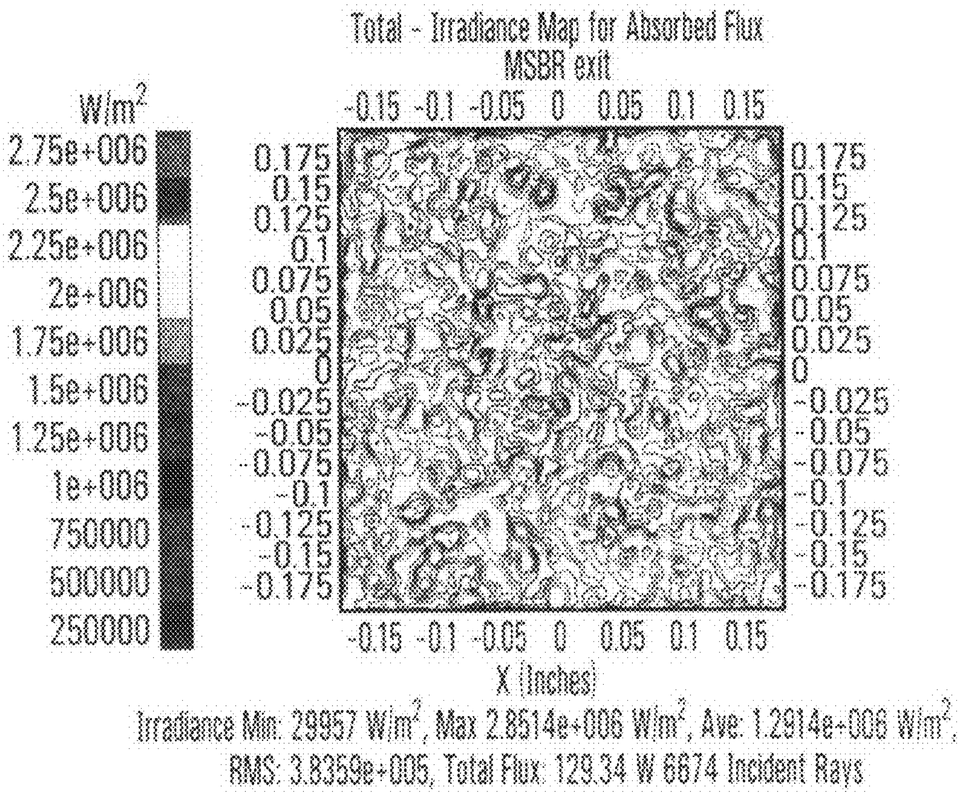

FIG. 10B

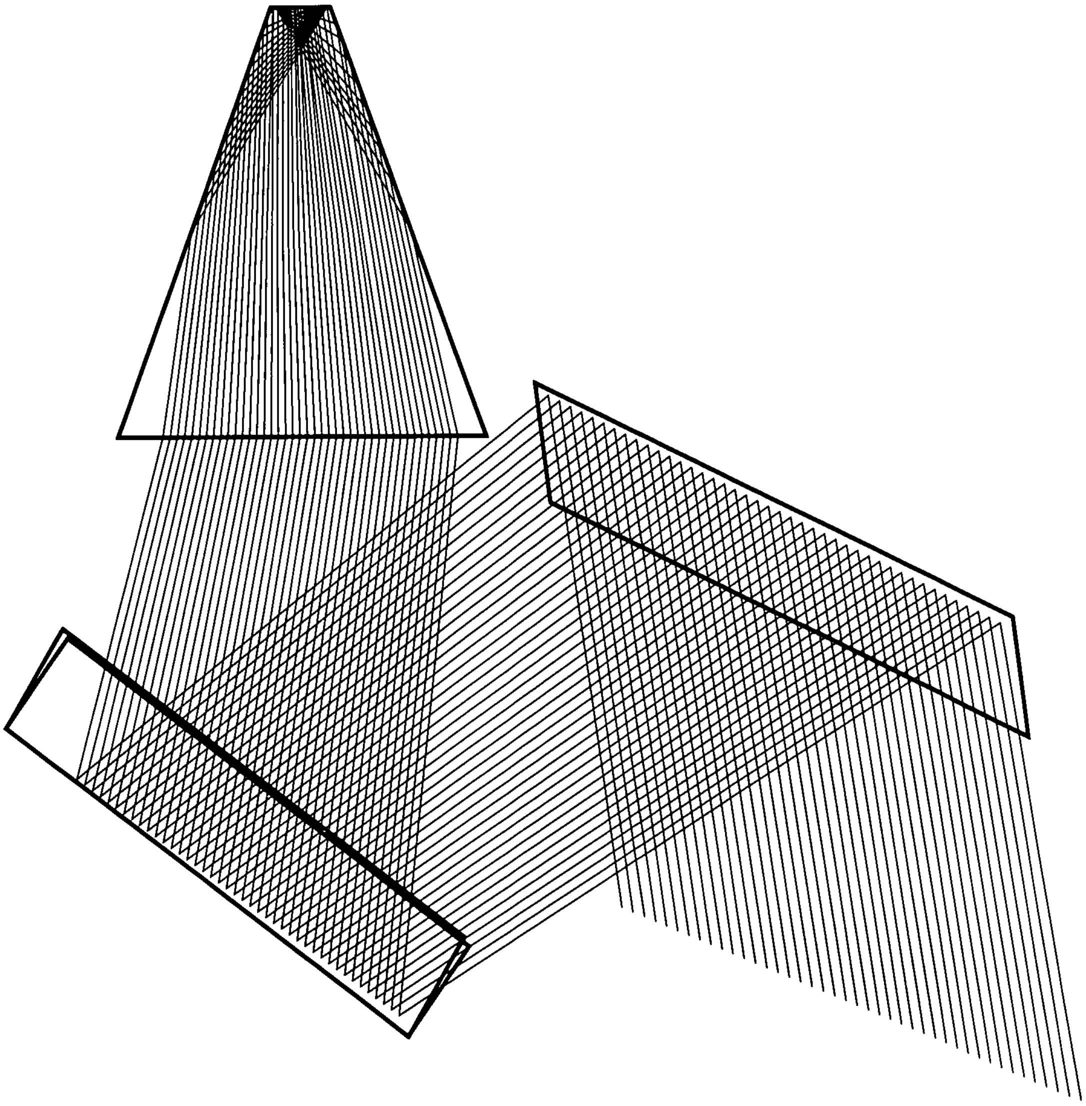

FIG. 10C

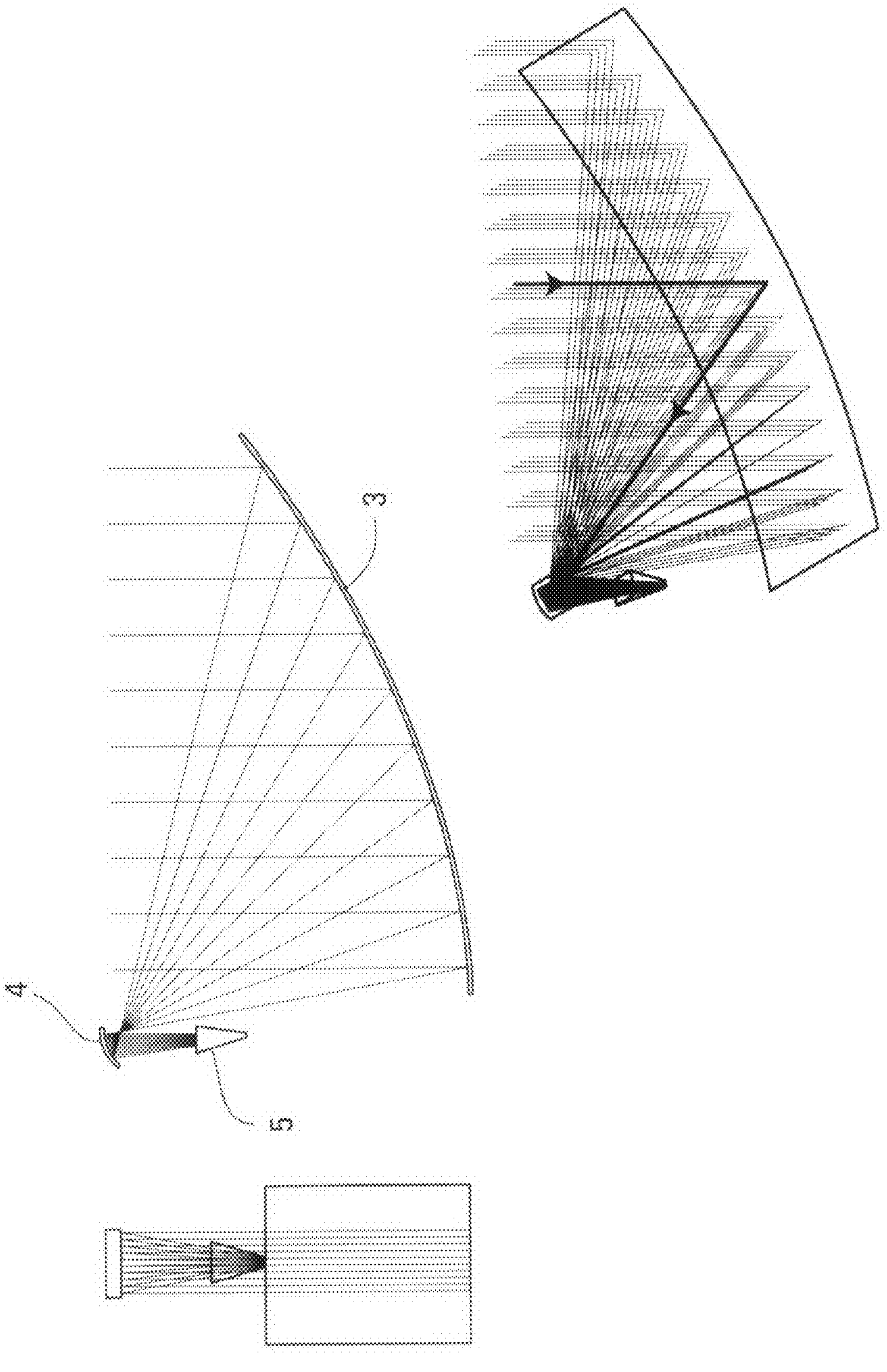

FIG. 11

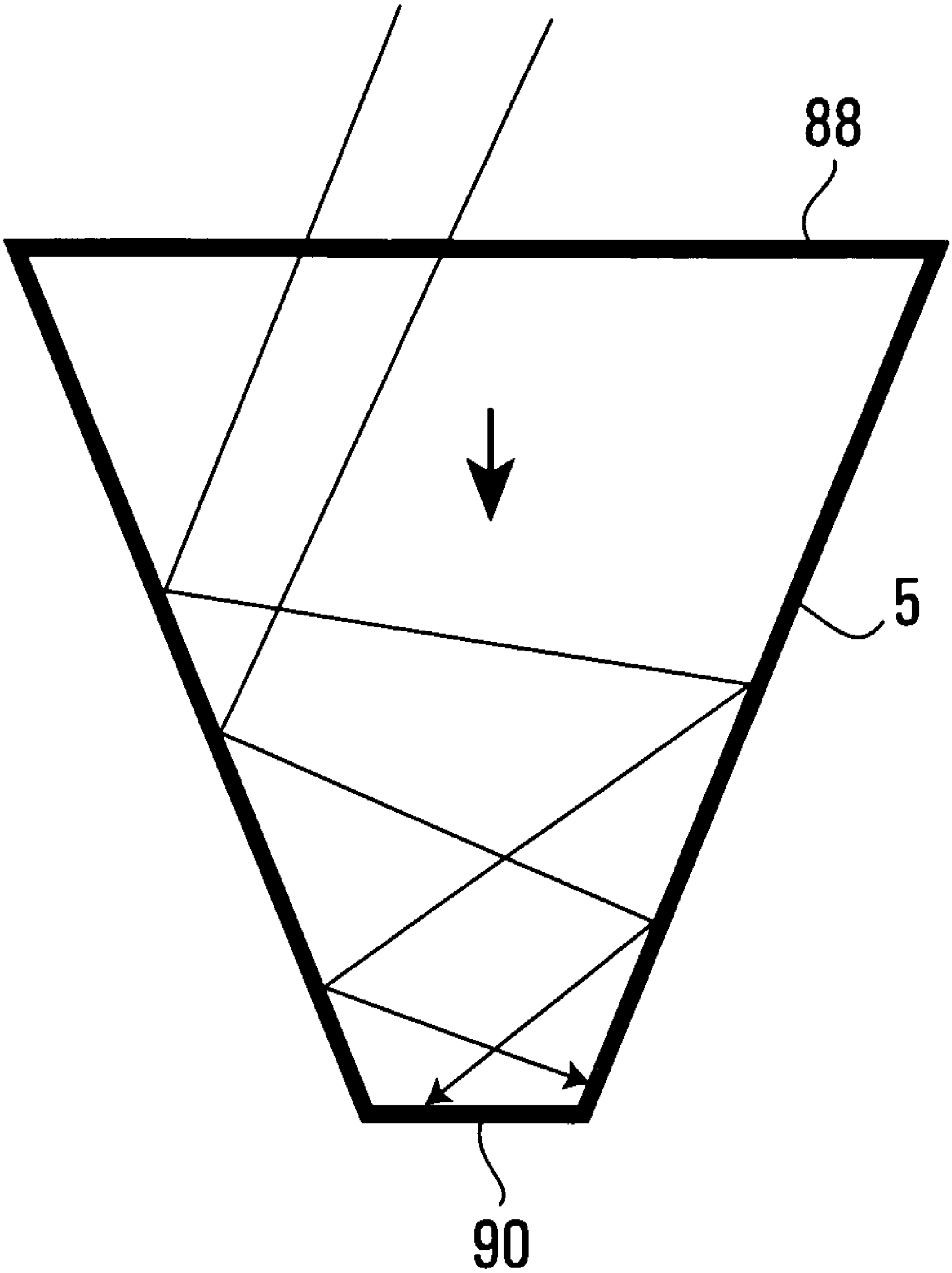

FIG. 12

SOLAR COLLECTOR

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This is a non-provisional U.S. application claiming priority from U.S. Provisional Patent Application No. 60/893,275 filed on Mar. 6, 2007, the disclosure of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to solar collectors, and in particular to solar collectors which collect and concentrate solar rays.

BACKGROUND OF THE INVENTION

[0003] Solar collectors for collecting solar energy generally fall into one of two categories: concentrating and non-concentrating. Concentrating solar collectors typically comprise a reflector for reflecting and concentrating received solar radiation towards an absorber. The absorber may include a conduit for carrying a heat transfer fluid for absorbing solar thermal energy and/or an array of photovoltaic cells for converting solar energy into electrical energy. The reflector is either in the form of a circular dish with the focal position above the center of the dish, or a trough-like, parabolic reflector which produces a line focus along the length of the reflector. In the latter case, the absorber typically comprises a radiation absorbing tube positioned centrally above the reflector and extending along its length.

[0004] Focussing or concentrating solar collectors typically require some type of sun tracking mechanism and tracking control system to vary the orientation of the collector to maintain the focal position of the solar radiation of the absorber surface. Non-focusing solar collectors generally comprise flat, solar absorbing panels which are fixed in position and do not actively track the sun.

[0005] An example of a trough-like solar collector system is disclosed in WO 2005/090873. The solar collector comprises a parabolic trough-like reflector having a longitudinal absorber positioned above the reflector and mounted thereon by means of a central support upstanding from the reflector. The reflector includes spaced apart ribs fixed to the underside of the reflector panel to help maintain the shape of the reflective surface. The absorber comprises a longitudinal plate having a radiation absorbing surface which may include an array of solar cells mounted thereon. A conduit is positioned adjacent the back of the plate for transferring solar thermal energy into a heat transfer fluid. Transparent panels extend from each side of the absorber to opposed longitudinal edges of the reflector to protect the reflective surface from weathering and to provide additional structural rigidity.

SUMMARY OF THE INVENTION

[0006] According to an aspect of the present invention, there is provided a solar collector comprising a trough-like reflector for receiving solar rays and for concentrating the rays in a direction generally transverse to the length of the reflector between its ends, and concentrator means for receiving the concentrated rays from the trough-like reflector and for concentrating the rays in one or more of a direction generally along said length and a direction generally transverse to said length.

[0007] According to another aspect of the present invention, there is provided an asymmetric solar concentrating trough based system, having means for actively tracking the sun on two axes; elevation (**1**) with individual troughs and collectively with an array of troughs tracking on azimuth (**2**) with a primary (**3**) and secondary (**4**) mirror for concentrating the sun on two axes.

[0008] According to another aspect of the present invention, there is provided a symmetric solar concentrating trough based system, having means for actively tracking the sun on two axes; elevation (**1**) with individual troughs and collectively with an array of troughs tracking on azimuth (**2**) with a primary (**3**) and secondary (**4**) mirror for concentrating the sun on two axes.

[0009] According to another aspect of the present invention, there is provided a two stage reflective solar concentration system where a first primary optical concentration reflector (**3**) is a two dimensional symmetric or asymmetric parabolic trough and second optical concentration stage (**4**) is a three dimensional modified paraboloid; both designed in combination so as to provide a concentration ratio in the range from about 80 to about 10,000 suns, or more.

[0010] According to another aspect of the present invention, there is provided a two stage concentration system with a third reflective or refractive (e.g. pyramidal frustum) optic stage (**5**) designed to accept the concentrated sunlight rays (**14**) and mix them with multiple bounces so as to produce a substantially uniform illumination on the target surface within about ±10% to ±30% maximum average illumination levels.

[0011] According to another aspect of the present invention, there is provided a solar concentrating receiver wherein heat is carried away from the concentrated solar area (**6**) by heat transfer fluid (**7**) running longitudinally through the receiver in close proximity to the focal line (**8**) of the secondary 3D paraboloid (**4**).

[0012] According to another aspect of the present invention, there is provided a solar concentrator or receiver wherein a high efficiency multi-sun solar cell (**9**) is placed at the solar focus area (**6**) to simultaneously produce heat and electricity.

[0013] According to another aspect of the present invention, there is provided a solar concentrator receiver wherein a "cold" mirror (**4**) is used as the second stage mirror to remove solar radiation at least one of below about 400 nm and above about 700 nm, allowing substantially only the visible light (**10**) only to pass through and where a translucent (fiber) optic light conductor (**13**) is placed at or near the solar focus area (**6**) allowing the transmission of visible light into buildings and/or areas requiring light. The cold mirror prevents heat (infrared (IR) solar radiation) and plastic damaging (Ultraviolet (UV) Solar wave lengths) from entering the fiber optic light conductor (**13**), and acts in an analogous way to a band pass filter in the electronics field.)

[0014] According to another aspect of the present invention, there is provided a solar concentrating receiver wherein one or more translucent lens(es) (**11**, **12**) (e.g. planar or focusing translucent plate(s)) are placed in the solar collection beam of light to remove the IR and/or UV solar radiation.

[0015] According to another aspect of the present invention, there is provided a solar concentrating receiver wherein either the cold mirror (**4**) or translucent lens (**11**, **12**) are thermally interconnected to one or more UV and/or IR filters to efficiently and simultaneously capture the heat and focus the light into the fiber optic light conductor (**13**).

[0016] According to another aspect of the present invention, there is provided a solar concentrator receiver wherein one or more thermal collection path(s) are thermally insulated with a thermal insulating material, e.g. mineral wool or similar high temperature, preferably, non-moisture absorbing insulation.

[0017] According to another aspect of the present invention, there is provided a solar receiver wherein one or more of the fluid path extrusion (**15**) and the receiver cover (**16**) (if any) are continuous over the length of the primary mirror (**3**); and the secondary reflector or concentrator (**4**) and the secondary reflector cover (**16**) (if any) and the optical mixer (**5**) and optical mixer extrusion (**17**) are segmented in shorter sections so as to help keep precise alignment between the secondary reflector (**4**) and the mixer (**5**) during fluid path extrusion (**15**) heat up and cool down from about −40 to +100° C. for example, or any other operating temperature range.

[0018] In the above aspects of the invention, reference numbers in parentheses refer to features of the drawings, which are for illustrative purposes only and in no way limiting of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Examples of embodiments of the present invention will now be described with reference to the drawings, in which:

[0020] FIG. **1**A shows a side view and part sectional view of a solar collector according to an embodiment of the present invention;

[0021] FIG. **1**B shows a front view of the solar collector of FIG. **1**A;

[0022] FIG. **2**A shows a perspective view of an array of solar collectors according to an embodiment of the present invention;

[0023] FIG. **2**B shows a side view of the solar collector array shown in FIG. **2**A;

[0024] FIG. **2**C shows a front view of the solar collector array shown in FIG. **2**A;

[0025] FIG. **2**D shows a top view of the solar collector array shown in FIG. **2**A;

[0026] FIG. **3** shows a perspective view of a solar collector according to another embodiment of the present invention;

[0027] FIG. **4** shows a perspective, part sectional view of part of the solar collector shown in FIG. **1**;

[0028] FIG. **5** shows a perspective view of part of the solar collector shown in FIG. **4**;

[0029] FIG. **6** shows part of the solar collector shown in FIG. **5**;

[0030] FIG. **7** shows a perspective view of part of the solar collector shown in FIG. **4**, and further including an optical waveguide;

[0031] FIG. **8** shows a graph of the spectrum of solar radiation versus energy;

[0032] FIG. **9** shows a perspective view of part of a solar collector according to an embodiment of the present invention;

[0033] FIG. **10** shows an example of a radiation mixer and graphs of irradiance as a function of area;

[0034] FIG. **11** shows an example of the geometry of an asymmetric solar collector according to an embodiment of the present invention and examples of the trajectories of solar rays; and

[0035] FIG. **12** shows a cross-sectional view through a mixer according to an embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0036] Referring to FIGS. **1**A and **1**B, a solar collector comprises a trough-like primary reflector **3** for receiving solar rays, a secondary reflector **4** spaced from the primary reflector **3** for receiving solar rays reflected from the primary reflector, and a receiver **20** for receiving solar rays reflected from the secondary reflector **4**. In this embodiment, the solar collector geometry is asymmetric, although in other embodiments, the geometry may be symmetric.

[0037] The primary reflector is shaped to concentrate the reflected radiation towards a focal line **21**, which may be positioned in front of the secondary reflector or mirror **4**, although in other embodiments, the focal line or position may be generally located behind the secondary reflector. The surface of the secondary reflector is curved also to concentrate the solar radiation in a first direction, e.g. x-direction shown by the arrow **22**. The secondary mirror **4** is also curved in an orthogonal direction, along the z-direction (into the page of FIG. **1**) to concentrate light in the z-direction (i.e. longitudinal direction). The receiver **20** further includes an optical distributor **24** (e.g. mixer) for receiving concentrated solar radiation from the secondary reflector **4** and more uniformly distributing the solar radiation over a predetermined area. An alternative or additional function of this device is to assist in increasing the amount of received solar radiation from the secondary reflector reaching a predetermined surface. The device may comprise a reflective or refractive element or a combination of both. An embodiment of a reflective version of the device, shown in FIG. **5**, comprises an element having tapered side walls **25**, **27**, **29**, **31**, and having a first, receiving end **33** defining an aperture for receiving solar rays from the secondary mirror **4**, the side walls tapering inwardly towards an opposite end **35** and defining an area **37**. A solar converter may be positioned at the opposed end **35** for converting solar radiation into electrical energy. The size and shape of the light receiving surface of the converter may substantially correspond to the size and shape of the area **37** so that substantially all available concentrated radiation from the secondary reflector and which enters the distribution device impinges on the converter. The distribution device may have any suitable shape, size and geometry. In the present embodiment, the distribution device **5** is frustopyramidal, having four flat tapered sides. In other embodiments, the distribution device may be conical, thereby forming a circular (or elliptical) area over which solar radiation is distributed, and which may be suitable, for example for circular solar cells. In other embodiments, the distribution device may have any number of sides, e.g. three, five, six, seven, eight, etc.

[0038] In a refractive version of the distribution device, the device may comprise a prism of solid translucent material, e.g. glass or other suitable material and have any suitable shape as described above.

[0039] Referring to FIGS. **5**, **6** and **7**, the receiver **20** further comprises a substrate **30** on which a number of distribution devices **5** may be mounted. FIGS. **5** to **7** show a solar cell **32** mounted on the substrate **30** having a solar radiation collecting area **6** which is registered with the lower area of the distribution device. In this embodiment, the substrate **30** forms part of the wall of a fluid carrying conduit **40**, which in this embodiment has three fluid carrying channels, **41**, **42**, **43**. Heat absorbed by the substrate **30** via an optional solar cell **32**

is transferred through the substrate to fluid, e.g. liquid flowing through the conduits to a suitable point of use, such as space heating and/or to provide a source of hot water for example. In other embodiments, any number of fluid carrying channels may be provided adjacent the substrate **30**.

[0040] Referring to FIG. **7**, the receiver includes a light pipe or optical waveguide **13** having a first end **45** which is positioned to receive sunlight from a distribution device **5** and has a second end **47** from which the light is emitted. The light transmitted by the waveguide **13** may, for example, be used to illuminate interior spaces in buildings or other spaces, where needed or desired. The optical waveguide may comprise any suitable material, for example a polymeric or plastic material, glass or any other suitable material. The optical properties of the material should preferably be such as to minimize any light escaping from the sides of the optical waveguide, for example, the refractive index of the material may be such as to provide total or almost total internal reflection. The optical waveguide may comprise a single unitary member or a plurality of individual waveguide members, e.g. a bundle of optical waveguides or fibres. The or each waveguide may have any suitable cross-sectional geometry, including rectangular or circular, and the lower end of the distribution device may be adapted to match the shape of the end **45** of the optical waveguide.

[0041] A means may be provided for filtering one or more parts of the solar spectrum so that only selected wavelengths are admitted to the optical waveguide or other light receiver. Such means may include any one or more of a coating on the primary and/or secondary reflectors **3**, **4** which selectively absorb certain wavelengths and reflect others, a lens positioned between the primary and secondary reflectors **3**, **4**, a lens positioned between the secondary reflector and the entrance aperture of the distribution device **5** and/or a coating on the reflective surfaces of the distribution device or a lens between the entrance aperture and the bottom portion of the distribution device.

[0042] Referring to FIGS. **4** and **7**, the receiver includes a translucent member **49** which is positioned above each distribution device **5** and may engage with the upper peripheral edge defining the entrance aperture of the distribution device to assist in holding each distribution device in place, so that effectively, each distribution device is clamped between the translucent plate **49** and substrate **30**. The translucent plate or lens assists in protecting the receiver from the ingress of external elements such as atmospheric elements, e.g. moisture, dust and other particulate matter and also insects. The translucent plate **49** may also serve as a filter to filter out certain parts of the solar radiation spectrum. Portions of the spectrum which may be filtered using any one or more of the filtering means described above may include ultraviolet light and/or shorter wavelength radiation and/or infrared light and/or longer wavelength radiation.

[0043] In some embodiments, the receiver may include a combination of a fluid conduit and one or more solar cells, without any optical waveguides. In another embodiment, the receiver may comprise a combination of a conduit and one or more optical waveguides in the absence of any solar cells, and in another embodiment, the receiver may include a combination of a conduit, one or more solar cells and one or more optical waveguides. In other embodiments, the receiver may include one or more solar cells in the absence of any conduit or optical waveguide and in other embodiments, the receiver may include one or more optical waveguides in the absence of any conduit or solar cells.

[0044] Referring to FIG. **1**B which shows a schematic front view of a solar collector of FIG. **1**A, the solar collector includes a plurality of arms or stantions **61** connected to the primary reflector structure along the edge thereof (or at any other suitable position) for supporting the receiver **20**. In this embodiment, the receiver comprises a continuous substrate **30** extending in the longitudinal (i.e. z) direction and which is connected to each stantion either directly or indirectly via a bracket **63** (shown in FIG. **4**). The secondary reflector **4** is divided into a plurality of discrete sections along the length of the solar collector, and each secondary reflector section may be connected to the substrate **30** via suitable brackets **65**. The sections **4***a*, **4***b*, **4***c* may be mounted to provide a gap **67** between the ends of adjacent sections to allow the adjacent ends to move towards and away from each other with thermal expansion and contraction. In use, the substrate **20** may be at a higher temperature than the secondary reflectors, and if made of a similar material, the substrate will expand more in the z-direction than the secondary reflector. The difference in movement in the z-direction between the secondary reflector and the substrate on which each distribution device **5** is mounted may be reduced by dividing the secondary reflector into discrete sections so that any differential displacement occurs over a limited length of the secondary reflector. Maintenance of alignment between the secondary reflector **4** and each distribution device is also assisted by connecting the secondary reflector to the substrate **20**. Advantageously, these features allow each secondary reflector associated with a distribution device to remain substantially aligned in the z-direction so that most of the available or substantially all light reflected and focussed by the secondary reflector in the z-direction, as indicated by the broken ray lines **69**, **70**, are directed into the distribution device entrance aperture. The discrete sections of the secondary reflector may have any desired or predetermined length, and alignment between each secondary reflector and its corresponding distribution device may be improved as the length of each section decreases. In the illustrative embodiment of FIG. **1**B, each section **4***a*, **4***b*, **4***c* spans four distribution devices **5**, although in other embodiments, a section may span any other number of distribution devices, for example one, two, three, five, six or more. Referring to FIG. **4**, the receiver includes upper, lower and rear housing panels or walls **73**, **75**, **77** which enclose the receiver elements, including the substrate, distribution devices and conduit. Insulating material may be provided within the housing in order to thermally insulate the fluid conduit, the substrate and any one or more other components of the receiver.

[0045] In one embodiment, the housing panels and the fluid conduit may comprise extrusions which run continuously from one end to the other of a solar collector. In one embodiment, and with reference to FIG. **4**, the receiver may include a channel member **79** for seating one or more distribution devices and which may be slidably coupled to the substrate **30** or capable of sliding relative thereto in the z-direction. The channel member may be formed by extrusion. The channel member may also be divided into discrete sections along the length of the receiver and each section may be associated with a corresponding secondary reflector section, for example as shown in FIG. **1**B. At least partially decoupling the mounting for one or more distribution devices from the substrate **30** may also assist in preserving alignment between each secondary reflector and its associated distribution device with changes in temperature.

[0046] Referring to FIG. **4**, the channel mounting has upper outwardly extending flanges **81**, **83** for mounting a translucent panel, e.g. filter or lens thereon. The channel section and flanges may all be formed as an integral one piece extrusion.

[0047] Referring to FIGS. **2**A to **2**D, one or more solar collectors may be mounted for rotation so that the longitudinal axis of the collector can be maintained substantially perpendicular to the direction of the sun's rays as the earth rotates. Advantageously, this helps to ensure that the position of focus of the sun's rays for each secondary reflector in the z-direction remains substantially fixed as the earth rotates to ensure that the rays are reflected into each distribution device and are not offset to one side or the other in the z-direction. This increases the amount of sunlight collected over a daily period. In addition, each solar collector can be mounted to rotate about a longitudinal axis thereof, for example rotational axis **1** shown in FIG. **1**A so that the solar collector can track the sun as its elevation changes over a daily period.

[0048] FIGS. **2**A to **2**D show an array of solar collectors positioned one behind the other and mounted together on a rotary support structure which collectively rotates the array about a vertical axis. The support structure includes a circular ring **201** with a framework positioned within the ring and upstanding therefrom for supporting each solar collector. The ring is supported by a plurality of discrete support members **203** spaced circumferentially around the support ring and which may include one or more bearing members and/or guide members for supporting and guiding the rotary ring as it rotates. Rotation of the support structure may be driven by any suitable means such as a motor via a cable attached at one or two different positions on the support ring or support structure and which is looped about a rotary drum or capstan, driven by the motor.

[0049] FIG. **10** shows an embodiment of a distribution device (e.g. mixer) having a frustopyramidal geometry and a graph showing the distribution of irradiance over the area of its lower aperture.

[0050] FIG. **11** shows the geometry of the primary reflector **3**, secondary reflector **4** and distribution device **5** according to an embodiment of the present invention, with ray lines illustrating the direction of solar rays reflected by and impinging on each element. FIG. **12** shows a side cross-sectional view through a distribution device illustrating multiple reflections in which each reflection results in forward travel of each ray towards the lower aperture **90** of the distribution device rather than backwards reflection towards the entrance aperture **88**.

[0051] In embodiments of the solar collector, any one or more components may comprise a suitable metallic material, for example aluminum or any other suitable material. Where differential thermal contraction and expansion is an important consideration, components may comprise the same or similar material.

[0052] Other aspects and embodiments of the invention may comprise any one or more features disclosed herein in combination with any one or more features disclosed herein. In any aspect or embodiment of the invention, any one or more features may be omitted altogether or may be substituted by an equivalent or variant thereof.

[0053] Numerous modifications to the embodiments disclosed herein will be apparent to those skilled in the art.

1. A solar collector comprising a trough-like reflector for receiving solar rays and for concentrating the rays in a direction generally transverse to the length of the reflector between its ends, and concentrator means for receiving the concentrated rays from the trough-like reflector and for concentrating the rays in one or more of a direction generally along said length and a direction generally transverse to said length.

2. A solar collector as claimed in claim **1**, wherein said concentrator means comprises at least one of a refractive element and a reflective element.

3. A solar collector as claimed in claim **1**, wherein said concentrator means comprises a plurality of elements positioned relative to one another in a direction along the length of the trough-like reflector.

4. A solar collector as claimed in claim **2**, wherein one or more of said elements redirects rays in opposite directions along said length to converge towards a predetermined area.

5. A solar collector as claimed in claim **1**, wherein said concentrator means concentrates the received rays from the trough-like reflector in a direction transverse to said length.

6. A solar collector as claimed in claim **1**, wherein said concentrator means concentrates solar rays received from the trough-like reflector towards a plurality of discrete areas spaced apart in a direction along the length of the trough-like reflector.

7. A solar collector as claimed in claim **6**, further comprising any one or more of a solar cell and an optical waveguide positioned at one or more discrete areas.

8. A solar collector as claimed in claim **6**, further comprising a ray distribution device for redistributing rays received from the concentrator means.

9. A solar collector as claimed in claim **8**, wherein the distribution device increases the uniformity of rays across at least one discrete said area.

10. A solar collector as claimed in claim **6**, wherein one or more of the distribution devices comprises a reflective device having opposed reflective side walls for reflecting solar rays received from the concentrator means.

11. A solar collector as claimed in claim **10**, wherein the distribution device is configured to prevent reflection by the reflective walls back towards the concentrator means.

12. A solar collector as claimed in claim **6**, wherein the distribution device comprises at least one wall which is angled in the ray direction towards an opposed wall of the distribution device.

13. A solar collector as claimed in claim **1**, further comprising one or more conduits for carrying fluid and which is positioned to receive thermal energy from solar rays emitted from the concentrator means.

14. A solar collector as claimed in claim **13**, comprising first and second channels extending generally in a direction along the length of the trough-like reflector and means for causing fluid to flow in a first direction along one of said conduits and in the opposite direction along the other conduit.

15. A solar collector as claimed in claim **13**, further comprising a plurality of upstanding members spaced apart along the length of the trough-like reflector and being coupled or connected to the conduit or another member which extends substantially continuously between the ends of the solar collector.

16. A solar collector as claimed in claim **15**, wherein said concentrator means is coupled to said conduit or said continuously extending member.

17. A solar collector as claimed in claim **1**, wherein said concentrator means comprises a plurality of discrete concentrators distributed in a direction along the length of the solar collector and, before thermal expansion, having a space therebetween to accommodate thermal expansion of each discrete concentrator in a direction along its length.

18. A solar collector as claimed in claim **17**, wherein a plurality of discrete concentrators are coupled to a common member extending in a direction along the length of the solar collector.

19. A solar collector as claimed in claim **1**, further comprising a plurality of discrete substrates positioned end to end in a direction along the length of the solar collector and having a gap therebetween, a plurality of discrete substrates being mounted to a common member extending along the length of the solar collector and optionally mounted on said common member in a manner which allows relative movement between the member and each substrate in a direction along the length of the solar collector.

20. A solar collector as claimed in claim **19**, comprising at least one of a solar cell and optical waveguide coupled to a discrete substrate.

21. A solar collector as claimed in claim **1**, further comprising filter means for filtering out one or more portions of the solar electromagnetic spectrum.

22. A solar collector as claimed in claim **21**, wherein said filter means comprises any one or more of a coating on the trough-like reflector, a coating on the concentrator means, a translucent member between the trough-like reflector and the concentrator means, a translucent member between the concentrator means and a means for receiving solar rays from the concentrator means.

23. A solar collector as claimed in claim **21**, wherein the filter means is adapted to filter out at least a portion of ultraviolet light and/or at least a portion of infrared light.

24. A solar collector as claimed in claim **21**, wherein said filter is adapted to transmit at least a portion of visible radiation.

25. A solar collector as claimed in claim **1**, mounted on a system capable of orienting the longitudinal axis of the solar collector in a plurality of different directions.

26. A solar collector as claimed in claim **1**, wherein said solar collector is mounted on a system capable of rotating said collector about a longitudinal axis thereof.

27. A solar collector as claimed in claim **1**, wherein a plurality of solar collectors are mounted on a common structure, the common structure enabling the elevation of each solar collector to be controlled individually or collectively such that each collector rotates about a different longitudinal axis and collectively the solar collectors rotate about a common axis which is substantially vertical or upright.

* * * * *

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Orsley

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(43) **Pub. Date: May 22, 2014**

(54) **SOLAR REDSHIFT SYSTEMS**

(76) Inventor: **Timothy James Orsley**, San Jose, CA (US)

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(86) PCT No.: **PCT/US12/43290**

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(2), (4) Date: **Jan. 13, 2014**

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G02B 27/10	(2006.01)
G02B 5/20	(2006.01)

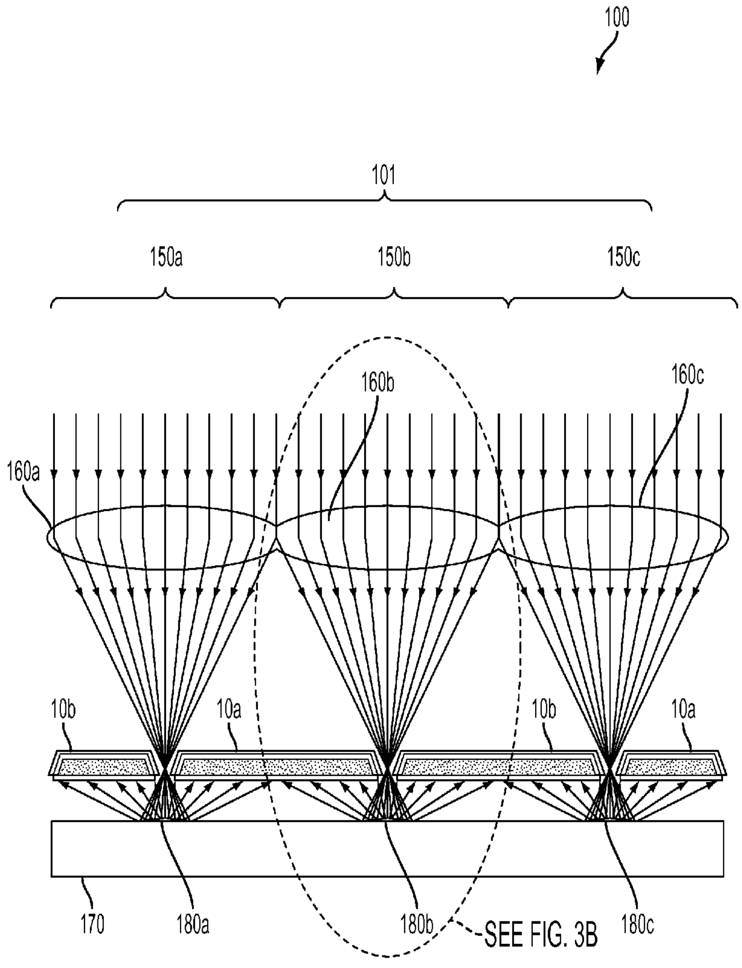
(52) **U.S. Cl.**

CPC ***A01G 9/02*** (2013.01); ***G02B 27/1006*** (2013.01); ***G02B 5/208*** (2013.01); ***A01G 33/00*** (2013.01); ***H01L 31/055*** (2013.01); *Y10S 977/774* (2013.01); *B82Y 20/00* (2013.01)

USPC **136/259**; 359/618; 359/350; 47/65.5; 47/1.4; 977/774; 977/948

(57) **ABSTRACT**

Solar-redshift systems comprise an integral array of redshift modules, each having at least a focusing device, a target, and a quantum-dot vessel. The quantum-dot vessel contains quantum dots that emit light having an emission wavelength. The focusing device directs incident solar radiation through a focusing gap and toward the quantum-dot vessel, or into a slab waveguide and then toward the quantum-dot vessel, causing the quantum dots to emit redshifted light having the emission wavelength. The redshifted light is directed to the target, examples of which include a photovoltaic material or a living photosynthetic organism. The target has increased sensitivity or response to photons having the wavelength of the redshifted light. A trapping reflector component of the quantum-dot vessel prevents loss of redshifted light to the environment outside the solar-redshift system and allows undesirable infrared light to be removed from the system.



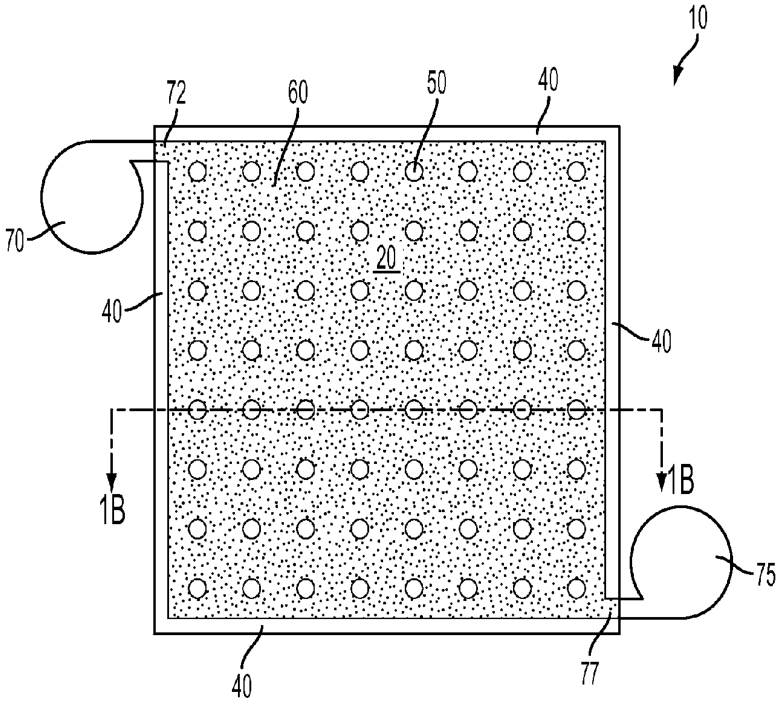


FIG. 1A

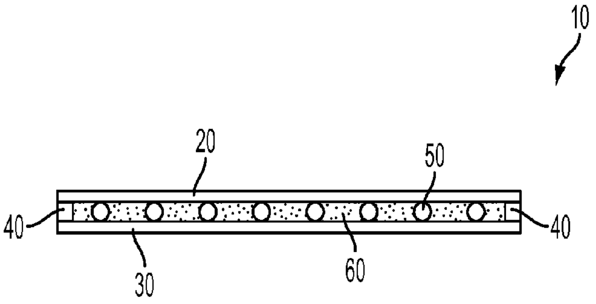
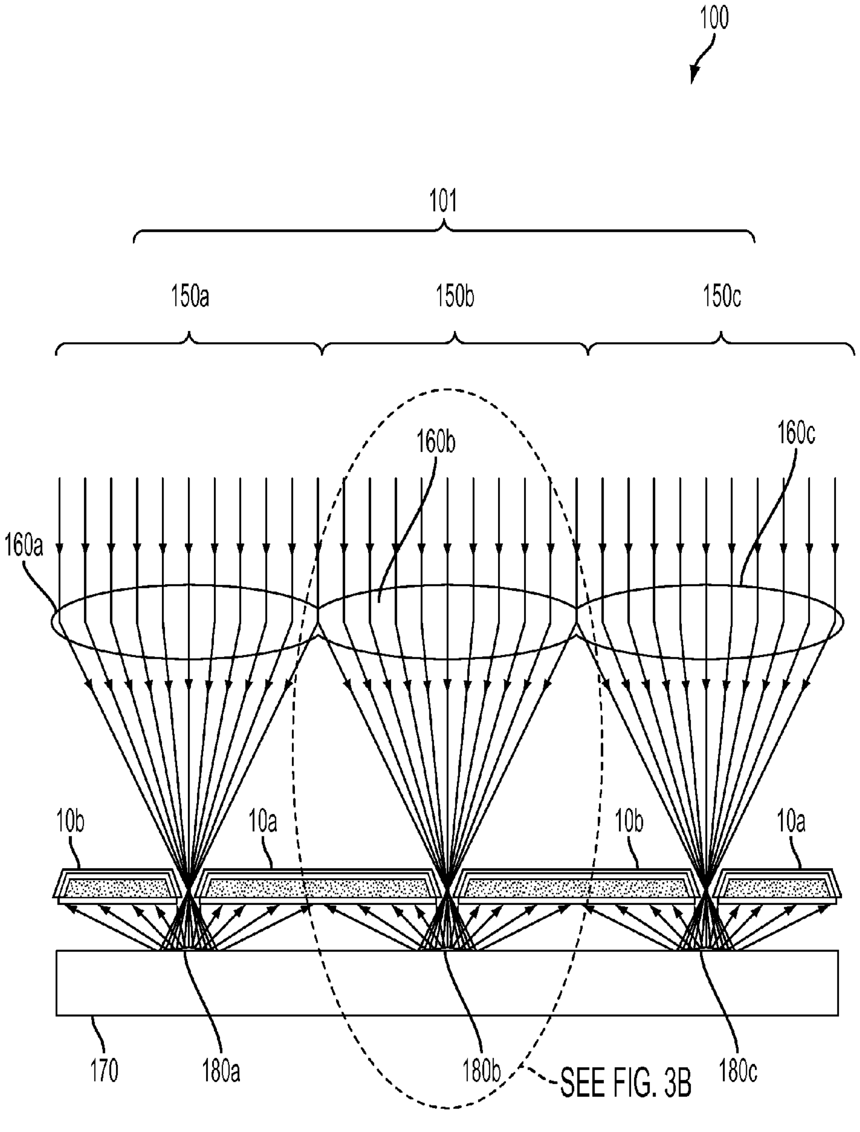


FIG. 1B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SEE FIG. 3B
180c

FIG. 2

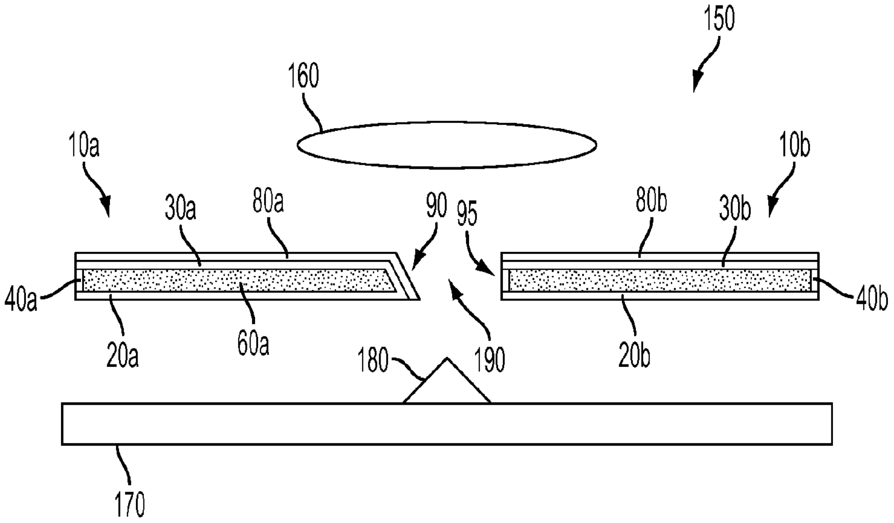
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FIG. 3A

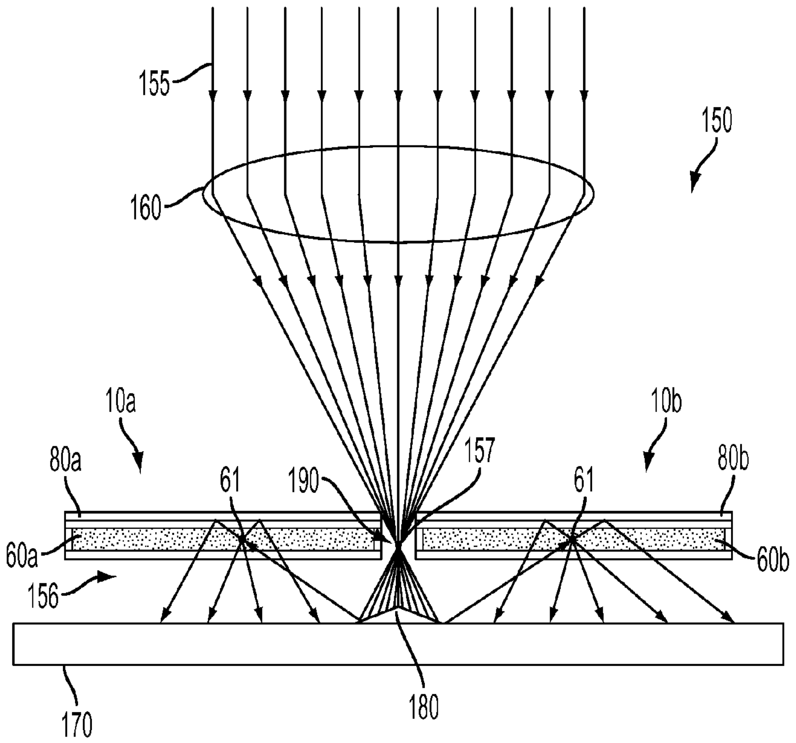
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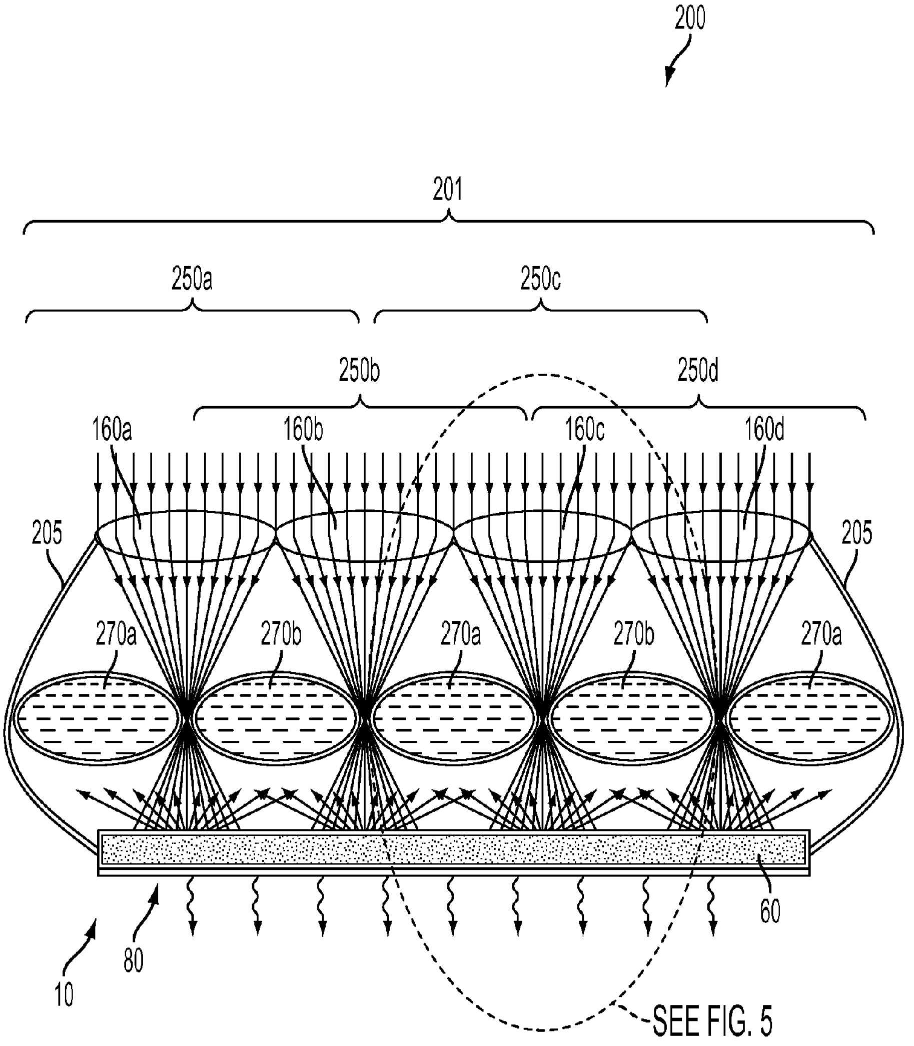
FIG. 3B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80
10
SEE FIG. 5

FIG. 4

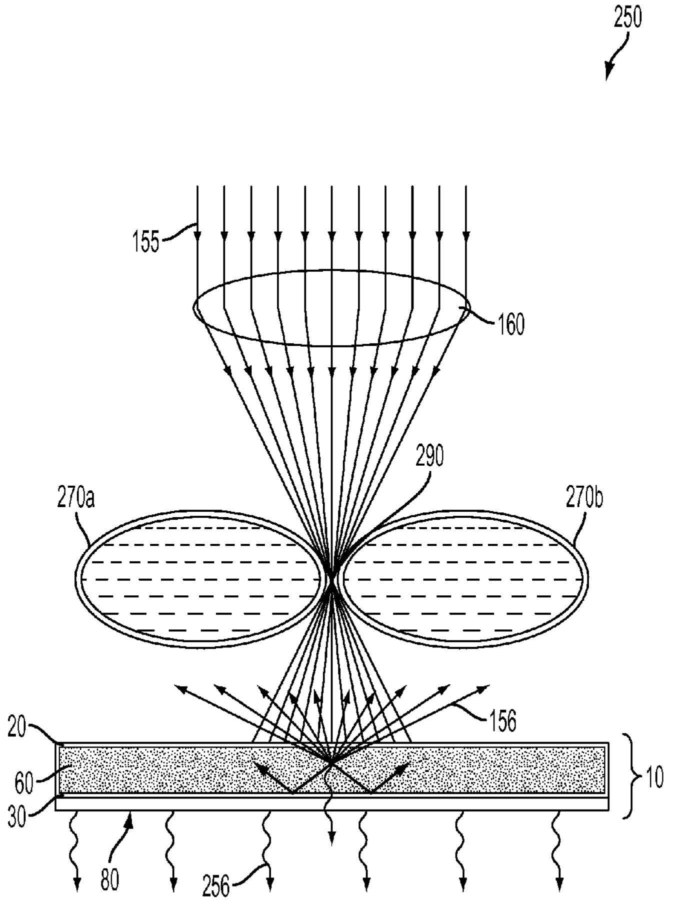
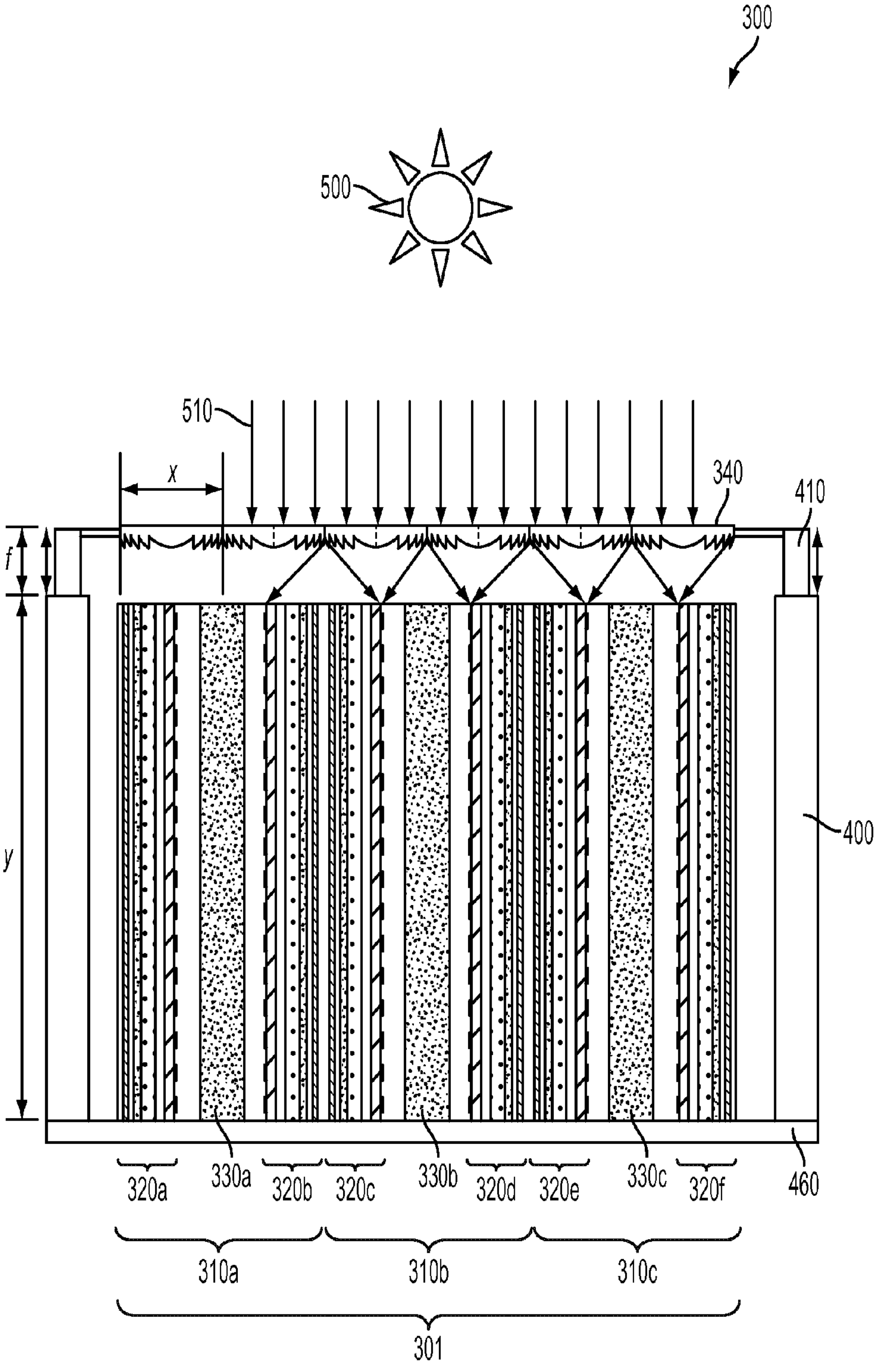


FIG. 5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320d
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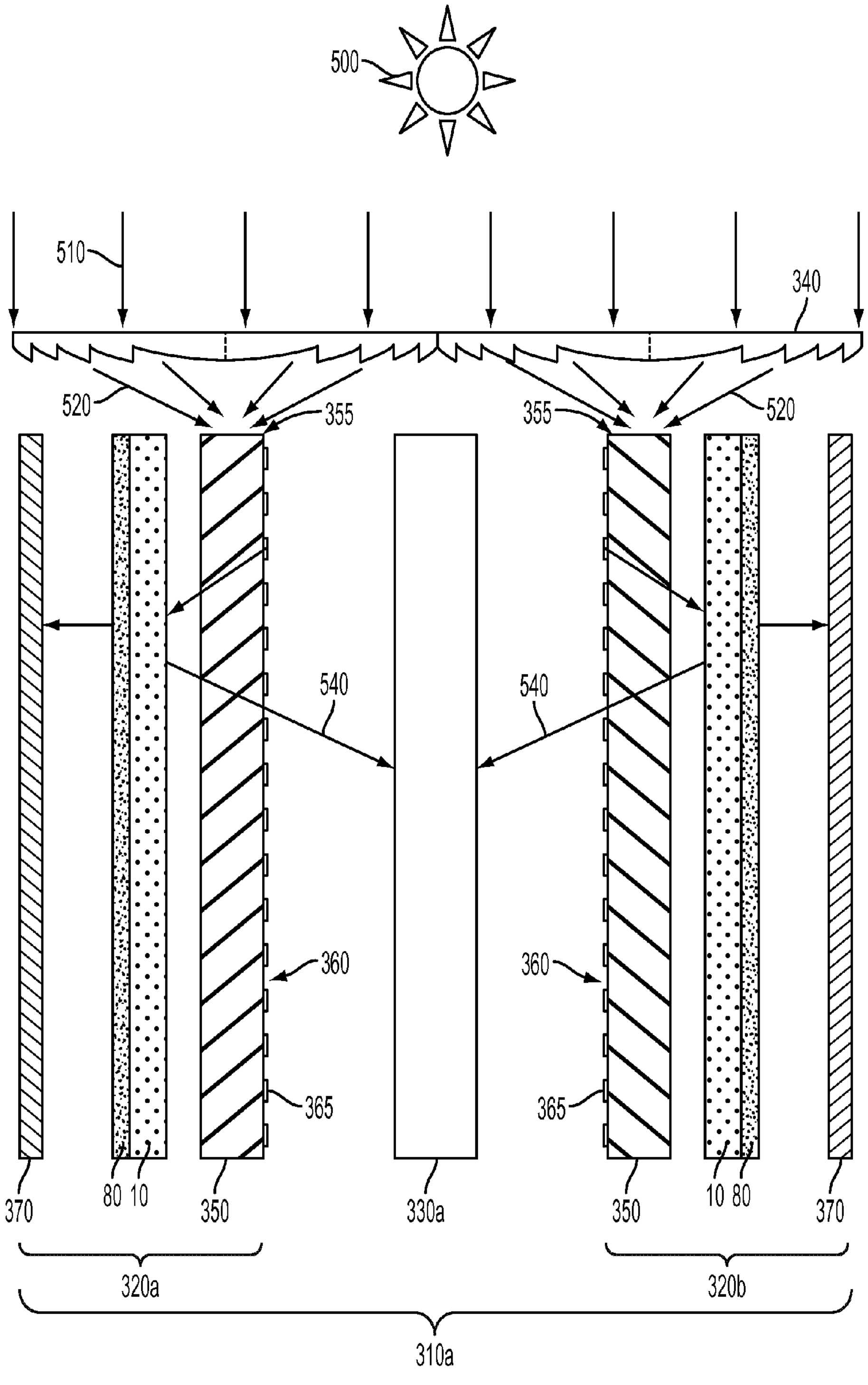
310b
310c
301

FIG. 6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320a
320b
310a

FIG. 7

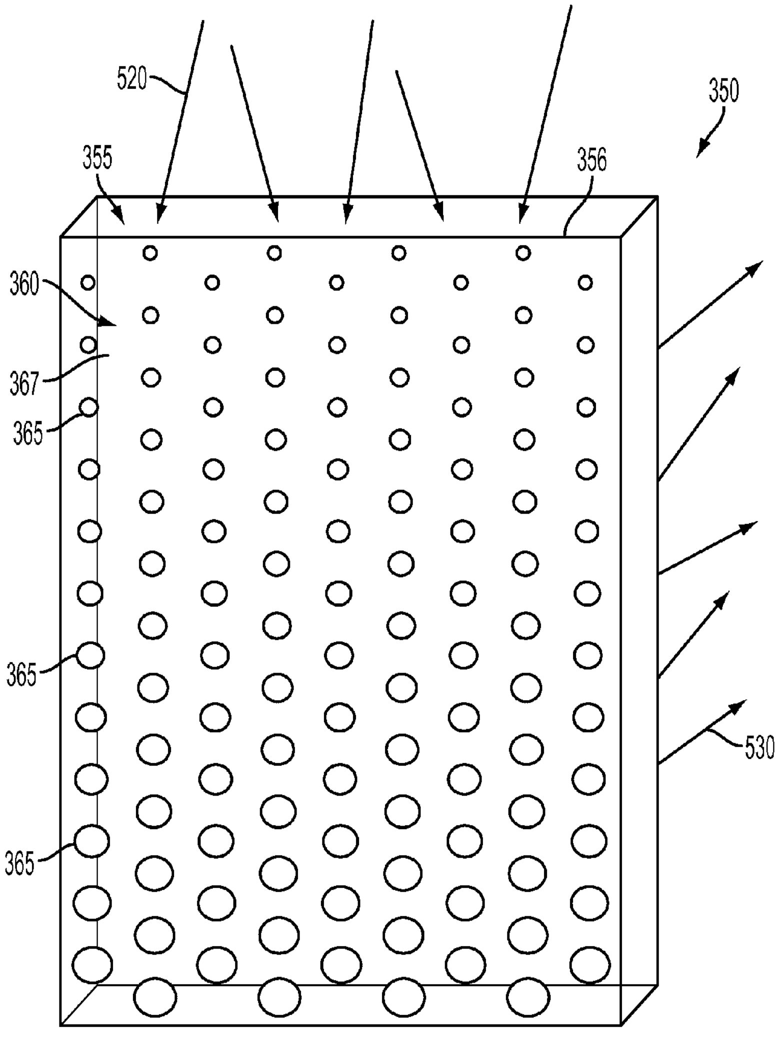


FIG. 8

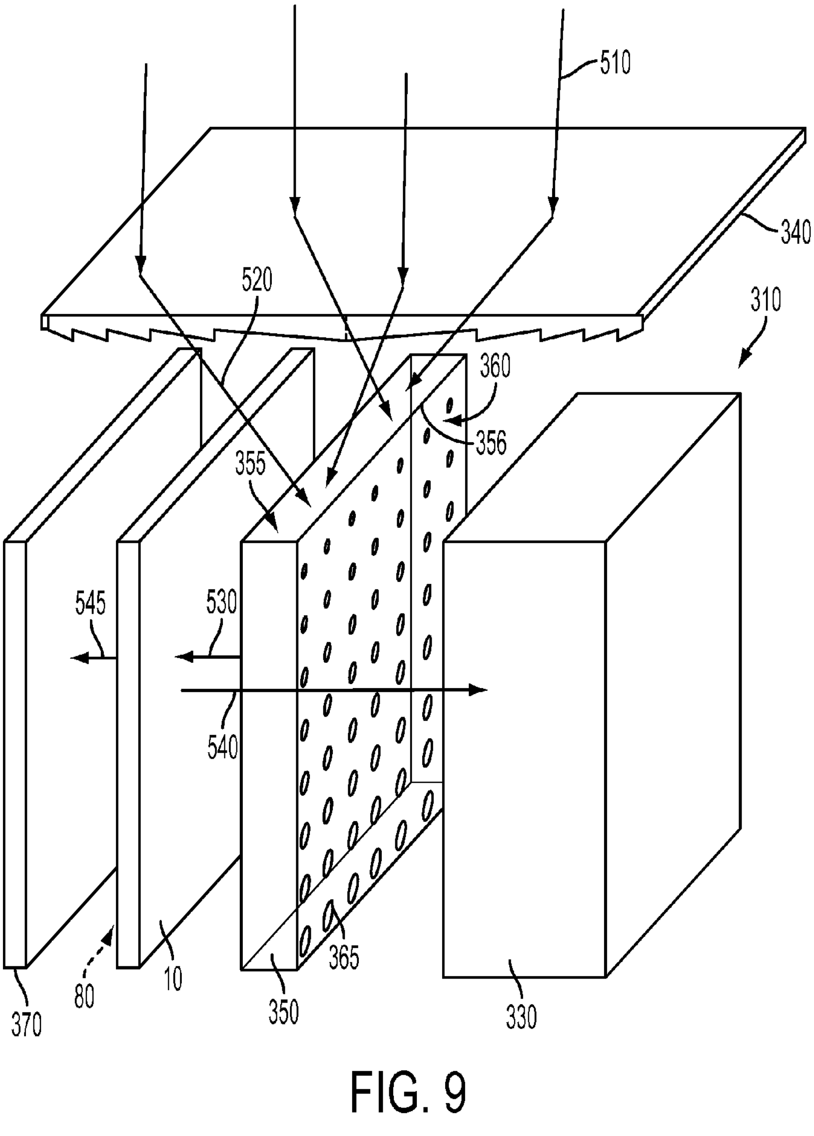
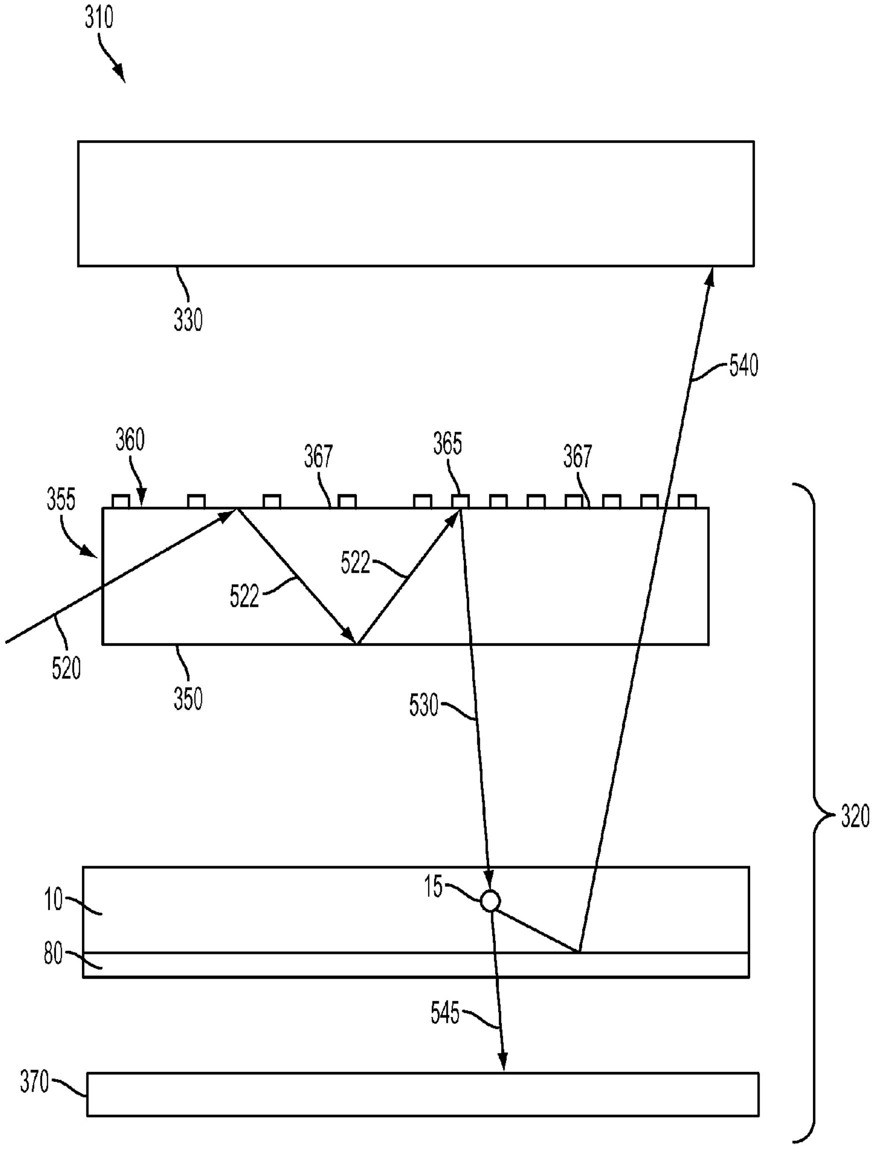


FIG. 9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10
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FIG. 10

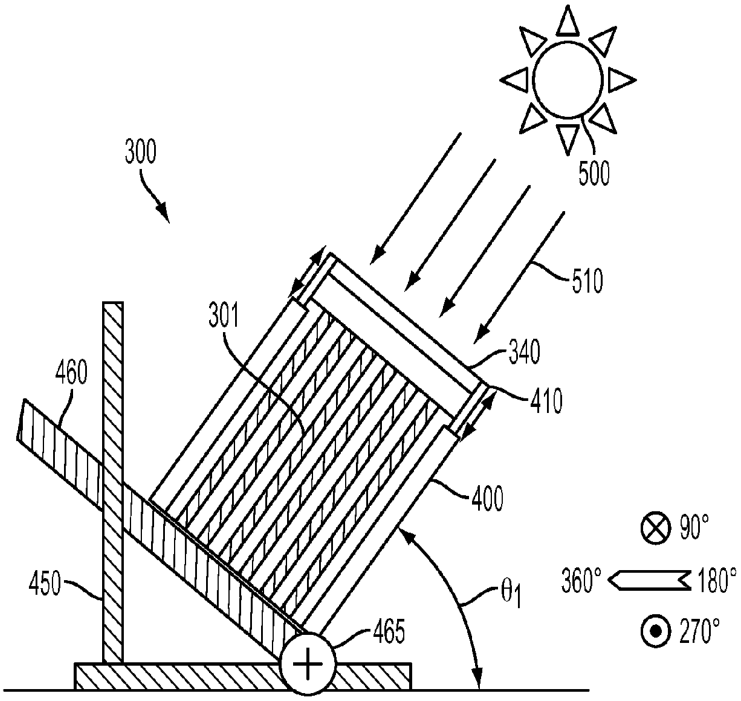

FIG. 11A

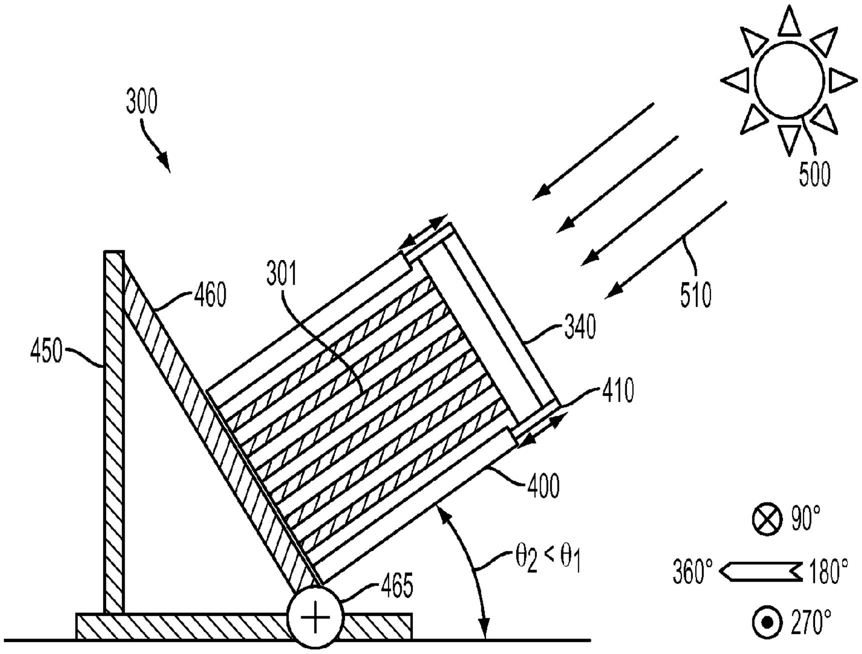

FIG. 11B

SOLAR REDSHIFT SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/513,256, filed Jul. 29, 2011.

TECHNICAL FIELD

[0002] The present specification relates generally to systems for utilizing solar radiation in energy collecting applications and, more particularly, to systems that convert incident solar radiation to wavelengths that promote energy collection by photovoltaics or photosynthetic organisms.

BACKGROUND

[0003] Sunlight can be harnessed as a source of clean energy in a variety of ways. With photovoltaic cells, sunlight strikes a photovoltaic material, exciting electrons in the photovoltaic material and resulting in a potential difference between electrodes placed on the photovoltaic material. This potential difference may be used to power an electric circuit or to store electrical energy in a storage device such as a battery. With living organisms, sunlight causes photosynthesis in an organism such as algae, causing the organism to grow. The organism then may be burned, for example as a carbon-neutral fuel source, and either the organism itself, or the secretions it produces metabolically, may be used as sources of bio-derived molecules, including ethanol and numerous other compounds that otherwise would be derived from petroleum.

SUMMARY

[0004] Systems are disclosed herein that optimally utilize solar radiation for producing energy from targets such as photovoltaic materials and/or living photosynthetic organisms. In various embodiments, the systems are solar-redshift systems. In embodiments of solar-redshift systems described herein, quantum dot plates are used to convert high-energy wavelengths in broad-spectrum incident solar radiation to selected lower-energy wavelengths such as for a specific energy-harnessing application. The solar-redshift systems are configured not only to optimize the wavelength spectrum of the solar radiation, but also to maximize the efficiency at which the solar radiation is made available to the energy-harnessing application.

[0005] In some embodiments, solar-redshift modules are provided. The solar-redshift modules may include at least one collecting target having a target wavelength, at least one quantum-dot vessel, and a focusing device that focuses incident solar radiation into the solar redshift system. The at least one collecting target may be selected from a growth vessel or a photovoltaic plate. The growth vessel may contain a living photosynthetic organism in a growth medium for sustaining the living photosynthetic organism, such that the target wavelength is a wavelength of increased photosynthetic response of the living photosynthetic organism. The photovolatic plate may include a photovoltaic material, such that the target wavelength is a wavelength of increased sensitivity of the photovoltaic material. The at least one quantum-dot vessel may include a sealed cavity defined between a first plate and a second plate. The first plate of the at least one quantum-dot vessel may be between the second plate and the collecting target. A quantum-dot suspension may be disposed in the sealed cavity and may contain quantum dots that emit redshifted light having the target wavelength when irradiated by incident solar radiation. The quantum-dot vessel may also include a trapping reflector that reflects at least a portion of the redshifted light emitted by the quantum dots toward the collecting target. The focusing device, the at least one quantum-dot vessel, and the at least one collecting target may be configured such that the incident solar radiation focused into the solar redshift system strikes the at least one quantum-dot vessel before striking the at least one collecting target.

[0006] In some embodiments, solar-redshift systems are provided. The solar-redshift systems may include an integral array of the solar-redshift modules.

[0007] In some embodiments, the solar-redshift systems may be configured as photovoltaic solar-redshift systems or as photosynthesis-enhancing solar-redshift systems. The photovoltaic solar redshift systems may include an integral array of photovoltaic plates that include a photovoltaic material having a wavelength of increased sensitivity. The photosynthesis-enhancing solar-redshift systems may include a growth vessel containing a living photosynthetic organism in a growth medium for sustaining the living photosynthetic organism. The living photosynthetic organism may have a wavelength of increased photosynthetic response

[0008] In some embodiments, parallel-plate solar-redshift systems are provided. The parallel-plate solar-redshift systems may include a parallel-plate configuration of solar-redshift modules and at least one focusing device. Each solar-redshift module may include at least one solar-radiation conversion assembly and a collecting target. The collecting target may be a growth vessel or a photovoltaic plate, for example. Such a growth vessel may contain a living photosynthetic organism in a growth medium for sustaining the living photosynthetic organism, and the living photosynthetic organism may have a wavelength of increased photosynthetic response. Such a photovoltaic plate may include a photovoltaic material having a wavelength of increased sensitivity. The at least one solar-radiation conversion assembly may include a waveguide, an infrared-radiation absorber, and a quantum dot vessel interposed between the waveguide and the infrared-radiation absorber. The quantum dot vessel contains a quantum-dot suspension of quantum dots that emit redshifted light having the wavelength of increased photosynthetic response or the wavelength of increased sensitivity when irradiated by incident solar radiation. The quantum-dot vessel also may include a trapping reflector that reflects the redshifted light toward the collecting target and transmits infrared light from the incident solar radiation in a direction away from the collecting target. The waveguide of the at least one solar-radiation conversion assembly may be interposed between the quantum dot vessel of the at least one solar-radiation conversion assembly and the collecting target. The waveguide may include a frustrating surface that scatters focused solar radiation within the waveguide toward the quantum dot vessel and permits redshifted light to pass through the waveguide from the quantum dot vessel toward the collecting target. The focusing device focuses incident solar radiation onto sun-facing edges of the waveguides of the solar-radiation conversion assemblies in respective solar-redshift modules.

[0009] Additional features and advantages of the embodiments described herein will be set forth in the detailed description that follows. These additional features and advantages should be in part readily apparent to those skilled in the art from the written description alone or should be readily recognized by practicing the embodiments described in the written description that follows, including the appended drawings and claims.

[0010] It is to be understood that both the foregoing general description and the following detailed description describe various embodiments and are intended to provide an overview or framework for understanding the nature and character of the claimed subject matter. The accompanying drawings are included to provide a further understanding of the various embodiments, and are incorporated into and constitute a part of this specification. The drawings illustrate the various embodiments described herein, and together with the description serve to explain the principles and operations of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1**A is a top plan view of a quantum-dot vessel, a component of the solar-redshift systems described herein.

[0012] FIG. **1**B is a cross-sectional side view of the quantum-dot vessel shown in FIG. **1**A.

[0013] FIG. **2** is a solar-redshift system according to illustrative embodiments described herein, which has a gap-to-reflector configuration including an integral array of photovoltaic solar-redshift modules, each of which includes a quantum-dot vessel.

[0014] FIG. **3**A is a solar-redshift module according to embodiments described herein and forming a component of the solar-redshift system of FIG. **2**, highlighting structural features that repeat within the integral array.

[0015] FIG. **3**B is the solar-redshift module from FIG. **3**A, illustrating via ray tracings the pathways of incident solar radiation and redshifted light within the solar-redshift module.

[0016] FIG. **4** is a solar-redshift system according to illustrative embodiments described herein, which has a gap-to-vessel configuration including an integral array of photosynthesis-enhancing solar-redshift modules with shared quantum-dot vessels.

[0017] FIG. **5** is a solar-redshift module according to embodiments described herein and forming a component of the solar-redshift system of FIG. **4**, highlighting structural features that repeat within the integral array.

[0018] FIG. **6** is a schematic plan view of a solar-redshift system according to embodiments described herein, which has a parallel-plate configuration.

[0019] FIG. **7** is an exploded plan view of the solar-redshift system of FIG. **6**.

[0020] FIG. **8** is a perspective view of a waveguide according to embodiments described herein, a component of parallel-plate solar-redshift systems such as the solar-redshift system of FIG. **6**.

[0021] FIG. **9** is an exploded perspective view of a solar-redshift module according to embodiments described herein, a component of the solar-redshift system of FIG. **6**.

[0022] FIG. **10** is a schematic diagram illustrating an example of a pathway of a light ray emanating from incident solar radiation and travelling through various components of the solar-redshift system of FIG. **6**.

[0023] FIG. **11**A is a schematic side-view of a solar-redshift system according to embodiments described herein, wherein the solar-redshift system is disposed on a platform for elevational adjustment of the solar-redshift system during the course of a calendar year and is inclined to an exemplary summer-solstice position.

[0024] FIG. **11**B is the solar-redshift system and platform of FIG. **11**A, elevationally adjusted to a lower position than the summer-solstice position of FIG. **11**A, as may be appropriate at the winter solstice, for example.

DETAILED DESCRIPTION

[0025] Solar-redshift modules and solar-redshift systems including the solar-redshift modules in various configurations now will be described. The following description initially will detail features common to each of the various embodiments of solar-redshift modules, solar-redshift systems, and configurations thereof. After the initial general description of common features, illustrative embodiments of solar-redshift modules and solar-redshift systems containing the common features will be described with specific references to the appended drawings.

[0026] Solar-redshift systems according to various embodiments described herein utilize quantum dots to transform solar radiation to redshifted light with increased proportions of wavelengths useful to a particular energy-harnessing process. In some embodiments described herein, the solar-redshift systems are configured as photovoltaic solar-redshift systems containing photovoltaic solar-redshift modules, and in other embodiments described herein, the solar-redshift systems are configured as photosynthesis-enhancing solar-redshift systems containing photosynthesis-enhancing solar-redshift modules. In further embodiments, hybrid systems may contain both photosynthesis-enhancing elements and photovoltaic elements. In general, these solar-redshift systems have in common both the incorporation of quantum dots to produce redshifted light and also the conservation of the redshifted light through various optical configurations of the systems.

[0027] As used herein, the term "solar radiation" refers to electromagnetic radiation produced by the sun, and particularly refers to the electromagnetic radiation with wavelengths ranging from about 100 nm (ultraviolet) to about 1 mm (far-infrared), which includes the entire visible portion of the electromagnetic spectrum (from about 380 nm to about 750 nm). As used herein, the term "incident solar radiation" refers to solar radiation that has passed through the atmosphere and a portion of the solar-redshift systems described herein without any intentional manipulation of the wavelengths of light inherently present in the solar radiation. Typically, all solar radiation entering a solar-redshift system described herein will meet the definition of "incident solar radiation" at least at the instant the solar radiation first enters the solar-redshift system.

[0028] The quantum dots in the solar-redshift systems according to various embodiments may be chosen to naturally emit an emission wavelength of light when exposed to light having a wavelength shorter than the emission wavelength. For example, a quantum dot may be chosen to strongly emit red light when exposed to a polychromatic light source containing a high amount of blue light. The emitted light of the emission wavelength then is directed to a collecting target, such as a photovoltaic plate or a living photosynthetic organism, which inherently has increased sensitivity or response to photons having the emission wavelength of the quantum dot over that attained from photons of the shorter wavelengths present in the light before the light encountered the quantum dots.

[0029] In each of the solar-redshift systems described herein, the quantum dots are retained in a quantum-dot vessel. The quantum-dot vessel may comprise, for example, two hermetically sealed plates, which may be made of a suitable material such as, for example, glass plates of a desired thickness. As is well understood, quantum dots have an emission wavelength unique to the material of the quantum dots and the size of the quantum dots, wherein photons having a higher energy (shorter wavelength) than the emission wavelength may be absorbed by the quantum dot and subsequently re-emitted as a photon of the emission wavelength. The quantum dots do not absorb photons having a lower energy (longer wavelength) than the emission wavelength of the quantum dots.

[0030] When incident solar radiation such as sunlight, for example, passes through the quantum dots sealed between the two plates, photons having a shorter wavelength than the emission wavelength of the quantum dots effectively are shifted to the lower-energy emission wavelength of the quantum dots. Thus, these photons emitted from the quantum dots as referred to hereinafter as "redshifted light."

[0031] The unique wavelength of the redshifted light, determined by the material and size of the quantum dots, becomes particularly advantageous in solar-collection systems when the unique wavelength is one desirable for a selected energy-harnessing application. For example, if a living organism such as algae is grown to produce biomass, photosynthesis of the algae may be most active at a certain wavelength unique to the species of algae. For example, photosynthesis in some species of algae is most active at about 680 nm, an emission wavelength easily attainable through selection of appropriate quantum dot materials and sizes. In such an application, redshifted light derived from the full spectrum of incident solar radiation causes wavelengths (green, blue, ultraviolet, for example) that otherwise would have been underutilized to be converted into a more highly useful form of energy, namely, the red light of 680 nm wavelength. Thus, the redshifted light may contribute more efficiently to the growth of the algae than the broad-spectrum incident solar radiation alone would have.

[0032] Sunlight includes a very broad spectrum of wavelengths that includes infrared, ultraviolet, and all parts of the visible spectrum. In applications involving photovoltaic cells and biomass production, typically a much narrower spectral range of incident light can be useful toward effective harnessing of the sunlight. For example, cadmium telluride (CdTe) photovoltaic materials respond most efficiently to light having a wavelength of approximately 600 nm (yellow-orange light). Other wavelengths may cause the electrons in the CdTe material to excite, but only at a lower effective sensitivity. As another example, certain varieties of green algae, which appear green because they reflect green light, respond photosynthetically most favorably to light having a wavelength of approximately 680 nm (red light). The reflection of the green light by the green algae is tantamount to wasting the energy that could have been harnessed from the sunlight used to grow the algae. Moreover, wavelengths such as those in the infrared can disadvantageously overheat the algae, thereby decreasing the efficiency of their growth.

[0033] Thus, embodiments described herein are directed to solar-redshift modules and to solar-redshift systems that may be constructed from either an integral array of solar-redshift modules or a parallel-plate configuration of solar-redshift modules. The solar-redshift modules may include at least one collecting target having a target wavelength, at least one quantum-dot vessel, and a focusing device that focuses incident solar radiation into the solar redshift system. In general, the at least one collecting target of a solar-redshift module may be selected from a growth vessel or a photovoltaic plate. These solar-redshift modules may be incorporated into solar-redshift systems such as, for example, a photovolatic solar-redshift system including only photovolatic solar-redshift modules with photovoltaic plates as collecting targets, as photosynthesis-enhancing solar-redshift systems including only photosynthesis-enhancing solar-redshift modules with growth vessels as collecting targets, or hybrid systems containing some photovolatic solar-redshift modules and some photosynthesis-enhancing solar-redshift modules.

[0034] In solar-redshift modules including a growth vessel as a collecting target (i.e., photosynthesis-enhancing solar-redshift modules), the growth vessel may contain a living photosynthetic organism in a growth medium for sustaining the living photosynthetic organism, such that the target wavelength is a wavelength of increased photosynthetic response of the living photosynthetic organism. In solar-redshift modules including a photovoltaic plate as a collecting target (i.e., photovolatic solar-redshift modules), the photovolatic plate may include a photovoltaic material, such that the target wavelength is a wavelength of increased sensitivity of the photovoltaic material. Regardless of the type of solar-redshift module present in the solar-redshift system, however, the focusing device, the at least one quantum-dot vessel, and the at least one collecting target may be configured such that the incident solar radiation focused into the solar redshift system strikes the at least one quantum-dot vessel before striking the at least one collecting target. Thus, the light that strikes the collecting target is never incident solar radiation directly from the sun but, rather, is light that is at least substantially enriched in the target wavelength of the collecting target.

[0035] Quantum-dot vessels and methods for their construction now will be described with reference to FIGS. **1**A and **1**B, which show a non-limiting embodiment of a quantum-dot vessel **10**. FIG. **1**A is a top plan view of the quantum-dot vessel **10**, and FIG. **1**B is a cross-sectional side view of the quantum-dot vessel **10** of FIG. **1**A. The quantum-dot vessel **10** may comprise a first plate **20** and a second plate **30**. Though the first plate **20** and the second plate **30** are shown in FIG. **1**A to be square or rectangular, it should be understood that the first plate **20** and the second plate **30** may have a desirable shape, according to the needs of the application involved. For example, the quantum-dot vessel **10** may be a long bar having a narrow width and a very long length or may be circular or another desired geometric shape.

[0036] Actual dimensions of the quantum-dot vessel **10** may be chosen according to needs of the energy-harvesting application. It is contemplated that the quantum-dot vessel **10** may have length and width dimensions independently ranging from about 1 mm to about 100 m, in some of these embodiments from about 1 cm to about 10 m, and in some of these embodiments from about 10 cm to about 2 m. Also, though the first plate **20** and the second plate **30** are shown to be flat, it should be understood that the plates need not necessarily be flat. Though flat plates are particularly advantageous, because they provide a maximum surface area for transmitting redshifted light, variations such as convexly or concavely curved plates are contemplated as alternatives. As a further alternative, the plates may be essentially flat except around edges, and the edges may be curved or bent so as to facilitate sealing the plates together.

[0037] The first plate **20** and the second plate **30** may be essentially the same size, as shown in FIG. **1**A, or different sizes. For example, the first plate **20** can be smaller than the second plate **30**, such that the quantum-dot vessel **10** will have a trapezoidal cross-section instead of the rectangular cross-section shown in FIG. **1**B. The first plate **20** and the second plate **30** are separated, in the embodiment shown, by separator structures **50** such as glass beads or pillars. For example, the separator structures **50** may be glass microspheres, such that when the separator structures **50** are sandwiched between the first plate **20** and the second plate **30**, a gap of from about 50 μm to about 500 μm, or in some embodiments from about 100 μm to about 350 μm, or in other embodiments from about 150 μm to about 250 μm is formed. The glass microspheres in some embodiments have minimal variance in diameters, so as to ensure consistent separation of the first plate **20** and the second plate **30**, as well as to ensure a constant optical-path length through all portions of the quantum-dot vessel **10**.

[0038] The first plate **20** and the second plate **30** may be sealed together, for example, along sealing edge **40**, such that the first plate **20**, the second plate **30**, and the sealing edge **40** together define a sealed cavity **60** between the first plate **20** and the second plate **30**. Sealing of the sealing edge **40** may be accomplished by a practical means such as, for example, frit sealing, wherein the sealed cavity **60** may be hermetically sealed. Hermetic sealing of the sealed cavity **60** in various embodiments can be selected because many types of quantum dots are extremely sensitive to oxygen, humidity, and other environmental factors. Thus, the hermetic sealing may prevent premature degradation of the quantum dots.

[0039] An example method for manufacturing the quantum-dot vessel **10** may comprise frit sealing the first plate **20** and the second plate **30** around the outer perimeter of the plates except at opposing corners, as illustrated in FIG. **1**A, with the plates separated with the separator structures **50**. Quantum dots may be dispersed within a suitable suspension medium, described below, and the resulting quantum-dot dispersion may be placed in a quantum-dot loader **70**. The quantum-dot loader **70** may be fit to the quantum-dot vessel **10**, for example, at a loading port **72** located at one of the opposing corners that were not frit sealed. Thereupon, means such as a vacuum pump **75** may be attached to a vacuum port **77** of the quantum-dot vessel **10**, such that when the vacuum pump **75** is activated, the quantum dots in the suspension medium are drawn from the quantum-dot loader **70** and into the sealed cavity **60**. Once the sealed cavity **60** is filled with quantum dots, the unsealed corners at the loading port **72** and the vacuum port **77** of the quantum-dot vessel **10** may be sealed, such that the sealing edge **40** is continuous around the outer perimeter of the quantum-dot vessel **10**. To avoid exposure of the quantum dots to oxygen during the filling process, the quantum-dot vessel **10** in some embodiments is filled in an inert environment such as in a nitrogen or an argon controlled atmosphere.

[0040] The quantum dots to be loaded into the quantum-dot vessel **10** may be any known or to-be-discovered type of quantum dot formed using any appropriate technique. It is readily known to those skilled in the art that one requiring quantum dots for a certain application may specify a desired emission wavelength and a selected material, with which information a supplier can readily determine from known information the quantum-dot size to produce quantum dots of the selected material and having the desired emission wavelength.

[0041] The material from which the quantum dots are made may include, as non-limiting examples: MgO; MgS; MgSe; MgTe; CaO; CaS; CaSe; CaTe; SrO; SrS; SrSe; SrTe; BaO; BaS; BaSe; BaTe; ZnO; ZnS; ZnSe; ZnTe; CdO; CdS; CdSe; CdTe; HgO; HgS; HgSe; HgTe; Al_2O_3; Al_2S_3; Al_2Se_3; Al_2Te_3; Ga_2O_3; Ga_2S_3; Ga_2Se_3; Ga_2Te_3; In_2O_3; In_2S_3; In_2Se_3; In_2Te_3; SiO_2; GeO_2; SnO_2; SnS; SnSe; SnTe; PbO; PbO_2; PbS; PbSe; PbTe; AlN; AlP; AlAs; AlSb; GaN; GaP; GaAs; GaSb; InN; InP; InAs; InSb; and ternary, quaternary, and higher alloys of any of the preceding materials including, but not limited to InGaP, AlInN, CuInGaS, CuInGaSe ("CIGS"), ZnCuInGaS, and (Al,In,Ga)(N,P,As). It is contemplated also that the quantum dots may comprise so-called core-shell structures, wherein individual quantum dots are made from a core of one of the above-listed materials and the core is surrounded by a shell of another of the above-listed materials.

[0042] The material chosen as the quantum dot material can be tailored through selection of quantum-dot size to emit a wavelength of light useful to a particular energy-harvesting application when the quantum dots are illuminated with incident solar radiation. As used herein, the term "quantum-dot size" refers to an average diameter of quantum dots taken over all quantum dots present in the quantum-dot vessel **10**. For example, a quantum dot made of $CdS_xSe_{1-x}(0 \leq x \leq 1)$ or ZnS with a quantum-dot size of from about 5.5 nm to about 6.5 nm will emit light having a wavelength of about 680 nm, a wavelength that enhances photosynthesis in certain species of algae. Likewise, a quantum dot made of CdSe with a quantum-dot size of from about 3.6 nm to about 4.6 nm will emit light having a wavelength of about 600 nm, a wavelength desirable for photovoltaic applications involving CdTe or CIGS as a photovoltaic material, for example.

[0043] The quantum dots may be contained within the quantum-dot vessel **10** in the form of a quantum-dot suspension or a functionalized matrix. The quantum-dot suspension or functionalized matrix may be formed by dispersing the quantum dots in a suspension medium, which subsequently may be loaded into the quantum-dot vessel **10**. The suspension or functionalized matrix may comprise a suitable suspension medium, examples of which are disclosed in U.S. Pat. App. Pub. No. 2010/0276638 to Liu, et al., which document is incorporated herein by reference in its entirety. In general, the suspension medium is a functionalized polymer, typically in liquid form. The suspension medium optionally may be crosslinked by heat, for example, once the quantum dots are added. When contained within the quantum-dot vessel **10**, the quantum-dot suspension is a liquid, a gel, or a solid; in one group of embodiments, the quantum-dot suspension is a gel or a solid. The suspension medium serves primarily to maintain physical separation among the quantum dots within the quantum-dot vessel **10**, and also to prevent agglomeration of the quantum dots within the quantum-dot vessel **10**. Separation and lack of agglomeration of the quantum dots ensures efficient exposure of the quantum dots to incident solar radiation and further may increase conversion efficiency of the incident solar radiation to redshifted light having the desired wavelengths.

[0044] In view of the general description above, pertaining to features generally common to embodiments of solar-redshift systems that will be described below, various illustrative configurations of solar-redshift systems now will be described. Initially, embodiments of gap-focus configurations will be described. The gap-focus configurations have in common that the focusing device focuses incident solar radiation through a focusing gap, after which the incident solar radiation is directed to a quantum-dot vessel and then to the collecting target. Illustrative embodiments of the gap-focus configurations include a gap-to-reflector configuration and a gap-to-vessel configuration. First, in illustrative embodiments, photovoltaic solar-redshift modules and photovoltaic solar-redshift systems having the gap-to-reflector configuration will be described with reference to FIGS. **2**, **3**A, and **3**B. Second, in illustrative embodiments, photosynthesis-enhancing solar-redshift modules and photosynthesis-enhancing solar-redshift systems having the gap-to-vessel configuration will be described with reference to FIGS. **4** and **5**. It should be noted that both of the gap-focus configurations may be employed equally well as bases for photovoltaic solar-redshift systems, for photosynthesis-enhancing solar-redshift systems, or hybrid solar-redshift systems. Thus, it should be understood that the general descriptions of photovoltaic solar-redshift systems in gap-to-reflector configurations and of photosynthesis-enhancing solar-redshift systems in gap-to-vessel configurations are not intended to be limiting. Third, embodiments of parallel-plate solar-redshift systems having parallel-plate configurations will be described with reference to FIGS. **6**-**11**. The illustrative embodiments of the parallel-plate solar-redshift systems are photosynthesis-enhancing solar-redshift systems. Even so, similar to the gap-focus configurations, the parallel-plate configuration can be adapted for use in photovoltaic solar-redshift systems, photosynthesis-enhancing solar-redshift systems, or combination system.

[0045] An illustrative embodiment of a solar-redshift module (e.g., a photovoltaic solar-redshift module) having a gap-to-reflector configuration is provided in FIG. **3**B and will be described below as a component of the photovoltaic solar-redshift system **100** of FIG. **2**. The gap-to-reflector configuration in general is arranged such that a focusing device **160** focuses the incident solar radiation following the incident-radiation optical path **155** through a focusing gap **190** between a first quantum-dot vessel **10***a* and a second quantum-dot vessel **10***b* toward a plate reflector **180**. The plate reflector **180** reflects the light to the quantum-dot vessels **10***a*, **10***b*, wherein the light is redshifted before ever encountering the collecting target (for example, photovoltaic plate **170** in FIG. **3**B). It should be understood that the photovoltaic solar-redshift system **100** of FIG. **2** is but one embodiment of a system including solar-redshift modules having the gap-to-reflector configuration and that in other embodiments the gap-to-reflector configuration may be used in a photosynthesis-enhancing solar redshift system (to be described below in further detail) by substituting a growth vessel as the collecting target in the place of the photovoltaic plate **170**.

[0046] Referring to FIG. **2**, an embodiment of a photovoltaic solar-redshift system **100** is provided as an example of a solar-redshift system having the gap-to-reflector configuration. The photovoltaic solar-redshift system **100** may comprise an integral array **101**. As used herein, the term "integral array" refers to a continuous system having repeating modular structures, wherein each of the modular structures is physically connected to at least one neighboring modular structure. Typically, each modular structure is physically connected to one or two neighboring structures in a one-dimensional array, or from one to four neighboring modular structures in a two-dimensional array.

[0047] The integral array **101** is made up of repeating units defined as the photovoltaic solar-redshift modules **150***a*, **150***b*, **150***c*. Though, for sake of clarity, the integral array **101** of FIG. **2** includes only three of the photovoltaic solar-redshift modules **150***a*, **150***b*, **150***c*, it should be understood that the integral array **101** may comprise any desired number of photovoltaic solar-redshift modules, for example, up to several million, from 2 to 100,000, from 5 to 50,000, or from 10 to 10,000. Likewise, it should be understood that the integral array **101** in FIG. **2** is shown effectively in cross-section as a one-dimensional array, and that, in practice, the integral array **101** may extend in a second dimension, into or out of the plane of FIG. **2**, so as to harvest energy from incident solar radiation falling on a large surface area, e.g. of land.

[0048] Each of the photovoltaic solar-redshift modules **150***a*, **150***b*, **150***c* comprises a photovoltaic plate **170**; a first quantum-dot vessel **10***a*; a second quantum-dot vessel **10***b*; a plate reflector **180***a*, **180***b*, **180***c*, respectively; and a focusing device **160***a*, **160***b*, **160***c*, respectively. Though FIG. **2** shows the photovoltaic plate **170** in the photovoltaic solar-redshift system **100** as a single, continuous piece of photovoltaic material, it should be understood that additional configurations are possible, wherein each of the photovoltaic solar-redshift modules **150***a*, **150***b*, **150***c* may comprise a separate piece of photovoltaic material. It should be understood that the photovoltaic plate may further comprise electrical contacts (not shown) electrically connected in a practical manner to a device such as an energy storage system (not shown) or a power delivery system (not shown). Likewise, though in FIG. **2** the focusing device **160***a*, **160***b*, **160***c* of each of the photovoltaic solar-redshift modules **150***a*, **150***b*, **150***c*, respectively, is depicted as part of an integral array of converging lenses, this configuration is to be understood as an example by way of illustration, not of limitation. It should be understood that numerous additional optical configurations and devices are possible. For example, as alternatives to the integral array of converging lenses, separate individual lenses may be used. Furthermore, other optical devices capable of directing rays of incident solar radiation may be used, such as for example, appropriately designed mirrors or solar collectors such as solar troughs.

[0049] It should be understood by the skilled person that variations in the direction of incident solar radiation relative to the focusing device **160***a*, **160***b*, **160***c* of each of the photovoltaic solar-redshift modules **150***a*, **150***b*, **150***c*, respectively, will occur over the course of a single day and also during the course of the year. Generally, the position of the sun in the sky may be expressed as polar coordinates that include an azimuth and an elevation. The azimuth coordinate is typically expressed as a bearing, with due north being 0° or 360°, due east being 90°, due south being 180°, and due west being 270°. Given the azimuth coordinate, the elevation coordinate allows an observer who first orients toward the azimuth to look up in the sky to a particular angle to find the sun. For the elevation coordinate, toward the horizon is defined as 0° elevation, and toward the zenith (directly overhead) is defined as 90° elevation.

[0050] For solar-collection systems such as, but not limited to, the solar-redshift systems described herein, variations over the course of a day arise from the movement of the sun across the sky from east to west and typically may be addressed by azimuthal single-axis tracking. Variations over the course of a year arise from the 23.5° angle of the earth's rotation axis relative to the plane of the earth's orbit and typically may be addressed by elevational single-axis tracking. To account for both daily and yearly variations in the direction of incident solar radiation may require dual-axis tracking.

[0051] Though mechanisms for single-axis tracking or dual-axis tracking are not shown in FIG. **2**, it is fully contemplated that the photovoltaic solar-redshift system **100** may further comprise such mechanisms. In one exemplary embodiment, a suitable mechanism may be incorporated that widens the focusing gaps **190** of the photovoltaic solar-redshift modules **150** over the course of the year, thereby reducing or eliminating any need for large-scale dual-axis tracking mechanisms such as those that may require constantly adjusting the inclination of the entire photovoltaic solar-redshift system **100** over the course of a year. In such an embodiment, a wider focusing gap **190** may permit incident solar radiation arriving at the focusing device **160** at a steeper angle (in winter compared to in summer, for example) to continue being focused through the focusing gap **190** over the course of a year without otherwise adjusting the inclination of the entire photovoltaic solar-redshift system **100**. This gap-widening principle could then be used in combination with an azimuthal single-axis tracking mechanism that adjusts the photovoltaic solar-redshift system **100** over the course of a day, such that the photovoltaic solar-redshift system **100** would provide the advantages of dual-axis tracking with the only the gross infrastructure of a single-axis tracking system. It should be noted, however, that widening the focusing gap **190** in this manner may also result in increased loss, owing to a heightened ability for reflected or redshifted light to escape back out through the focusing gap **190** without striking the quantum-dot vessels **60***a*, **60***b* or the photovoltaic plate **170**.

[0052] A photovoltaic solar-redshift module **150**, isolated from the integral array **101** shown in FIG. **2** to illustrate specific details, is described now with reference to FIGS. **3**A and **3**B. The photovoltaic solar-redshift module **150** comprises a photovoltaic plate **170**, a first quantum-dot vessel **10***a*, a second quantum-dot vessel **10***b*, a plate reflector **180**, and a focusing device **160**. The first quantum-dot vessel **10***a* and the second quantum-dot vessel **10***b* are interposed between the focusing device **160** and the photovoltaic plate **170** along an incident-radiation optical path **155**.

[0053] The photovoltaic plate **170** comprises a photovoltaic material having at least one wavelength of increased sensitivity. As used herein, the "sensitivity" of a photovoltaic material to a given wavelength of incident electromagnetic radiation refers to the efficiency by which the photovoltaic material converts the electromagnetic radiation to an electrical potential. A wavelength of light to which a given photovoltaic material is more sensitive (i.e., has a higher quantum efficiency for producing an electrical potential in the photovoltaic material) than to others is defined herein as a property inherent to the photovoltaic material itself, namely, as a "wavelength of increased sensitivity" of the photovoltaic material. Thus, the term "a photovoltaic material having at least one wavelength of increased sensitivity" is equivalent to stating that the photovoltaic material is more sensitive to one particular wavelength (i.e., the wavelength of increased sensitivity) than it is to other wavelengths.

[0054] Generally, photovoltaic materials are characterized in that they produce an electric potential when exposed to incident electromagnetic radiation. The effective quantum efficiency of a photovoltaic material, an increase of which correlates to the magnitude of the electric potential, typically is a function of the wavelengths of light present in the incident electromagnetic radiation. The response of photovoltaic materials to electromagnetic radiation typically varies with respect to the wavelength of the electromagnetic radiation incident on the photovoltaic material, such that each photovoltaic material is more sensitive to certain wavelengths than to others.

[0055] In view of the above definitions, a given photovoltaic material may possess one wavelength of increased sensitivity or multiple wavelengths of increased sensitivity, because the response of the given photovoltaic material varies with respect to wavelength of light incident on the photovoltaic material. The given photovoltaic material also may possess at least one wavelength of optimal sensitivity. In quantitative terms, a wavelength of increased sensitivity may be defined further as any wavelength of incident light that results in an effective quantum efficiency in the photovoltaic material that is higher, in some embodiments at least 10% higher, in some embodiments at least 25% higher, or in some embodiments at least 50% higher, than the lowest effective quantum efficiency achieved from exposing the photovoltaic material to monochromatic light of each wavelength in the visible spectrum (from about 380 nm to about 750 nm). The wavelength of optimal sensitivity is defined herein as the wavelength of incident light in the visible spectrum that results in the highest effective quantum efficiency for producing an electric potential in the photovoltaic material.

[0056] The photovoltaic plate **170** may be formed from or may comprise at least one photovoltaic material. The photovoltaic material may be any known or to-be-discovered photovoltaic material. Examples of known photovoltaic materials suitable for use in the photovoltaic plate **170** include, but are not limited to: Si, $CuInSe_2$, MgO; MgS; MgSe; MgTe; CaO; CaS; CaSe; CaTe; SrO; SrS; SrSe; SrTe; BaO; BaS; BaSe; BaTe; ZnO; ZnS; ZnSe; ZnTe; CdO; CdS; CdSe; CdTe; HgO; HgS; HgSe; HgTe; Al_2O_3; Al_2S_3; Al_2Se_3; Al_2Te_3; Ga_2O_3; Ga_2S_3; Ga_2Se_3; Ga_2Te_3; In_2O_3; In_2S_3; In_2Se_3; In_2Te_3; SiO_2; GeO_2; SnO_2; F-doped SnO_2 (SnO_2:F); SnS; SnSe; SnTe; PbO; PbO_2; PbS; PbSe; PbTe; AlN; AlP; AlAs; AlSb; GaN; GaP; GaAs; GaSb; InN; InP; InAs; InSb; ternary, quaternary, and higher alloys of any of the preceding materials including, but not limited to InGaP, AlInN, CuInGaS, CuInGaSe ("CIGS"), ZnCuInGaS, (Al,In,Ga)(N,P,As), and (Cu,Ag,Au)(Al,Ga,In)$(S,Se,Te)_2$; and even organic photovoltaic materials such as squarylium and cyanine-TCNQ compounds. The photovoltaic material may be a bulk material or may be a coating or functional layer deposited on an appropriate substrate such as silicon. In the formulas of photovoltaic cells including parentheses, one, two, or three of the elements in each set of parentheses may be included in the compound.

[0057] The first quantum-dot vessel **10***a* and the second quantum-dot vessel **10***b* may be, but need not be, geometrically or structurally identical. Nevertheless, the quantum-dot vessels **10***a*, **10***b* both comprise identical functional components, even if the functional components are configured slightly differently, such as with respect to geometry or cross-section. Thus, structural features of the quantum-dot vessels will be described with reference to only the first quantum-dot vessel **10***a*, with the understanding that second quantum-dot vessel **10***b* comprises corresponding structural features. Referring jointly to FIGS. **3**A and **3**B, the first quantum-dot vessel **10***a* comprises a sealed cavity **60***a* defined between a first plate **20***a* and a second plate **30***a*. The first plate **20***a* and the second plate **30***a* may be hermetically sealed, as described above with reference to FIGS. **1**A and **1**B, about a sealing edge **40***a*. Thus, a sealed cavity **60***a* is defined between the first plate **20***a* and the second plate **30***a*.

[0058] In the first quantum-dot vessel **10***a*, a quantum-dot suspension is disposed within the sealed cavity **60***a*. The quantum-dot suspension comprises quantum dots suspended in a suspension medium. The quantum dots are formed of a quantum-dot material and have a quantum-dot size, wherein the quantum dots emit a redshifted light **156** having the wavelength of increased sensitivity when the quantum dots are irradiated by incident solar radiation. As such, a synergy is present between the emission wavelength of the quantum dots and the wavelength of increased sensitivity of the photovoltaic material in the photovoltaic plate **170**. Suitable quantum-dot materials, quantum-dot sizes, and suspension media, are as described above with reference to the quantum dot vessel **10** of FIGS. **1**A and **1**B.

[0059] The first quantum-dot vessel **10***a* and the second quantum-dot vessel **10***b* are configured between the photovoltaic plate **170** and the focusing device **160** such that a focusing gap **190** is defined between the first quantum-dot vessel **10***a* and the second quantum-dot vessel **10***b*. The size of the focusing gap **190** is defined, in particular, by the shortest distance between first gap edge **90** of the first quantum-dot vessel **10***a* and the second gap edge **95** of the second quantum-dot vessel **10***b*. The first gap edge **90** and the second gap edge **95** may have a desired profile, which may be the same or different from one another, and of which two non-limiting examples are shown in FIG. **3**A. Namely, first gap edge **90** is shown as sloping inwardly, such that the focusing gap **190** narrows in a direction from the focusing device **160** toward the photovoltaic plate **170** and is narrowest adjacent to the first plate **20***a* of the first quantum-dot vessel **10***a*, i.e., the closest point within the focusing gap **190** to the photovoltaic plate **170**. Alternatively, the second gap edge **95** is shown as perpendicular to the first plate **20***b* of the second quantum-dot vessel **10***b*. Gap edges, such as shown for first gap edge **90**, may be advantageous because a narrower width of the focusing gap **190** may decrease losses of incident solar radiation upwardly through the focusing gap **190**, such as may occur when the incident solar radiation reflects off the photovoltaic plate **170**.

[0060] Referring specifically to FIG. **3**B, the focusing device **160** is an optical apparatus that directs incident solar radiation along the incident-radiation optical path **155** (referring to the entire ray tracing from above the focusing device **160** until the rays enter the first quantum-dot vessel **10***a* or the second quantum dot vessel **10***b*) through the focusing gap **190** and onto the plate reflector **180**. As noted above, the focusing device **160**, though depicted in FIG. **3**B as a converging lens, may be selected from any appropriate optical device having an equivalent function, namely, an optical device that can direct the incident solar radiation through the focusing gap **190**. Alternative devices in this regard include, for example, converging mirrors, or solar collectors such as troughs. The plate reflector **180** is disposed on a surface of the photovoltaic plate **170** and reflects the incident solar radiation toward at least one of the quantum dot vessels (here, the first quantum-dot vessel **10***a* or the second quantum-dot vessel **10***b*). Note that, for clarity, only two ray paths on each side of the plate reflector **180** are shown in FIG. **3**B. It should be readily ascertainable from the geometric configuration of the plate reflector **180** in the example shown in FIG. **3**B that light rays incident on the plate reflector **180** will be reflected toward one of the quantum-dot vessels **10***a*, **10***b*.

[0061] In FIG. **3**B, as a non-limiting example, the focusing device **160** is shown as a converging lens arranged with respect to the focusing gap **190** such that a focal point **157** of the focusing device **160**, representing the narrowest width of the incident radiation optical path **155**, is disposed within the focusing gap **190** itself. As such, in some embodiments the width of the focusing gap **190** can be intentionally chosen as equal to, or nearly equal to, the width of the focal point **157** of the focusing device **160**. However, maintaining the position of the focal point **157** at a fixed location within the focusing gap **190** may require additional means such as single-axis tracking or dual-axis tracking, described above. Nevertheless, the configuration shown in FIG. **3**B may decrease or eliminate the need generally for dual-axis tracking, provided the focusing gap **190** is sufficiently wide to allow incident solar radiation to pass through the focusing gap **190** at all months of the year without unacceptably decreasing the intensity of light hitting the plate reflector **180**.

[0062] The plate reflector **180** reflects the incident solar radiation toward at least one of the quantum-dot vessels **10***a*, **10***b*. The plate reflector **180** may be reflective of all wavelengths or of only selected wavelengths. As such, the plate reflector **180** may be, for example, a silvered mirror, a shiny or polished metal, or a painted surface such as a surface painted white. In one group of embodiments, the plate reflector **180** is a shiny or polished metal such as aluminum, stainless steel, or silver, for example. In some embodiments, the profile of the plate reflector **180** is chosen such that upward reflection of any portion of the incident solar radiation back through the focusing gap **190** is minimized or avoided entirely.

[0063] When the incident solar radiation enters the quantum-dot vessels **10***a*, **10***b* and contacts the quantum dots therein, redshifted light **156** is emitted from the quantum dots in all directions, including upward and away from the photovoltaic plate **170**. This effect is illustrated in FIG. **3**B within the first quantum-dot vessel **10***a* and the second quantum-dot vessel **10***b* where the light rays intersecting the quantum dot suspension at reference point **61**. Thus, each of the quantum-dot vessels **10***a*, **10***b* in each photovoltaic solar-redshift module **150** and, referring to FIG. **2**, in the integral array **101**, comprises a trapping reflector **80***a*, **80***b* that reflects at least a portion of said redshifted light **156** toward the photovoltaic plate **170**. Specifically, the trapping reflector **80***a*, **80***b* reflects the portion of redshifted light **156** that is emitted upwardly, away from the photovoltaic plate **170**. Without the trapping reflector **80***a*, **80***b*, some redshifted light **156** of the most desirable wavelengths for the energy-harvesting application involved with the photovoltaic solar-redshift system **100** may be lost without benefiting the system.

[0064] The trapping reflector may be, for example, a coating on any surface of the second plate **30***a*, **30***b* of the quantum-dot vessels **10***a*, **10***b* or, as a further example, a reflective object contacting the sunward surface of the second plate **30***a*, **30***b* in a manner that prevents escape of redshifted light **156**. Additionally, the trapping reflector **80***a*, **80***b* may be reflective to the wavelength of the redshifted light **156** yet transmissive of other wavelengths of light. Thus, the trapping reflector **80***a*, **80***b* ensures not only that the most desirable wavelengths of redshifted light **156** are produced by emission from the quantum dots, but also that losses of redshifted light **156** due to upward reflection are minimized or prevented entirely.

[0065] Having described various embodiments of a gap-to-reflector configuration of a solar-redshift system, particularly with exemplary reference to the photovoltaic solar-redshift systems using photovoltaic plate **170** as a collecting target, now additional solar-redshift systems having a gap-to-vessel configuration will be described. An illustrative embodiment of a solar-redshift module (e.g., a photosynthesis-enhancing solar-redshift module) having a gap-to-reflector configuration is provided in FIG. **5** and will be described below as a component of the photosynthesis-enhancing solar-redshift system **200** of FIG. **4**. The gap-to-vessel configuration in general is arranged such that a focusing device **160** focuses the incident solar radiation following the incident-radiation optical path **155** through a focusing gap **290** directly onto the quantum-dot vessel **10**, wherein the incident solar radiation is redshifted before ever encountering a collecting target (e.g., first growth vessel **270***a* or second growth vessel **270***b*). Whereas in the gap-to-reflector configuration, a focusing gap **190** (FIG. 3B) is defined between two quantum-dot vessels **10***a*, **10***b* (FIG. 3B), in the gap-to-vessel configuration, the focusing gap **290** is defined between two separate collecting targets (e.g., first growth vessel **270***a* and the second growth vessel **270***b*). It should be understood that the photosynthesis-enhancing solar-redshift system **200** of FIG. **4** is but one embodiment of a system including solar-redshift modules having the gap-to-vessel configuration and that in other embodiments the gap-to-vessel configuration may be used in a photovoltaic solar redshift system by substituting photovoltaic plates as the collecting target in the place of the growth vessels **270***a*, **270***b*.

[0066] Referring to FIG. **4**, an embodiment of a photosynthesis-enhancing solar-redshift system **200** is provided as an example of a solar-redshift system having the gap-to-vessel configuration. Analogous to the photovoltaic solar-redshift system **100** (see FIG. **2**), the photosynthesis-enhancing solar-redshift system **200** comprises an integral array **201**. The integral array **201** can be made up of repeating units defined as photosynthesis-enhancing solar-redshift modules. Four photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d* are shown in FIG. **4**. Though, for sake of clarity, the integral array **201** shown in FIG. **4** includes only four of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d*, it should be understood that the integral array **201** may comprise any desired number of photosynthesis-enhancing solar-redshift modules, for example, up to several million, from 2 to 100,000, from 5 to 50,000, or from 10 to 10,000. Likewise, it should be understood that the integral array **201** in FIG. **4** is shown effectively in cross-section as a one-dimensional array, and that, in practice, the integral array **201** may extend in a second dimension, into the plane of FIG. **4**, so as to harvest energy from incident solar radiation falling on a large surface area of land. The integral array **201** may be an open system or may be a component of a larger apparatus such as a closed bioreactor (not shown).

[0067] The photosynthesis-enhancing solar-redshift system **200** optionally may comprise system walls **205** containing some or all of the components of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d*. The system walls **205** may be provided, for example, to prevent dirt or other contaminants from adversely affecting optical transmission through various components of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d*. The system walls **205**, when present, also may act as reflectors to prevent escape of stray light from the portion of the photosynthesis-enhancing solar-redshift system **200** enclosed within the system walls **205**.

[0068] Each of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d* comprises a quantum-dot vessel **10**; a focusing device **160***a*, **160***b*, **160***c*, **160***d*, respectively; a first growth vessel **270***a*, and a second growth vessel **270***b*. Though FIG. **4** shows the quantum-dot vessel **10** in the photosynthesis-enhancing solar-redshift system **200** as a single, continuous quantum-dot vessel, it should be understood that additional configurations are possible, wherein each of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d* may comprise a separate quantum-dot vessel not physically connected to the quantum-dot vessel of another module. Likewise, though in FIG. **4** the focusing device **160***a*, **160***b*, **160***c*, **160***d* corresponding to each of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d*, respectively, is depicted as part of an integral array of converging lenses, this configuration is to be understood as an example by way of illustration, not of limitation. It should be understood that numerous additional optical configurations and devices are possible. For example, as alternatives to the integral array of converging lenses, separate individual lenses may be used. Furthermore, other optical devices capable of directing rays of incident solar radiation may be used, such as for example, appropriately designed mirrors or solar collectors such as solar troughs.

[0069] It should be understood by the skilled person that variations in the direction of incident solar radiation relative to the focusing device **160***a*, **160***b*, **160***c*, **160***d* corresponding to each of the photosynthesis-enhancing solar-redshift modules **250***a*, **250***b*, **250***c*, **250***d*, respectively, will occur over the course of a single day and also during the course of the year. Variations over the course of a day arise from the movement of the sun across the sky from east to west and typically may be addressed by azimuthal single-axis tracking. Variations over the course of a year arise from the 23.5° angle of the earth's rotation axis relative to the plane of the earth's orbit typically may be addressed by elevational single-axis tracking. To account for both the daily and yearly variations of the angle of incident solar radiation may require dual-axis tracking.

[0070] Though mechanisms for single-axis tracking or dual-axis tracking are not shown in FIG. **4**, it is fully contemplated that the photosynthesis-enhancing solar-redshift system **200** may further comprise such mechanisms. In one exemplary embodiment, a suitable mechanism may be incorporated that widens the focusing gaps **290** of the photovoltaic solar-redshift modules **250** over the course of the year, thereby reducing or eliminating any need for large-scale dual-axis tracking mechanisms such as those that may require constantly adjusting the inclination of the entire photosynthesis-enhancing solar-redshift system **200** over the course of a year. In such an embodiment, a wider focusing gap **290** may permit incident solar radiation arriving at the focusing device **160** at a steeper angle (in winter compared to in summer, for example) to continue being focused through the focusing gap **290** over the course of a year without otherwise adjusting the inclination of the entire photosynthesis-enhancing solar-redshift system **200**. This gap-widening principle could then be used in combination with an azimuthal single-axis tracking mechanism that adjusts the photosynthesis-enhancing solar-redshift system **200** over the course of a day, such that the photosynthesis-enhancing solar-redshift system **200** would provide the advantages of dual-axis tracking with only the gross infrastructure of a single-axis tracking system. It should be noted, however, that widening the focusing gap **290** in this manner may also result in increased loss, owing to a heightened ability for reflected or redshifted light to escape back out through the focusing gap **290** without striking the quantum-dot vessel **60** or the growth vessels **270***a*, **270***b*.

[0071] A photosynthesis-enhancing solar-redshift module **250**, isolated from the integral array **201** shown in FIG. **4** to illustrate specific details, will be described now with reference to FIG. **5**. The photosynthesis-enhancing solar-redshift module **250** comprises a quantum-dot vessel **10**, a focusing device **160**, a first growth vessel **270***a*, and a second growth vessel **270***b*. The first growth vessel **270***a* and the second growth vessel **270***b* are interposed between the focusing device **160** and the quantum-dot vessel **10** along an incident-radiation optical path **155**.

[0072] The first growth vessel **270***a* and the second growth vessel **270***b* can be enclosed containers, or conduits (shown in cross-section) such as pipes or tubes, made of materials suitable for growing a photosynthetic organism therein. As used herein, the term "photosynthetic organism" refers to any organism in which photosynthesis occurs as part of a metabolic pathway for sustaining the organism or for causing the organism, or cells thereof, to grow and/or reproduce. Examples of photosynthetic organisms include, without limitation, plants, algae, and photosynthetic bacteria such as cyanobacteria. A "living photosynthetic organism," in contrast with a "dead photosynthetic organism," is any photosynthetic organism in which photosynthesis continues to occur when the organism is exposed to light.

[0073] In some embodiments, the living photosynthetic organism may be an organism having utility for producing biomass, wherein the biomass may be burned as a fuel source. In some embodiments, the living photosynthetic organism may be an organism that contains in its body or secretes from its body chemical compounds that can be used, for example, as fuels or as a source for various feedstocks to synthesize bio-derived chemicals or commodities. One highly suitable living photosynthetic organism, as a non-limiting example, is algae. Suitable materials of the first growth vessel **270***a* and the second growth vessel **270***b*, when used to enclose growing algae in a liquid medium such as a nutrient-rich algae growth medium include without limitation, for example, glass, acrylic, and various polymers. In some embodiments, such materials are highly transmissive to the wavelengths of light most conducive to photosynthesis by the algae.

[0074] Algae that may be used as the living photosynthetic organism in the photosynthesis-enhancing solar-redshift module **250** include, but are not limited to, *Chlorophyta* (green algae), *Charophyta* (Stoneworts and Brittleworts), *Euglenophyta* (Euglenoids), *Chrysophyta* (golden-brown and yellow-green algae and diatoms), *Phaeophyta* (brown algae), *Rhodophyta* (red algae), *Cyanophyta* (blue-green algae, same as blue-green bacteria or cyanobacteria), and the *Pyrrhophyta* (dinoflagellates). In one group of embodiments, the living photosynthetic organism in the photosynthesis-enhancing solar-redshift module **250** include cyanobacteria such as, for example, species *Synechocystis* sp. Most algae are photoautotrophs. As examples of the utility of algae in the photosynthesis-enhancing solar-redshift module **250**, most dried algae mass, wet algae colonies, or algae metabolites are known to provide some levels of lipid, saccharidic substances including polysaccharides and sulfated materials (cellulose, hemicellulose, pectin, alginic acid, carrageenan, agarose, porphyran, fucelleran, funoran, starch, simple sugars, and the like), glycoproteins, and a variety of photosynthetic pigments (chlorophyll, astaxanthin, etc) that may be used as a feedstock for bio-derived molecules or bio-derived fuels.

[0075] Further suitable species of algae that may be used in the photosynthesis-enhancing solar-redshift module **250** include, but are not limited to; *Actinastnim; Actinochloris; Anabaena; Ankistrodesnnis; Apatococcus; Asterarcys; Auzenochlorella; Bacilliarophy; Botrydiopsis; Botryococcus; Bracteacoccus; Biimilleriopsis; Chaetophora, Chantransia; Charachtm; Chlamydomonas, Chlorella; Chlorideilcr, Chlorobotrys; Chlorococcum; Chlorokybus; Chloroliimula; Chlormonas; Chlorophyceae; Chlorosarcinopsis; Chlorotetraedron; Chloricystis; Coccomyxa; Coelasirella; Coelastropsis; Coelastrum; Coenochloris; Coleochaete; Cosmarium; Crucigenia; Crucigeniella; Desmodesmus; Diadesmis; Dictyococciis; Dictyosphaenum; Dipfosphaera; Dunaliella; Ellipsoidion; Enallax; Ettlia; Euglena; Fortiea; Geminella; Gonium; Graesiella; Haematococcus; Heterococcus; Interfilum; Isochrysis; Kentrosphaera; Keratococcus; Klebsormidium; Koliella; Lagerheimia; Lobosphaera; Macrochloris; Microthamnion; Monodus; Monoraphidium; Mougeotia; Muriella; Mychonastes; Myrmecia; Nannochlolis; Nannochloropsis; Nautococcus; Navicular, Navioua; Neochloris; Neodesmus; Neospongiococcum; Nephrochlamys; Oocystis; Oonephris; Orthotrichum; Pediastrum; Phaeodactylum; Pithophora; Pleurastrum; Pleurochrysis; Porphyridium; Possonia; Prasiolopsis; Protosiphon; Prymnesium, Pseudollipsoidion; Pseudendoclonium; Pseudocharaciopsis; Pseudococcomyxa; Pseudoendoclonium; Raphidocelis; Raphidonema; Rhexinema; Rhopalocystis; Scenedesmus; Schroederiella; Scotiella; Scotiellopsis; Selenastrum, Sphaerocystis; Spirogyra; Spirulina; Spongiochloris; Stichococcus; Stigeoclonium; Synechoccus; Synechocystis* sp.; *Tetradesmus; Tetrahedron; Tetraselmis; Tetrastrum; Tribonema; Vischeria; Willea; Xanthonema*; and *Zygnema*. These species are known to produce or secrete various lipids, which in turn can be used as precursors to useful bio-derived substances.

[0076] The living photosynthetic organism has at least one wavelength of increased photosynthetic response. Analogously to the photovoltaic materials described above, photosynthesis in living photosynthetic organisms, including in the species of algae listed above, progresses with varying rates and/or intensities as a function of the wavelength of light that provides the energy for the photosynthesis. Thus, the term "photosynthetic response" of a living photosynthetic organism at a particular wavelength refers qualitatively to the intensity of photosynthesis that occurs as a result of light having the particular wavelength striking the organism. Photosynthetic response may be ascertained by a known technique, such as by monitoring output of certain metabolites from the organism or by monitoring volume and speed of oxygen production by the organism. A wavelength of light to which a given living photosynthetic organism is more responsive (i.e., has an increased rate of photosynthesis) than to others is defined herein as a property inherent to the living photosynthetic organism itself, namely, as a "wavelength of increased photosynthetic response" of the living photosynthetic organism. Thus, the term "a photosynthetic material having at least one wavelength of increased photosynthetic response" is equivalent to stating that the living photosynthetic organism is more responsive to one particular wavelength (i.e., the wavelength of increased photosynthetic response) than it is to other wavelengths. The term “a photosynthetic material having at least one wavelength of enhanced photosynthetic response” can be used interchangeably with “a photosynthetic material having at least one wavelength of increased photosynthetic response”.

[0077] In the photosynthesis-enhancing solar-redshift system **200**, the quantum dots are selected, with respect to material and quantum-dot size, to emit redshifted light having wavelengths as close as feasible to a wavelength of increased photosynthetic response for the particular algae. Without intent to be limited by theory, it is believed that photosynthesis does not take significant advantage of wavelengths toward the center of the visible, such that redshifting these wavelengths toward a move valuable wavelength would increase photosynthetic growth efficiency. As a non-limiting example, one potential wavelength to target for such a shift is 680 nm (red), which is particularly valuable to photosynthesis. Red is more valuable than green and blue, at least for green plants and green algae, because green light is typically reflected and blue light, though not completely reflected, has a higher energy and, therefore, tends to generate more heat than the red and green light do.

[0078] Regardless of the type of living organism present in the photosynthesis-enhancing solar-redshift module **250**, the living photosynthetic organism inherently has at least one wavelength of increased photosynthetic response. Likewise, the living photosynthetic organism may have also a wavelength of optimal photosynthetic response. In quantitative terms, a wavelength of increased photosynthetic response may be defined further as any wavelength of incident light that results in a photosynthetic response from the living photosynthetic organism that is higher, in some embodiments at least 10% higher, in some embodiments at least 25% higher, or in some embodiments at least 50% higher, than the lowest photosynthetic response achieved from exposing the organism to monochromatic light of each wavelength in the visible spectrum (from about 380 nm to about 750 nm). As used herein, the wavelength of optimal photosynthetic response is defined as the wavelength of incident light in the visible spectrum that results in the highest photosynthetic response from the living photosynthetic organism.

[0079] The growth vessels **270***a*, **270***b* may have any suitable shape, size, and wall thickness, and in some embodiments are transparent to at least the wavelengths of increased photosynthetic response of the living photosynthetic organism growing in the growth vessels **270***a*, **270***b*. Also, the shape of the growth vessels **270***a*, **270***b* can be selected in some embodiments so that surface area directed downward (i.e., toward the quantum-dot vessel **10**) is maximized. Thus, the generally ovular shapes presented in the Figures of the growth vessels **270***a*, **270***b* are illustrative only, not limiting, and the ovular shapes may be used instead of circular shapes that may not allow redshifted light **156** to pass into the vessels as efficiently.

[0080] The first growth vessel **270***a* and the second growth vessel **270***b* are configured between the quantum-dot vessel **10** and the focusing device **160** such that a focusing gap **290** is defined between the first growth vessel **270***a* and the second growth vessel **270***b*. The size of the focusing gap **290** is defined, in particular, by the shortest distance between the first growth vessel **270***a* and the second growth vessel **270***b*, accounting for the respective geometries thereof.

[0081] Referring still to FIG. **5**, the focusing device **160** is an optical apparatus that directs incident solar radiation along the incident-radiation optical path **155** (referring to the entire ray tracing from above the focusing device **160** until the rays enter the quantum-dot vessel **10**) through the focusing gap **290** and onto the first plate **20** of the quantum-dot vessel **10**. The incident solar radiation then enters the sealed cavity **60** of the quantum-dot vessel and strikes the quantum dots therein. The focusing device **160**, though depicted in FIG. **5** as a converging lens, may be another appropriate optical device having an equivalent function, namely, an optical device that can direct the incident solar radiation through the focusing gap **290**. Alternative devices in this regard include, for example, converging mirrors, or solar collectors such as troughs.

[0082] In FIG. **5**, as a non-limiting illustrative embodiment, the focusing device **160** may be a converging lens arranged with respect to the focusing gap **290** such that the focal point of the focusing device **160**, representing the narrowest width of the incident-radiation optical path **155**, is located within the focusing gap **290** itself. As such, in some embodiments the width of the focusing gap **290** may be intentionally chosen as equal to, or nearly equal to, the width of the focal point of the focusing device **160**. However, maintaining the position of the focal point at a fixed location within the focusing gap **290** may require additional apparatus such as single-axis tracking or dual-axis tracking, described above. Nevertheless, that the configuration shown in FIG. **5** may decrease or eliminate the need generally for dual-axis tracking, provided the focusing gap **290** is sufficiently wide to allow incident solar radiation to pass through the focusing gap **290** in all months of the year without unacceptably decreasing the intensity of light hitting the quantum-dot vessel **10**.

[0083] The quantum-dot vessel **10** in the photosynthesis-enhancing solar-redshift module **250** may comprise a sealed cavity **60** defined between a first plate **20** and a second plate **30**. The first plate **20** and the second plate **30** may be hermetically sealed, as described above with reference to FIGS. **1**A and **1**B but not shown in FIG. **5**, which depicts a continuous quantum-dot vessel shared among additional photosynthesis-enhancing solar-redshift modules not shown. In the quantum-dot vessel **10**, a quantum-dot suspension is disposed within the sealed cavity **60**. The quantum-dot suspension comprises quantum dots suspended in a suspension medium. The quantum dots are formed of a quantum-dot material and have a quantum-dot size, wherein the quantum dots emit a redshifted light **156** having the wavelength of increased photosynthetic response when the quantum dots are irradiated by incident solar radiation. As such, a synergy is present between the emission wavelength of the quantum dots and the wavelength of increased photosynthetic response of the living photosynthetic organism in the growth vessels **270***a*, **270***b*. Suitable quantum-dot materials, quantum-dot sizes, and suspension media, are as described above with reference to the quantum-dot vessel **10** of FIGS. **1**A and **1**B.

[0084] When the incident solar radiation traveling along the incident-radiation optical path **155** enters the quantum-dot vessel **10** and contacts the quantum dots therein, redshifted light **156** is emitted from the quantum dots in all directions, including downward (with respect to the orientation in FIG. **5** only) and away from the growth vessels **270***a*, **270***b*. Thus, the quantum-dot vessel **10** in each photosynthesis-enhancing solar-redshift module **250** and, referring to FIG. **4**, in the integral array **201**, comprises a trapping reflector **80** that reflects at least a portion of the redshifted light **156** toward the growth vessels **270***a*, **270***b*. Specifically, the trapping reflector **80** reflects the portion of redshifted light **156** that is emitted downwardly, away from the growth vessels **270***a*, **270***b*. Without the trapping reflector **80**, some redshifted light **156** of the most desirable wavelengths for the energy-harvesting application involved with the photosynthesis-enhancing solar-redshift system **200** may be lost without benefiting the growth of the living photosynthetic organism.

[0085] The trapping reflector **80** can be, for example, a partly reflective coating on any surface of the second plate **30** of the quantum-dot vessel **10** or, as a further example, a reflective object contacting the surface of the second plate **30** of the quantum-dot vessel **10** opposite the growth vessels **270***a*, **270***b* so as to prevent escape of the redshifted light **156** through the second plate **30**, in a direction away from the growth vessels **270***a*, **270***b*, is prevented. Additionally, the trapping reflector **80** may be reflective to the wavelength of the redshifted light **156**. For example, if a wavelength of increased photosynthetic response is 680 nm (red), the trapping reflector **80** may be a layer of red paint on a surface of the second plate **30**.

[0086] In some embodiments, the trapping reflector is highly transmissive of undesirable light **256** having wavelengths that are not helpful, or even harmful, to the growth of the living photosynthetic organism. The undesirable light **256** may be infrared light. The trapping reflector **80** may in some embodiments transmit 50%, in some embodiments 75%, in some embodiments 90%, or in some embodiments even 100%, of all infrared light having a wavelength of from 700 nm to 1 mm.

[0087] Because wavelengths of increased photosynthetic response generally are shorter than the 700 nm to 1 mm of infrared light, the prevalence of infrared radiation in the light emerging from the quantum-dot vessel **10** is unaffected, as compared to the prevalence of the infrared radiation in incident solar radiation. This is because the quantum dots redshift only photons having a higher energy (shorter wavelength) than the emission wavelength of the quantum dots. The emission wavelength of the quantum dots is chosen to match a wavelength of increased photosynthetic response of the living photosynthetic organism. Thus, the redshifted light in the flux emanating from the quantum-dot vessel **10** can comprise a substantial amount of unconverted infrared radiation, i.e., radiation that is not redshifted by the quantum dots because it has a longer wavelength than the emission wavelength of the quantum dots. This infrared light, if reflected toward the growth vessels **270***a*, **270***b*, may cause overheating of the living photosynthetic organism, resulting in inefficient growth of the organism, or even death of the organism. Thus, in some embodiments the trapping reflector **80** both reflects the redshifted light **156** and transmits infrared light as the undesirable light **256**. Thus, in some embodiments, the photosynthesis-enhancing solar-redshift module **250** provides: (1) that the most desirable wavelengths of redshifted light **156** are produced by emission from the quantum dots; (2) that losses of redshifted light **156** due to transmission in a direction away from the growth vessels **270***a*, **270***b* are minimized or prevented entirely; and (3) that the living photosynthetic organism is isolated from most or all undesirable light **256** present in the incident solar radiation.

[0088] The photovoltaic solar-redshift modules and the photosynthesis-enhancing solar-redshift modules have been described above as components of solar-redshift systems and as non-limiting examples of solar-redshift modules having a gap-to-reflector configuration or a gap-to-vessel configuration. In additional embodiments, solar-redshift modules having a parallel-plate configuration will now be described with reference to the exemplary embodiments of a parallel-plate solar redshift system of FIGS. **6**-**11**. Just as the solar-redshift systems having modules with a gap-to-reflector configuration or a gap-to-vessel configuration may be adaptable, the parallel-plate solar-redshift systems may be adapted to include photovoltaic materials, photosynthetic organisms in growth vessels, or both, as collecting targets for capturing energy from light sources such as incident solar radiation.

[0089] Referring to the illustrative embodiment of FIG. **6**, a parallel-plate solar-redshift system **300** may include a parallel-plate configuration **301** of solar-redshift modules **310***a*, **310***b*, **310***c* and at least one focusing device **340**. It should be understood foremost that the parallel-plate solar-redshift system **300** of FIG. **6** is shown as containing three solar-redshift modules **310***a*, **310***b*, **310***c* for clarity purposes only. In practice, however, the parallel-plate solar-redshift system according to the embodiments to be described below may contain any desired number of solar-redshift modules such as 1, 2, 5, 10, 50, 100, 500, 1000, 10,000, or even more than 10,000, for example.

[0090] As used in the context of the parallel-plate solar-redshift system **300**, the term "parallel-plate configuration" means that the functional components of the parallel-plate solar-redshift system **300** are configured as a series of parallel plates, wherein parallel plates of individual solar-redshift modules are, as a group, parallel to other parallel plates of neighboring solar-redshift modules. As used herein with regard to parallel plates, generally the term "plate" means a three-dimensional structure having one dimension substantially smaller than at least one of the other two dimensions, in some embodiments of both of the other two dimensions. With regard to the dimensions of any one parallel plate, as used herein, the "length" of a plate refers to the dimension measured from the edge of the plate that faces the focusing device **340** during operation of the parallel-plate solar-redshift system **300** to the edge of the plate opposite the focusing device **340**; the "width" or the "thickness" of a plate is measured perpendicular to the length of the plate, from an edge of the plate that faces a neighboring plate to an opposite edge of the plate that faces another neighboring plate.

[0091] In the parallel-plate solar-redshift system **300** of FIG. **6**, for example, the width of the parallel plates in the direction of the dimension labeled x may be substantially smaller than the length in the direction of the dimension labeled y, and also may be substantially smaller than a depth into the plane of the figure but not apparent from the figure itself. In some non-limiting embodiments, the plates may be rectangular solids or may be rectangular solids with cavities defined therein. Regardless, it should be understood that the plates need not be rectangular solids and need only be amenable to arrangement in a parallel-plate configuration. In some embodiments, however, the assembly width x is optimized with respect to the plate length y. In some embodiments, the ratio y/x of the plate length y to the assembly width x may be chosen such that y/x is from about 5:1 to about 20:1, such as from about 5:1 to about 15:1, from about 8:1 to about 12:1, or about 10:1. In this context, "about" may be regarded as encompassing a range of ±10% from a stated figure (e.g., "about 10:1" may be regarded as from 9:1 to 11:1).

[0092] An optimal ratio y/x may result in a desirable intensity of redshifted light being directed to the collecting targets

330*a*, **330***b*, **330***c* along their entire respective lengths. As used here, the term "desirable intensity" means an intensity that is less than the full intensity of the sun and is conducive to the chosen energy harnessing application for which the parallel-plate solar redshift system **300** is used. For example, certain types of photosynthetic organisms may thrive under a maximum intensity of redshifted light that is approximately 10% the intensity of full sun. By appropriate selection of x and y, a desirable intensity can be achieved. In some embodiments, the substantially uniform intensity is sufficient for producing energy from the entire length of the collecting targets **330***a*, **330***b*, **330***c*, whether the collecting targets **330***a*, **330***b*, **330***c* are photovoltaic plates or growth vessels containing living photosynthetic organisms.

[0093] Each of the solar-redshift modules **310***a*, **310***b*, **310***c* in the parallel-plate solar-redshift system **300** may include at least one solar-radiation conversion assembly **320***a*, **320***b*, **320***c*, **320***d*, **320***e*, **320***f* and a collecting target **330***a*, **330***b*, **330***c*. In the embodiment of FIG. **6**, each solar-redshift module **310***a*, **310***b*, **310***c* includes two opposing solar-radiation conversion assemblies. For example, solar-redshift module **310***a* contains a first solar-radiation conversion assembly **320***a* and a second solar-radiation conversion assembly **320***b* opposing the first solar-radiation conversion assembly **320***a*, such that the two solar-radiation conversion assemblies **320***a*, **320***b* surround a single collecting target **330***a*. Even so, it should be understood that the solar-redshift module **310***a* may still function even in the absence of either the first solar-radiation conversion assembly **320***a* or the second solar-radiation conversion assembly **320***b*.

[0094] Reference now will be made to FIGS. **6-10** to describe the collecting target **330***a* and the various components of the solar-radiation conversion assemblies **320***a*, **320***b*, all of which being themselves components of the solar-redshift module **310***a*. It should be understood that the description of solar-radiation conversion assemblies **320***a*, **320***b* applies equally to the solar-radiation conversion assemblies in other solar-redshift modules of the parallel-plate solar-redshift system **300**.

[0095] Referring particularly to FIG. **7**, the solar-redshift module **310***a* includes a collecting target **330***a* and solar-radiation conversion assemblies **320***a*, **320***b*. It should be understood that FIG. **7** is presented as an exploded view and that each of the parallel plates that form the collecting target **330***a* and the components of the solar-radiation conversion assemblies **320***a*, **320***b* may be touching or may have some amount of distance between them. In some embodiments, each of the parallel plates may contact neighboring plates. In other embodiments, some parallel plates have space between them. In still other embodiments, some parallel plates touch and others do not. In embodiments where at least some of the parallel plates do not touch neighboring plates, thermal management of the parallel-plate solar-redshift system **300** as a whole may outweigh the space-saving benefit of having all parallel plates touch. It should be recognized that FIGS. **6-10** are intended to be regarded as schematic illustrations only. Therefore, except as stated otherwise herein, FIGS. **6-10** are not intended to limit embodiments of the parallel-plate solar-redshift system **300** to any particular absolute thicknesses of the parallel plates in the dimension parallel to the assembly width x in FIG. **6**, or to any relative thickness of any one of the parallel plates to any other parallel plate. Though illustrative embodiments are provided herein of exemplary thicknesses and relative thicknesses, it should be understood that such thicknesses and relative thicknesses may be optimized according to the desired application, as well as to the choices of quantum dots and collecting targets.

[0096] In some embodiments, the collecting target **330***a* may be a growth vessel containing a living photosynthetic organism. The growth vessel may contain a growth medium for sustaining the living photosynthetic organism. The living photosynthetic organism may have a wavelength of increased photosynthetic response. In such embodiments, the growth vessel may be any enclosed container that can be incorporated in the parallel-plate configuration. The growth vessel may be made of any material suitable for growing a photosynthetic organism therein such as, for example glass or acrylic. The living photosynthetic organism and the growth medium may be any of the photosynthetic organisms or growth media described above with reference to the embodiments of photosynthesis-enhancing solar-redshift systems **200** (FIG. **4**). In this regard, the concept of the wavelength of increased photosynthetic response has also been fully described above with regard to the photosynthesis-enhancing solar-redshift systems **200** and applies equally to the parallel-plate solar-redshift system **300**. Though in non-limiting illustrative embodiments, in the parallel-plate solar redshift system **300**, the growth vessels may have thicknesses of from about 1 mm to about 10 mm, the thickness of the growth vessels may be less than 1 mm or greater than 10 mm, depending on the application. The limit in thickness of a growth vessel in a parallel-plate configuration such as in the parallel-plate solar redshift system **300** may be limited to the extent that living photosynthetic organisms (e.g., algae) in the center of the growth vessel may be shaded by other organisms closer to the sides of the growth vessel closest to illumination sources. Also, the shading effect may be overcome to some extent by turbulent flow within the growth vessel.

[0097] In other embodiments, the collecting target **330***a* may be a photovoltaic plate comprising a photovoltaic material having a wavelength of increased sensitivity. The photovoltaic plate may be formed from the photovoltaic material or may be formed from a suitable substrate such as a metal, silicon, ceramic, or plastic, for example, which is coated with the photovoltaic material or otherwise has a layer of photovoltaic material disposed thereon. A layer of photovoltaic material disposed on the photovoltaic plate may be a continuous layer or may be a layer patterned in a suitable manner that enables electrical energy to be efficiently harvested from the photovoltaic plate. The photovoltaic material may be any of the photovoltaic materials described above with reference to the embodiments of photovoltaic solar-redshift systems **100** (FIG. **2**). In this regard, the concept of the wavelength of increased sensitivity has also been fully described above with regard to the photovoltaic solar-redshift systems **100** and applies equally to the parallel-plate solar-redshift system **300**. The photovoltaic plate may additionally include electrical connections (not shown) adapted to utilize electrical energy produced by the photovoltaic plate during the operation of the parallel-plate solar-redshift system **300**.

[0098] With regard to the parallel-plate solar-redshift system **300** (FIG. **6**) as a whole, in some embodiments either each of the collecting targets **330***a*, **330***b*, **330***c* is a growth vessel or each of the collecting targets **330***a*, **330***b*, **330***c* is a photovoltaic plate. In other embodiments of the parallel-plate solar-redshift system **300**, some of the collecting targets (**330***a* and **330***c*, for example) may be growth vessels, while others (**330***b*, for example) may be photovoltaic plates.

[0099] Referring to FIG. **7**, in the solar-redshift module **310***a*, the at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) includes a waveguide **350**, an infrared-radiation absorber **370**, and a quantum-dot vessel **10** interposed between the waveguide **350** and the infrared-radiation absorber **370**.

[0100] The quantum-dot vessel **10** has been described in detail above with regard to embodiments of both the photovoltaic solar-redshift systems **100** (FIG. **2**) and the photosynthesis-enhancing solar redshift systems **200** (FIG. **3**). In the parallel-plate solar-redshift systems **300**, the quantum-dot vessel **10** is configured as a plate adapted to fit into the parallel-plate configuration. The quantum-dot vessel **10** may include a sealed cavity that contains a quantum-dot suspension including quantum dots. Though not apparent in FIG. **7**, the quantum-dot vessel **10** may include the features of the quantum-dot vessel **10** in FIG. **1**B such as the sealed cavity **60** defined between a first plate **20** and a second plate **30** and, optionally, a sealing edge **40** and separator structures **50**. may be defined between first and second plates The quantum dots are chosen such that they emit redshifted light having the target wavelength of the collecting target **330***a* (e.g., the wavelength of increased photosynthetic response or the wavelength of increased sensitivity, as appropriate to the conversion target with which the quantum-dot vessel **10** is associated) when irradiated by incident solar radiation. These concepts with regard to the parallel-plate solar-redshift systems **300** are identical to the respective concepts as they pertain to the photovoltaic solar-redshift systems **100** (FIG. **2**) and the photosynthesis-enhancing solar redshift systems **200** (FIG. **3**).

[0101] The quantum-dot vessel **10** may further include a trapping reflector **80** that reflects the redshifted light toward the collecting target **330***a* but transmits all, or at least a portion of, the infrared light from the incident solar radiation in a direction away from the collecting target **330***a*. Specifically, the trapping reflector **80** may reflect the portion of redshifted light that is emitted in a direction away from the collecting target **330***a*. Without the trapping reflector **80** some redshifted light of the most desirable wavelengths for the energy-harvesting application involved with the parallel-plate solar-redshift system **300** may be lost without benefiting the system. In some embodiments, the trapping reflector may be a coating layer on a surface of the quantum-dot vessel **10** farthest from the collecting target **330***a*. For example, the coating layer may be a paint having the desired reflectivity and transmissivity characteristics. In some embodiments, the trapping reflector **80** may be reflective to the wavelength of the redshifted light yet transmissive of other wavelengths of light. Thus, the trapping reflector **80** may ensure not only that the most desirable wavelengths of redshifted light produced by emission from the quantum dots in the quantum-dot vessel **10** are effectively utilized, but also that losses of redshifted light due to reflection away from the collecting target **330***a* are minimized or prevented entirely.

[0102] In non-limiting illustrative embodiments, the quantum-dot vessel **10** may have a thickness of from about 300 μm to about 1.5 mm. The thickness may include, for example, the thickness of two sheets of encapsulating material such as glass (for example, a first plate **20** and a second plate **30**, see FIG. **1**B) that enclose a sealed cavity **60** (FIG. **1**B) containing a suspension of quantum dots. Thus, in the illustrative embodiments the sheets of encapsulating material each may be from about 100 μm to about 700 μm thick and the sealed cavity that contains the quantum dots may be about 100 μm thick. It should be understood that the illustrative thicknesses of growth vessel are not meant to be limiting and that the growth vessels may have thicknesses less than 300 μm or substantially greater than 1.5 mm. As noted above, the thicknesses of the quantum-dot vessel **10** are shown schematically and not to scale in FIGS. **6-10**.

[0103] Referring again to FIG. **7**, the infrared-radiation absorber **370** of the at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) may be any material that absorbs infrared radiation, typically by converting it to heat. In some embodiments, the infrared-radiation absorber **370** is physically isolated from the quantum-dot vessel **10** or any other neighboring parallel plate to enable removal of the heat. Such heat may be efficiently removed in some embodiments by simply allowing air to circulate through the space between the infrared-radiation absorber **370** and the neighboring parallel plate. In other embodiments, additional structures may be contemplated for insertion between the infrared-radiation absorber **370** and neighboring parallel plates, such as a coolant plate (not shown) or cooling loop (not shown) through which a coolant medium such as water may be circulated. In some embodiments, each solar-radiation conversion assembly **320***a*, **320***b* has one unique infrared-radiation absorber **370** not shared by any neighboring solar-radiation conversion assembly. In other embodiments not shown, solar-radiation conversion assemblies of neighboring solar-redshift modules may share a common infrared-radiation absorber **370**.

[0104] In some embodiments, the infrared-radiation absorber **370** of the at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) may be a photovoltaic plate comprising a photovolatic material such as those described above for use as the collecting target **330***a*, particularly those capable of converting infrared light to electrical energy. In such embodiments, the infrared-radiation absorber **370** may be a photovoltaic plate, even if the collecting target **330***a* is a growth vessel. Thus, energy-collecting benefits may be realized through not only the collecting target **330***a*, but also the infrared-radiation absorber **370**, particularly from the infrared radiation that may have been converted to heat.

[0105] Generally, the thickness of the infrared-radiation absorber **370** may vary to the application of the parallel-plate solar redshift system **300**. In some embodiments, it may be advantageous if the infrared-radiation absorber **370** is sufficiently thick (for example, 1 cm to 10 cm) to absorb a substantial amount of heat during daylight hours and then radiate the heat during cooler nighttime hours. The ability of the infrared-radiation absorber **370** to absorb and radiate heat in this manner may advantageously maintain consistency of the temperature of the collecting target **330***a*, particularly when the collecting target **330***a* is a growth vessel containing a living photosynthetic organism (e.g., algae) that grows optimally at a particular range of temperatures.

[0106] The at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) is arranged in the parallel-plate configuration such that the waveguide **350** of the at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) is interposed between the quantum-dot vessel **10** of the at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) and the collecting target **330***a*.

[0107] According to some embodiments, the waveguide **350** of the at least one solar-radiation conversion assembly **320***a* (and/or **320***b*) may be a transparent or translucent material through which focused solar radiation **520** can travel by total internal reflection after entering through a sun-facing edge **355** of the waveguide **350**. Suitable materials for the waveguide **350** in this regard include, without limitation, glasses and substantially clear polymers such as acrylics, for example. In some embodiments, the waveguide **350** may be transparent to essentially all wavelengths of the solar spectrum. In other embodiments, the waveguide **350** may be colored, such as by an appropriate dye, such that the waveguide **350** is transparent to some wavelengths but absorbs other wavelengths. Generally, though in some embodiments it may be desirable that the waveguide **350** be transparent over a broad range, such as the entire solar spectrum, in some embodiments the transparency of the waveguide **350** over wavelengths shorter than the target wavelength (i.e., the wavelength of increased sensitivity and/or the wavelength of increased photosynthetic response) such as, for example, wavelengths shorter than about 700 nm, that can be redshifted by the quantum dots in the quantum-dot vessel **10**.

[0108] Additional features of the waveguide **350** will be described now with reference to FIGS. **8-10**. It should be understood that the rectangular shapes of the waveguide **350** of FIGS. **8-10** are presented as illustrative embodiments only and that neither the shape nor the proportions of the waveguide **350** should be regarded as limiting. As shown in the illustrative embodiment of FIG. **8**, the waveguide **350** includes a frustrating surface **360**. The frustrating surface **360** may include an unblocked portion **367** and may further include scattering features **365** dispersed across the frustrating surface **360**.

[0109] The schematic depictions of FIGS. **9** and **10** clarify the functionality of the frustrating surface **360** and of the waveguide **350** as a component of the solar-redshift module **310**. In general, the frustrating surface **360** scatters any guided solar radiation **522** (FIG. **10**) within the waveguide **350** toward the quantum-dot vessel **10** and permits redshifted light **540** to pass through the waveguide **350** from the quantum-dot vessel **10** toward the collecting target **330**. During operation of the parallel-plate solar-redshift system **300**, as will be described in greater detail below, incident solar radiation **510** is focused by the at least one focusing device **340**. The resulting focused solar radiation **520** is directed into the waveguide **350** through a sun-facing edge **355** of the waveguide **350**.

[0110] One light ray of the solar radiation inside the waveguide **350** is shown in FIG. **10** as guided solar radiation **522**. It should be understood that the guided solar radiation **522** travels through the waveguide **350** at various angles, depending on the angle at which the focused solar radiation **520** enters through the sun-facing edge **355**. At least a portion of the guided solar radiation **522** may be trapped in the waveguide **350** by total internal reflection, but eventually the guided solar radiation **522** will strike a scattering feature **365** of the frustrating surface **360**, wherein the guided solar radiation **522** would not be reflected by total internal reflection. For this purpose, scattering features **365** may be provided on the frustrating surface **360** to scatter the guided solar radiation **522** generally toward the quantum-dot vessel **10**. Though for sake of clarity only one ray of scattered solar radiation **530** is shown in FIG. **10**, it should be understood that the guided solar radiation **522** striking the scattering features **365** may be scattered in many directions, generally toward the quantum-dot vessel **10**.

[0111] An non-limiting illustrative embodiment of a configuration of the frustrating surface **360** of the waveguide **350** is shown in FIG. **8**. In the exemplary configuration of FIG. **8**, the scattering features **365** are arranged as a pattern of dots having increasing size with respect to distance from the sun-facing edge **355** of the waveguide **350**. Nevertheless, even at the lowest region of the frustrating surface **360** (i.e., farthest from the sun-facing edge **355**), the frustrating surface **360** includes unblocked portion **367** between the scattering features **365**.

[0112] In some embodiments, the scattering features **365** may be any structure and/or marking that frustrates total internal reflection within the waveguide **350** itself. For example, the scattering features **365** may be a coating material such as an opaque paint or may be an etched portion of the frustrating surface **360**. If the scattering features **365** are paint dots, for example, in one illustrative embodiment the paint dots may be formed from a white paint that does not inherently absorb any portion of guided solar radiation **522** that strikes the paint dots from inside the waveguide **350**. Increasing the size of the scattering features **365** with respect to distance from the sun-facing edge **355** may cause the intensity of scattered solar radiation **530** emerging out the back side of the waveguide **350** (parallel to and opposite the frustrating surface **360**) to be substantially uniform across the entire surface area of the back side of the waveguide **350**. The uniform intensity may result because the guided solar radiation **522** may have a higher intensity nearest the sun-facing edge **355** of the waveguide **350**, such that scattering features **365** that are smaller, fewer in number, or both, may cause an equivalent intensity of scattered solar radiation **530** as the scattering features **365** far from the sun-facing edge **355** that are larger, more numerous, or both. In this regard, the configuration of scattering features **365** of FIG. **8** may have any configuration known to be useful for the purpose of providing uniform light output across a surface area such as in liquid-crystal display (LCD) backlight technologies, for example.

[0113] Referring to FIGS. **8-10**, when the scattered solar radiation **530** reaches the quantum-dot vessel **10**, which contains a quantum-dot suspension, it encounters quantum dots, as particularly illustrated in FIG. **10** quantum dot **15**. As described above, the quantum dot **15** has an emission wavelength unique to the material of the quantum dot **15** and the size of the quantum dot **15**, wherein photons having a higher energy (shorter wavelength) than the emission wavelength may be absorbed by the quantum dot and subsequently re-emitted as a photon of the emission wavelength. The quantum dot **15** does not absorb photons having a lower energy (longer wavelength) than the emission wavelength of the quantum dot **15**. Thus, if the scattered solar radiation **530** has a higher energy (shorter wavelength) than the emission wavelength of the quantum dot **15**, the quantum dot **15** absorbs the scattered solar radiation **530** and emits redshifted light **540** having the emission wavelength. Conversely, if the scattered solar radiation **530** has a lower energy (longer wavelength) than the emission wavelength of the quantum dot **15**, the quantum dot **15** does not absorb or redshift the scattered solar radiation **530**.

[0114] As described above, the quantum-dot vessel **10** includes a trapping reflector **80** that, in some embodiments, is reflective to desirable wavelengths such as those of the redshifted light **540** and is transmissive of undesirable wavelengths such as infrared, for example. This is illustrated in FIG. **10**, in which undesirable light **545**, which may or may not encounter the quantum dot **15** but by no means is absorbed by the quantum dot, passes through the trapping reflector **80**

and is allowed to pass toward the infrared-radiation absorber **370**. At the infrared-radiation absorber **370** the undesirable light **545** is absorbed, and/or converted to heat, and/or otherwise removed from the parallel-plate solar-redshift system **300**. On the other hand, the redshifted light **540** is reflected back toward the waveguide **350**, passes through the waveguide **350**, and emerges through the frustrating surface **360** of the waveguide **350** in the unblocked portion **367** between the scattering features **365**.

[0115] The redshifted light **540** that emerges from the frustrating surface **360** of the waveguide **350** proceeds to reach the collecting target **330**, where it may be used to enhance efficiency of energy production. For example, in some embodiments the redshifted light **540** may enhance growth of the living photosynthetic organism when the collecting target **330** is a growth vessel and the living photosynthetic organism has a wavelength of increased photosynthetic response near or equal to the wavelength of the redshifted light **540**. In other embodiments the redshifted light **540** may cause the photovoltaic material to produce energy at increased efficiency when the collecting target **330** is a photovoltaic plate and the photovoltaic material has a wavelength of increased sensitivity near or equal to the wavelength of the redshifted light **540**.

[0116] Having described above the components and general principles that relate to the solar-redshift modules **310***a*, **310***b*, **310***c* of the parallel-plate solar-redshift system **300**, the interaction of the solar-redshift modules **310***a*, **310***b*, **310***c* with the at least one focusing device **340** and the application of the parallel-plate solar-redshift system **300** for energy harnessing now will be described with reference to FIGS. **6**, **7**, **11**A, and **11**B.

[0117] In the parallel-plate solar-redshift system **300**, the at least one focusing device **340** focuses the incident solar radiation **510** (such as radiation emanating directly from the sun **500**, for example) onto sun-facing edges **355** of the waveguides **350** of the solar-radiation conversion assemblies **320***a*, **320***b* in respective solar-redshift modules **310***a*. In the illustrative embodiments of FIGS. **6** and **7**, the at least one focusing device **340** is a fresnel lens having multiple zones, each of which focuses the incident solar radiation **510** onto a sun-facing edge **355** of one respective waveguide **350**. In some orientations of the parallel-plate solar-redshift system **300** of FIG. **6** and the solar-redshift module **310***a* of FIG. **7** during their operation, the sun **500** in FIGS. **6** and **7** moves into or out of the planes of the respective figures during the course of a day, not across the respective figures from left to right. It should be understood that the at least one focusing device **340** need not be such a fresnel lens and that any suitable apparatus may be used such as an array of converging lenses, for example. In some embodiments, however, substantially all of the incident solar radiation **510** can be focused onto the sun-facing edges **355** of the waveguides **350**, effectively leaving in a shadow the sun-facing edges of other plates such as the collecting targets **330***a*, **330***b*, **330***c* and the quantum dot vessels **10**.

[0118] In some embodiments, the at least one focusing device **340** may be mounted on an outer housing **400** of the parallel-plate solar-redshift system **300**. The focusing device may be substantially parallel to a base support **460** into which the parallel plates may be fastened. The outer housing **400** may additionally include an azimuthal focus adjustment mechanism **410** (shown schematically in FIG. **6**) that moves the at least one focusing device **340** toward or away from the parallel plates. Particularly in the illustrative embodiment of FIG. **6**, the azimuthal focus adjustment mechanism **410** may change the focal distance f of the at least one focusing device **340** to optimize the amount of incident solar radiation **510** that is focused directly onto the sun-facing edges **355** of the waveguides **350**. In some embodiments, the sun-facing edges **355** of the waveguides **350** are oriented such that a lateral edges **356** (FIGS. **8** and **9**) of the waveguides **350** run from east to west. Thus, during operation of the parallel-plate solar-redshift system **300**, as the sun **500** moves through the sky from east to west during the course of one day, the azimuthal focus adjustment mechanism **410** may be used to maintain the focus of the incident solar radiation **510** on the sun-facing edges **355** of the waveguides **350** by simply changing the focal distance f. In this regard, the azimuthal focus adjustment mechanism **410** in combination with the at least one focusing device **340** according to embodiments herein may be a configuration that alleviates a need for a more complicated system of solar tracking over the course of a day. Without the azimuthal focus adjustment mechanism **410**, for example, solar tracking over the course of a day may require mechanisms and apparatus that rotate and/or tilt the entire parallel-plate configuration of the parallel-plate solar-redshift system **300**.

[0119] The parallel-plate solar-redshift system **300** is shown in FIGS. **11**A and **11**B schematically in operational positions on a support structure **450**. It should be understood that the configuration of FIGS. **11**A and **11**B together represents only one simplified example of how the parallel-plate solar-redshift system **300** may be implemented and that numerous other configurations are possible. In the illustrative embodiment, the parallel-plate solar-redshift system **300** may rest on a base support **460** that is part of the support structure **450**. The base support **460** may be inclined with respect to the ground and may be operatively connected to any suitable elevational adjustment mechanism (not shown) that adjusts the inclination of the base support **460**. For example, adjustment of the inclination of the base support **460** may include movement of the base support **460** about a pivot point **465**.

[0120] In the schematic depiction of FIG. **11**A, the base support **460** is set to provide a summer-solstice inclination angle θ_1 to the outer housing **400**. In FIG. **11**B, the base support **460** is set to provide a winter-solstice inclination angle θ_2 to the outer housing **400**. Because the track of the sun across the sky daily from east to west occurs at a lower elevation in the winter than in the summer, naturally the summer-solstice inclination angle θ_1 is less than the winter-solstice inclination angle θ_2. For purposes of illustration only, the sun **500** in FIG. **11**A is shown at solar noon on the summer solstice, and the sun **500** in FIG. **11**B is shown at solar noon on the winter solstice. As used herein, the term "solar noon" refers to the time of a given day when the sun reaches its highest elevation in the sky over where the parallel-plate solar-redshift system **300** is being operated, without regard to the local time established at the same location by arbitrary time-zone boundaries.

[0121] The parallel-plate solar-redshift system **300** of FIGS. **11**A and **11**B is oriented in an exemplary manner for how it may be used in the northern hemisphere, particularly north of the Tropic of Cancer. Namely, both the summer-solstice inclination angle θ_1 and the winter-solstice inclination angle θ_2 are expressed as elevation angles, for which an elevation of 0° would cause the side of the focusing device **340** facing the sun **500** to face due south (shown as bearing 180°) and an elevation of 90° would cause the side of the focusing device **340** facing the sun **500** to face straight up (i.e., toward the zenith). Due east (indicated as bearing 90°) is depicted into the plane of FIGS. **11**A and **11**B, and due west (indicated as bearing 270°) is depicted out of the plane of FIGS. **11**A and **11**B. Accordingly, the parallel-plate configuration **301** is oriented such that the lateral edges **356** of the sun-facing edges **355** of the waveguides (see FIG. **9**, for example) run from east to west.

[0122] In general, if the parallel-plate solar-redshift system **300** is deployed at a latitude L north of the Tropic of Cancer as provided in FIGS. **11**A and **11**B, the summer-solstice inclination angle θ_1 may be expressed according to the equation $\theta_1 \approx 90° - (L - 23.5°)$ and the winter-solstice inclination angle θ_2 may be expressed according to the equation $\theta_2 \approx 90°$ $(L + 23.5°)$. These relationships hold for locations south of the Tropic of Capricorn, provided the parallel-plate solar-redshift system **300** is oriented in reverse, such that an elevation of **0**° would cause the side of the focusing device **340** facing the sun **500** to face due north (shown as bearing 360°) instead of due south.

[0123] North of the Tropic of Cancer and south of the Tropic of Capricorn, when the parallel-plate solar-redshift system **300** is operated over the course of the year, the elevation angle of the base support **460** may be adjusted to match the elevation of the sun **500** on a given day. It should be understood that the elevation of the sun **500** on a given day is readily ascertainable from common sources such as astronomical tables, for example. In some embodiments, the elevation angle of the base support **460** may be decreased incrementally from the summer-solstice inclination angle θ_1 at the summer solstice to the winter-solstice inclination angle θ_2 at the winter solstice then increased incrementally from the winter-solstice inclination angle θ_2 to the summer-solstice inclination angle θ_2 at the next summer solstice. The incremental adjustments of inclination angle may be made in a manner that causes incident solar radiation **510** to strike the focusing device **340** substantially perpendicularly at solar noon each day over the course of an entire year.

[0124] Though not illustrated in FIGS. **11**A and **11**B, it should be apparent that if the parallel-plate solar-redshift system **300** is deployed between the Tropic of Cancer and the Tropic of Capricorn, on two days of the year (i.e., when the sun **500** is directly overhead), the inclination angle of the base support **460** may be 90°. Then, while the sun **500** is directly overhead in the same hemisphere as where parallel-plate solar-redshift system **300** is located, the inclination angle of the base support **460** may be less than 90°. While the sun **500** is directly overhead in the opposite hemisphere from where parallel-plate solar-redshift system **300** is located, the inclination angle of the base support **460** may be greater than 90°. Inclination angles greater than 90° may be accomplished, for example, by moving the pivot point **465** up the base support **460** a suitable distance to cause the parallel-plate solar-redshift system **300** to rock back and forth.

[0125] The schematics of FIGS. **11**A and **11**B illustrate that the parallel-plate solar-redshift system **300** according to embodiments herein may have a dual-axis tracking ability with only the level of external movement apparatus that would be required in a single-axis tracking system. In particular, to track the sun over the course of a year, an elevational adjustment mechanism (such as one that moves the base support **460** relative to the support structure **450**, for example) may be required to lower the inclination angle from the summer inclination angle θ_1 to the winter inclination angle θ_2 or to raise the inclination angle from the winter inclination angle θ_2 to the summer inclination angle θ_1. Tracking the sun during the course of a single day, on the other hand, may be accomplished with a less substantial apparatus that may be easier to maintain than an apparatus requiring rotation of the entire parallel-plate solar-redshift system **300** to follow the azimuthal location of the sun, for example. In particular, the azimuthal focus adjustment mechanism **410** that moves the at least one focusing device **340** relative to the parallel-plate configuration **301** may be used to efficiently and accurately maintain focus of the incident solar radiation **510** on the sun-facing edges **355** of the waveguides **350** (see FIGS. **6** and **7**, for example).

[0126] Thus, various embodiments of solar-redshift systems have been described in detail provided, in each of which quantum dots may be used to convert high-energy wavelengths in broad-spectrum incident solar radiation to selected lower-energy wavelengths, so as to improve efficiency for a specific energy-harnessing application, such as photosynthetic or photovoltaic conversion. The solar-redshift systems are configured not only to optimize the wavelength spectrum of the solar radiation, but also to maximize the efficiency at which the solar radiation is made available to the energy-harnessing application. Particular solar-redshift systems described herein may also mitigate or eliminate the need for incorporating equipment-intensive dual-axis tracking mechanisms.

[0127] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention belongs. The terminology used in the description herein is for describing particular embodiments only and is not intended to be limiting. As used in the specification and appended claims, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0128] Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, and so forth as used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless otherwise indicated, the numerical properties set forth in the specification and claims are approximations that may vary depending on the desired properties sought to be obtained in embodiments of the present invention. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. One of ordinary skill in the art will understand that any numerical values inherently contain certain errors attributable to the measurement techniques used to ascertain the values.

[0129] As used herein, the terms "horizontal" and "vertical" are relative terms only, are indicative of a general relative orientation only, and do not necessarily indicate perpendicularity. These terms, as well as terms such as "left," "right," "into the plane," and "out of the plane" also may be used for convenience to refer to orientations used in the figures, which orientations are used as a matter of convention only and are not intended as characteristic of the devices shown, except where explicitly noted to the contrary. The embodiments described herein may be used in any desired orientation.

[0130] It should be apparent to those skilled in the art that various modifications and variations can be made to the embodiments described herein without departing from the spirit and scope of the claimed subject matter. Thus it is intended that the specification cover the modifications and variations of the various embodiments described herein provided such modification and variations come within the scope of the appended claims and their equivalents.

1-35. (canceled)

36. A redshift system comprising:

a collecting target comprising a target wavelength;

a quantum dot vessel comprising quantum dots disposed therein, the quantum dots emitting redshifted light comprising the target wavelength in response to being irradiated by electromagnetic radiation comprising a wavelength different than the target wavelength;

a waveguide interposed between the collecting target and the quantum dot vessel; and

a focusing device configured to focus the electromagnetic radiation comprising the wavelength different than the target wavelength on an edge of the waveguide;

wherein the collecting target, the waveguide, and the quantum dot vessel are arranged in a parallel-plate configuration; and

wherein the waveguide comprises a frustrating surface configured to scatter the focused electromagnetic radiation within the waveguide toward the quantum dot vessel and permit redshifted light emitted by the quantum dot vessel to pass through the waveguide toward the collecting target.

37. The redshift system of claim **36**, wherein the quantum dot vessel comprises a first quantum dot vessel and a second quantum dot vessel, the collecting target is positioned between the first quantum dot vessel and the second quantum dot vessel, and the waveguide comprises a first waveguide interposed between the collecting target and the first quantum dot vessel and a second waveguide interposed between the collecting target and the second quantum dot vessel.

38. The redshift system of claim **36**, wherein the quantum dot vessel comprises a sealed cavity defined between a first plate and a second plate.

39. The redshift system of claim **36**, wherein the quantum dot vessel comprises a trapping reflector that reflects a portion of the redshifted light emitted by the quantum dots toward the collecting target and transmits infrared light from the electromagnetic radiation in a direction away from the collecting target.

40. The redshift module of claim **39**, wherein the trapping reflector is configured to transmit in the direction away from the collecting target at least 50% of infrared light comprising a wavelength of from 700 nm to 1 mm.

41. The redshift system of claim **36**, wherein the focusing device comprises a fresnel lens or an array of converging lenses.

42. The redshift system of claim **36**, further comprising an azimuthal focus adjustment mechanism that changes a focal distance of the focusing device from the edge of the waveguide.

43. The redshift system of claim **42**, wherein the electromagnetic radiation comprises incident solar radiation, the edge of the waveguide comprises a sun-facing edge that is aligned from east to west, and changing the focal distance of the focusing device with the azimuthal focus adjustment mechanism over the course of a day maintains focus of the incident solar radiation on the sun-facing edge of the waveguide.

44. The redshift system of claim **36**, further comprising an elevational adjustment mechanism that adjusts an elevational angle of the redshift system over the course of a year.

45. The redshift system of claim **36**, wherein the waveguide is configured to trap the focused electromagnetic radiation by total internal reflection, and the frustrating surface of the waveguide comprises scattering features configured to scatter the focused solar radiation within the waveguide toward the quantum dot vessel.

46. The redshift system of claim **36**, further comprising an infrared-radiation absorber, wherein the quantum dot vessel is interposed between the waveguide and the infrared-radiation absorber, and the collecting target, the waveguide, the quantum dot vessel, and the infrared-radiation absorber are arranged in the parallel-plate configuration.

47. The redshift system of claim **46**, wherein the infrared-radiation absorber comprises a photovoltaic plate comprising a photovoltaic material.

48. The redshift module of claim **36**, wherein the collecting target comprises a growth vessel for containing a living photosynthetic organism, and the target wavelength comprises a wavelength of increased photosynthetic response of the living photosynthetic organism.

49. The redshift module of claim **48**, wherein the living photosynthetic organism comprises algae.

50. The redshift system of claim **48**, wherein the living photosynthetic organism is selected from the group consisting of green algae, cyanobacteria, *Synechocystis* sp., and *Chlorella vulgaris*.

51. The redshift system of claim **36**, wherein the collecting target comprises a photovoltaic plate.

52. A redshift system comprising:

a collecting target comprising a target wavelength;

an infrared-radiation absorber;

a waveguide interposed between the collecting target and the infrared-radiation absorber;

a focusing device configured to focus electromagnetic radiation comprising a wavelength different than the target wavelength on an edge of the waveguide; and

a quantum dot vessel interposed between the waveguide and the infrared-radiation absorber and comprising quantum dots disposed therein, the quantum dots emitting redshifted light comprising the target wavelength in response to being irradiated by the electromagnetic radiation comprising the wavelength different than the target wavelength;

wherein the collecting target, the infrared-radiation absorber, the waveguide, and the quantum dot vessel are arranged in a parallel-plate configuration; and

wherein the waveguide comprises a frustrating surface configured to scatter the focused electromagnetic radiation within the waveguide toward the quantum dot vessel and permit redshifted light emitted by the quantum dot vessel to pass through the waveguide toward the collecting target, and the quantum dot vessel comprises a trapping reflector that reflects a portion of the redshifted light emitted by the quantum dots toward the collecting target and transmits infrared light from the electromagnetic radiation toward the infrared-radiation absorber.

53. A redshift module comprising:

a collecting target comprising a target wavelength;

a quantum dot vessel comprising quantum dots disposed therein, the quantum dots emitting redshifted light comprising the target wavelength in response to being irradiated by electromagnetic radiation comprising a wavelength different than the target wavelength; and

a focusing device configured to focus the electromagnetic radiation through a focusing gap of one of the collecting target or the quantum dot vessel;

wherein the focusing device, the quantum-dot vessel, and the collecting target are arranged such that the electromagnetic radiation focused through the focusing gap strikes the quantum-dot vessel without first striking the collecting target.

54. The redshift module of claim **53**, wherein the collecting target comprises a first collecting target and a second collecting target each positioned between the focusing device and the quantum-dot vessel, the focusing gap is defined between a first edge of the first collecting target and a second edge of the second collecting target, and the focusing device is configured to focus the electromagnetic radiation through the focusing gap and toward the quantum-dot vessel.

55. The redshift module of claim **53**, wherein the quantum-dot vessel comprises a first quantum-dot vessel and a second quantum-dot vessel each positioned between the focusing device and the collecting target, the focusing gap is defined between the first quantum-dot vessel and the second quantum-dot vessel, the focusing device is configured to focus the electromagnetic radiation through the focusing gap and onto a plate reflector, and the plate reflector is configured to reflect the electromagnetic radiation toward at least one of the first quantum-dot vessel or the second quantum-dot vessel.

* * * * *

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(54) **ONSITE INTEGRATED PRODUCTION FACTORY**

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(73) Assignee: **M HIKARI & ENERGY LABORATORY CO., LTD.**, Kamakura-shi (JP)

(21) Appl. No.: **13/453,496**

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Related U.S. Application Data

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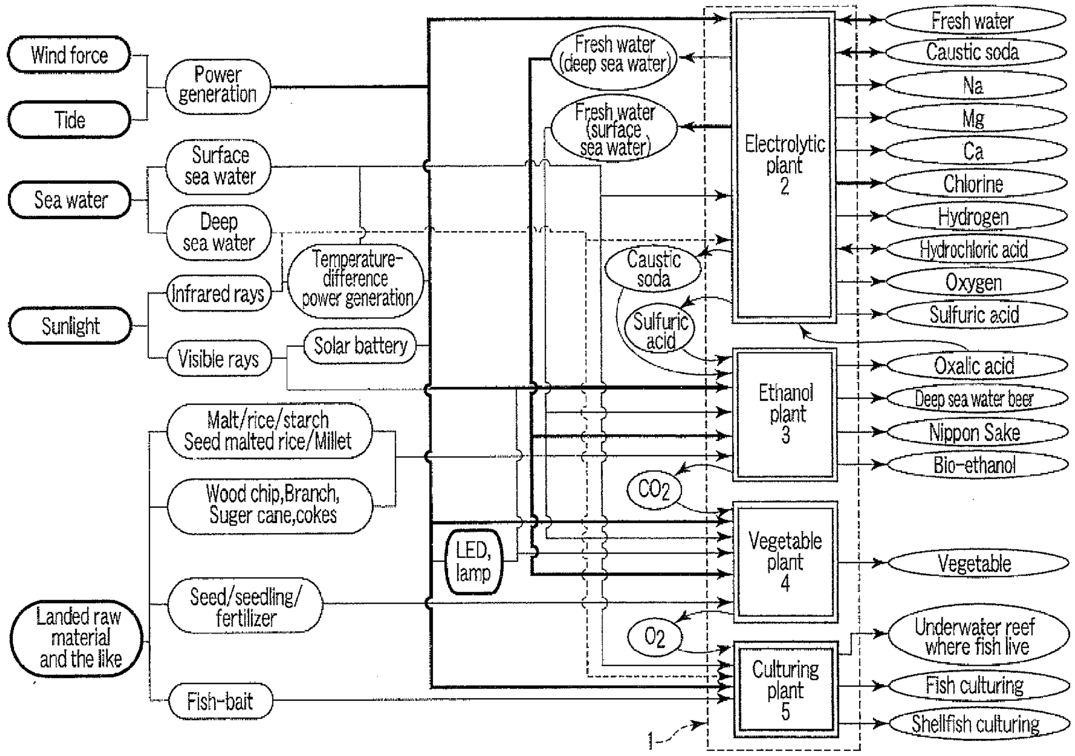
A01K 61/00	(2006.01)
H01L 35/30	(2006.01)
C25C 7/06	(2006.01)
A01G 9/00	(2006.01)

(52) **U.S. Cl.** **435/289.1**; 204/242; 204/243.1; 47/1 1R; 47/65; 119/215; 136/205

(57) **ABSTRACT**

An onsite integrated production factory having an electrolytic plant, an ethanol plant, a vegetable plant, a culturing plant, and a power generation unit. The onsite integrated production facility is arranged so that fresh water, sulfuric acid or caustic soda produced by and received from the electrolytic plant is used in the ethanol plant to produce and output oxalic acid, sodium oxalate, fuel bioethanol. The oxalic acid or sodium oxalate produced in and received from the ethanol plant is used for removing calcium contained in the sea water in the electrolytic plant. The vegetable plant produces vegetables for generation and outputting of oxygen by receiving the carbon dioxide generated during the fermentation process in the ethanol plant and fresh water from the electrolytic plant. The culturing plant has a fishery farm or reef for using the oxygen generated in the vegetable plant.



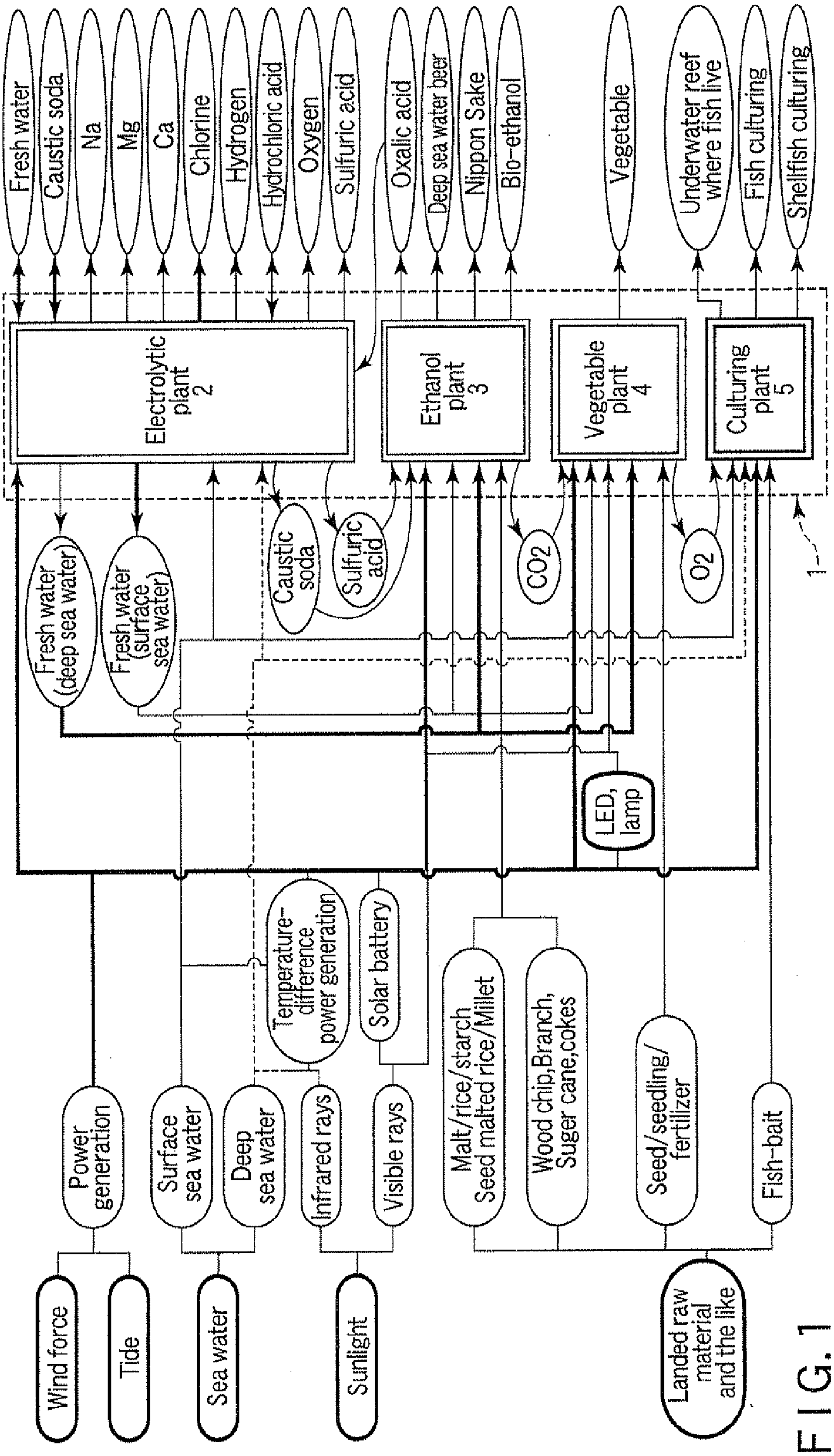
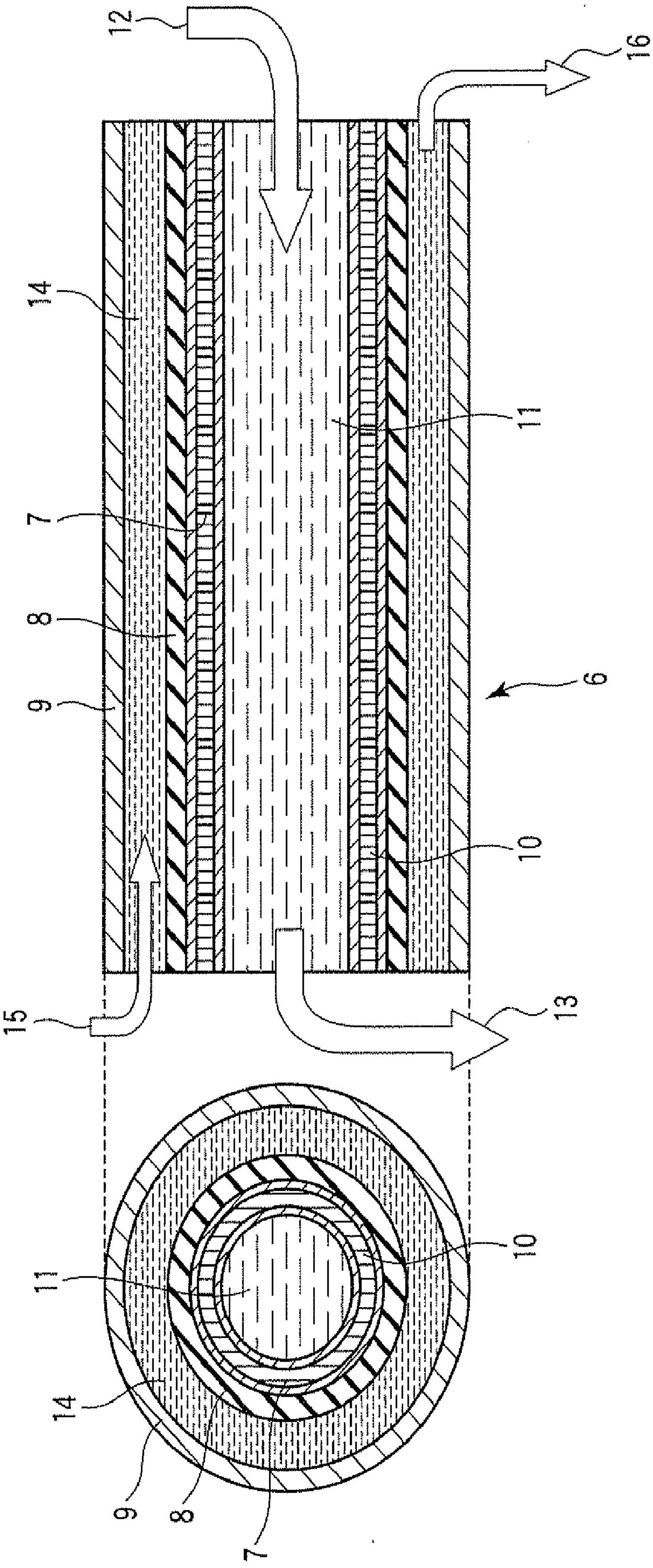

Wind force
Tide
Sea water
Sunlight
Landed raw material and the like
Power generation
Surface sea water
Deep sea water
Infrared rays
Visible rays
Malt/rice/starch Seed malted rice/Millet
Wood chip,Branch, Suger cane,cokes
Seed/seedling/fertilizer
Fish-bait
Temperature-difference power generation
Solar battery
LED, lamp
Fresh water (deep sea water)
Fresh water (surface sea water)
Caustic soda
Sulfuric acid
CO2
O2
Electrolytic plant 2
Ethanol plant 3
Vegetable plant 4
Culturing plant 5
1
Fresh water
Caustic soda
Na
Mg
Ca
Chlorine
Hydrogen
Hydrochloric acid
Oxygen
Sulfuric acid
Oxalic acid
Deep sea water beer
Nippon Sake
Bio-ethanol
Vegetable
Underwater reef where fish live
Fish culturing
Shellfish culturing

FIG. 1



F I G. 2

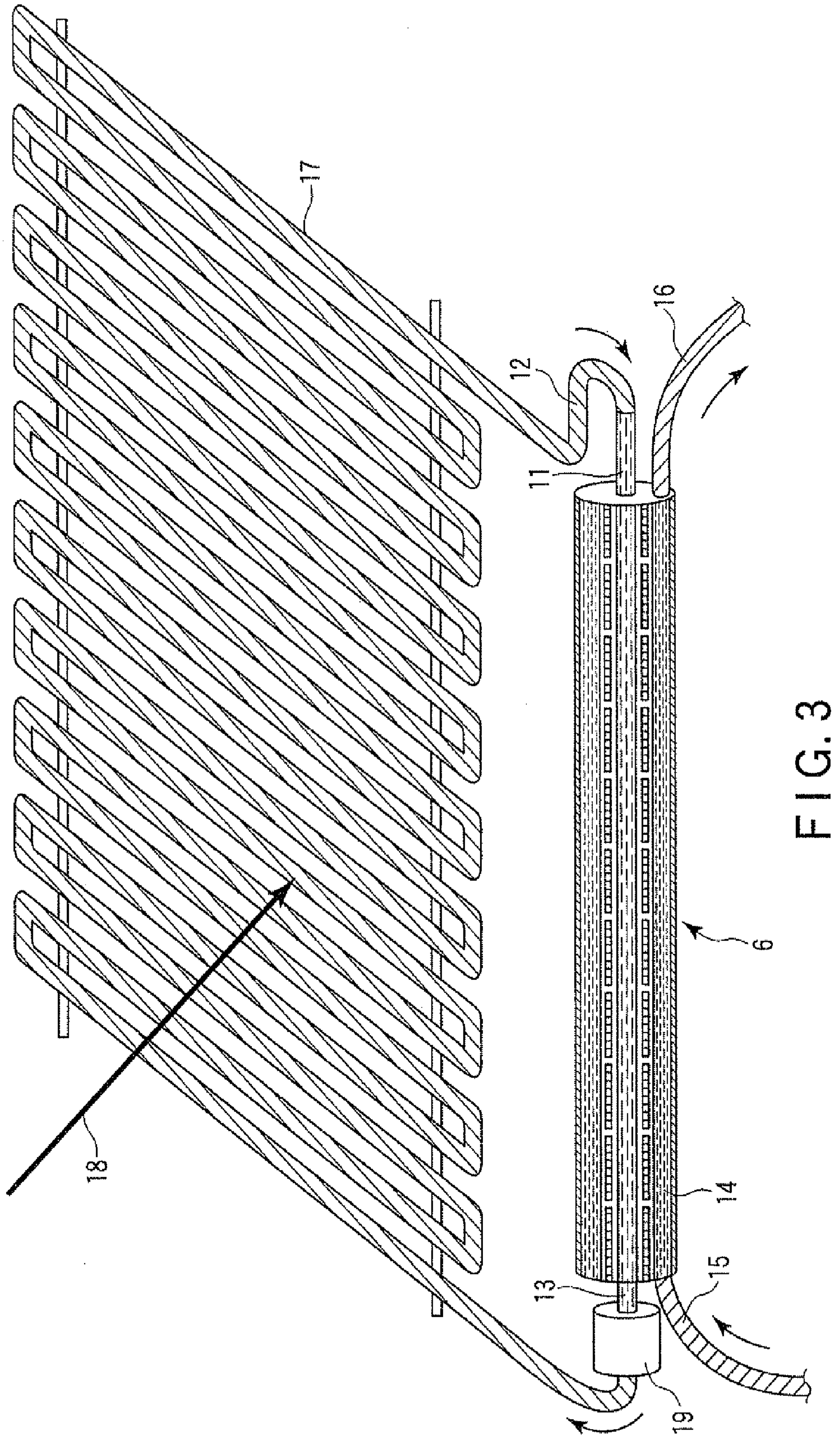


FIG. 3

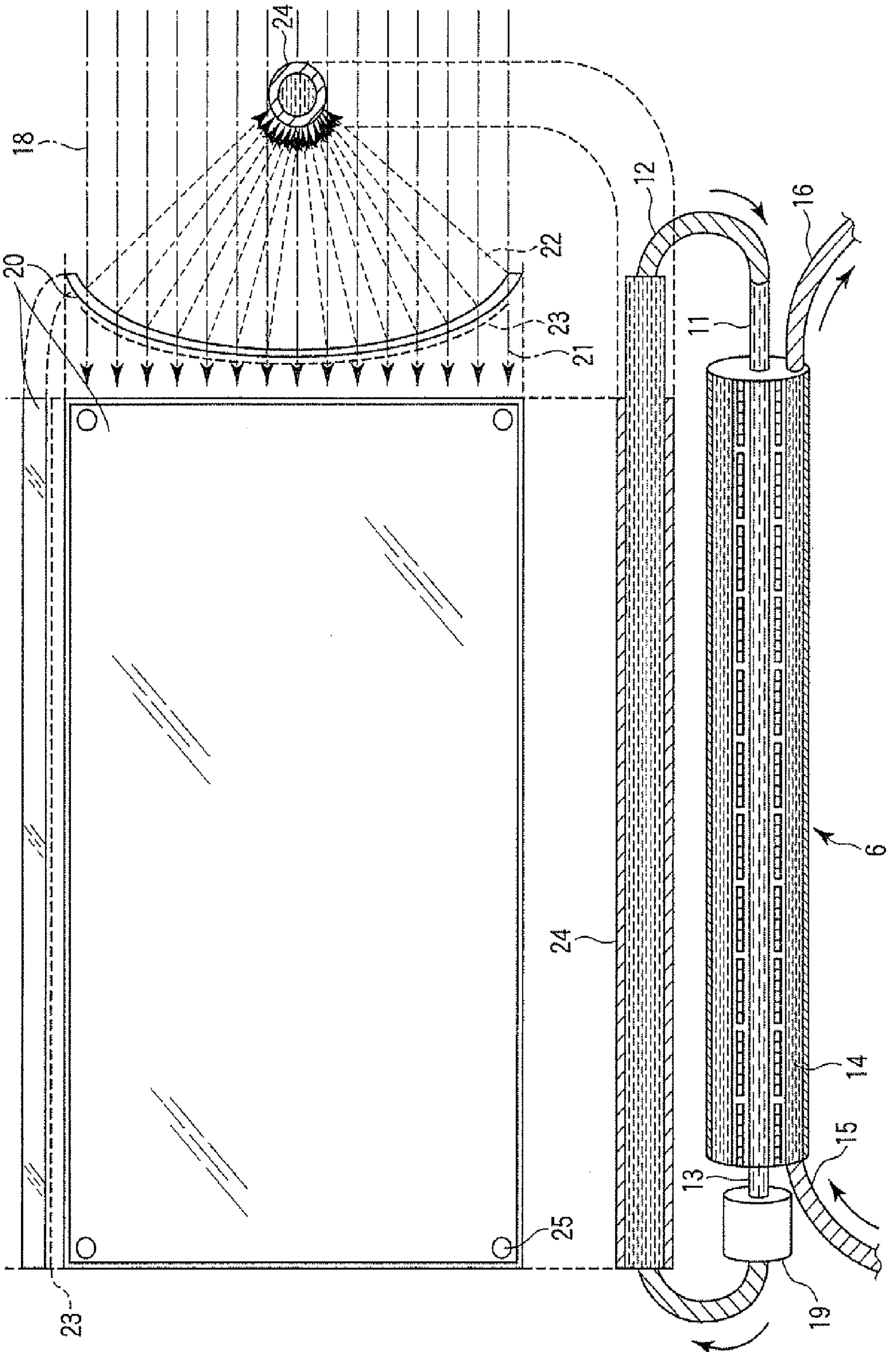


FIG. 4

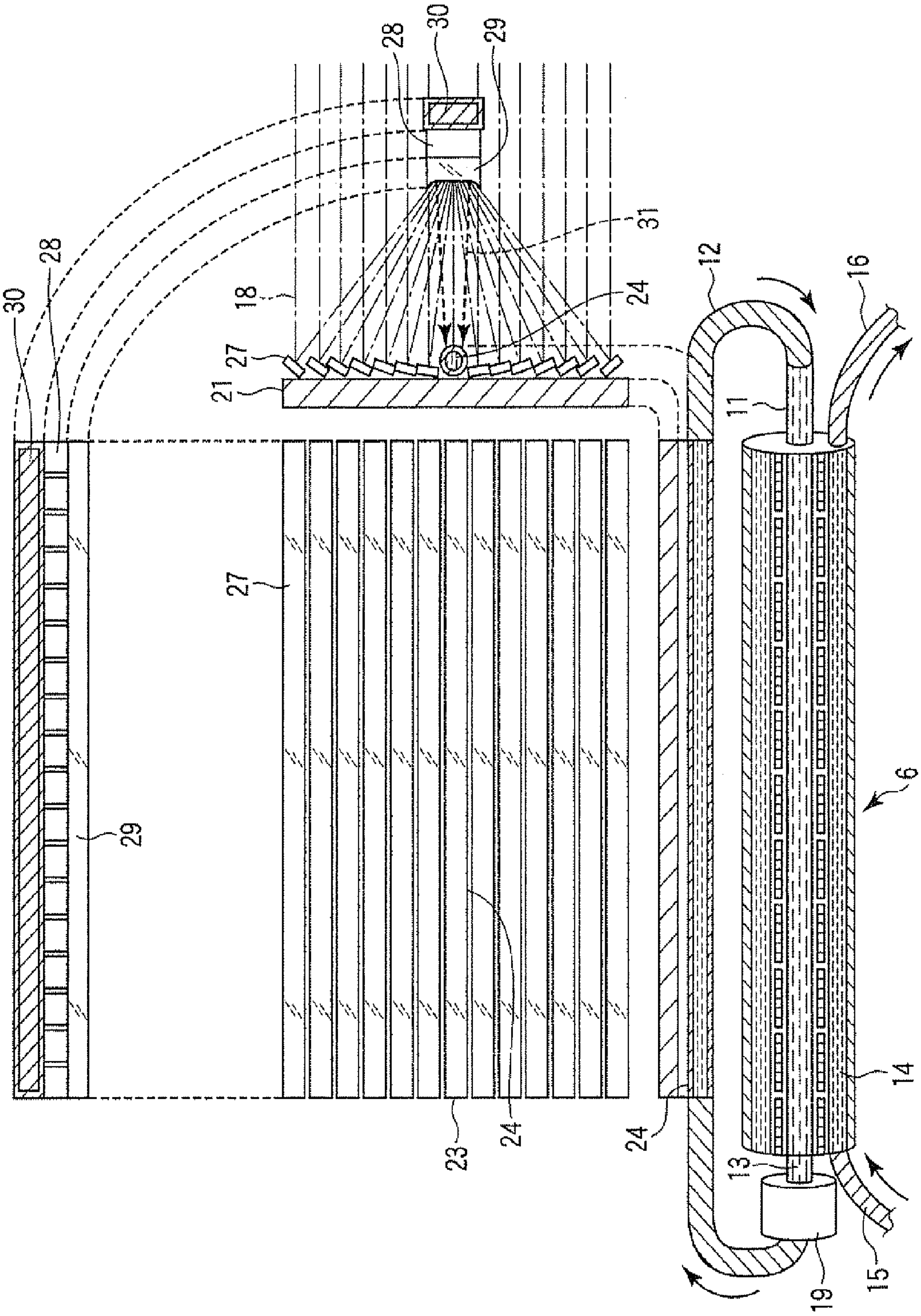


FIG. 5

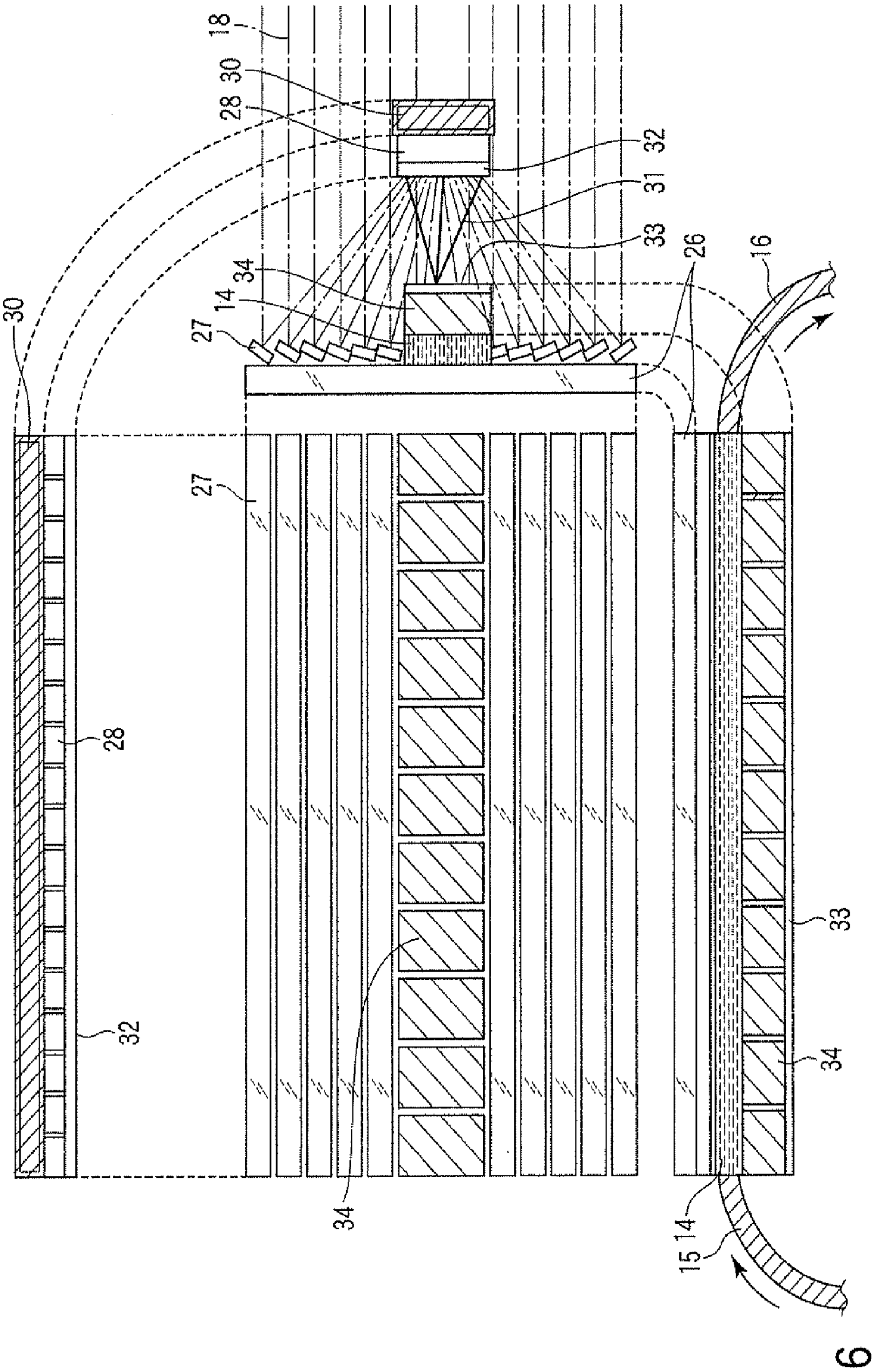


FIG. 6

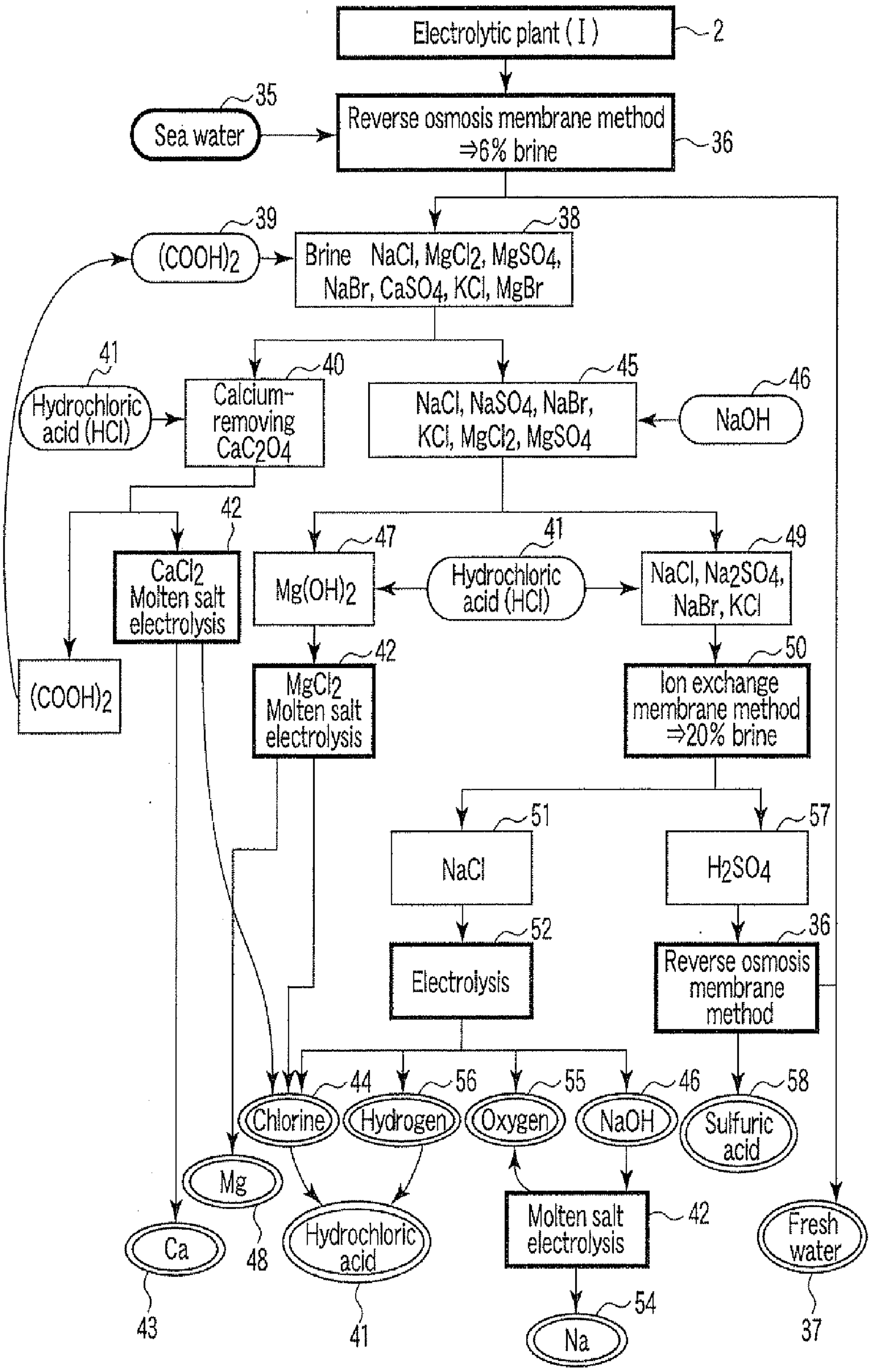

Electrolytic plant (I)
2
Sea water
35
Reverse osmosis membrane method ⇒6% brine
36
(COOH)2
39
Brine NaCl, MgCl2, MgSO4, NaBr, CaSO4, KCl, MgBr
38
41
Hydrochloric acid (HCl)
Calcium-removing CaC2O4
40
NaCl, NaSO4, NaBr, KCl, MgCl2, MgSO4
45
NaOH
46
42
CaCl2 Molten salt electrolysis
Mg(OH)2
47
41
Hydrochloric acid (HCl)
NaCl, Na2SO4, NaBr, KCl
49
(COOH)2
MgCl2 Molten salt electrolysis
42
Ion exchange membrane method ⇒20% brine
50
NaCl
51
H2SO4
57
Electrolysis
52
Reverse osmosis membrane method
36
Chlorine
44
Hydrogen
56
Oxygen
55
NaOH
46
Sulfuric acid
58
Mg
48
Ca
43
Hydrochloric acid
41
Molten salt electrolysis
42
Fresh water
37
Na
54

FIG. 7

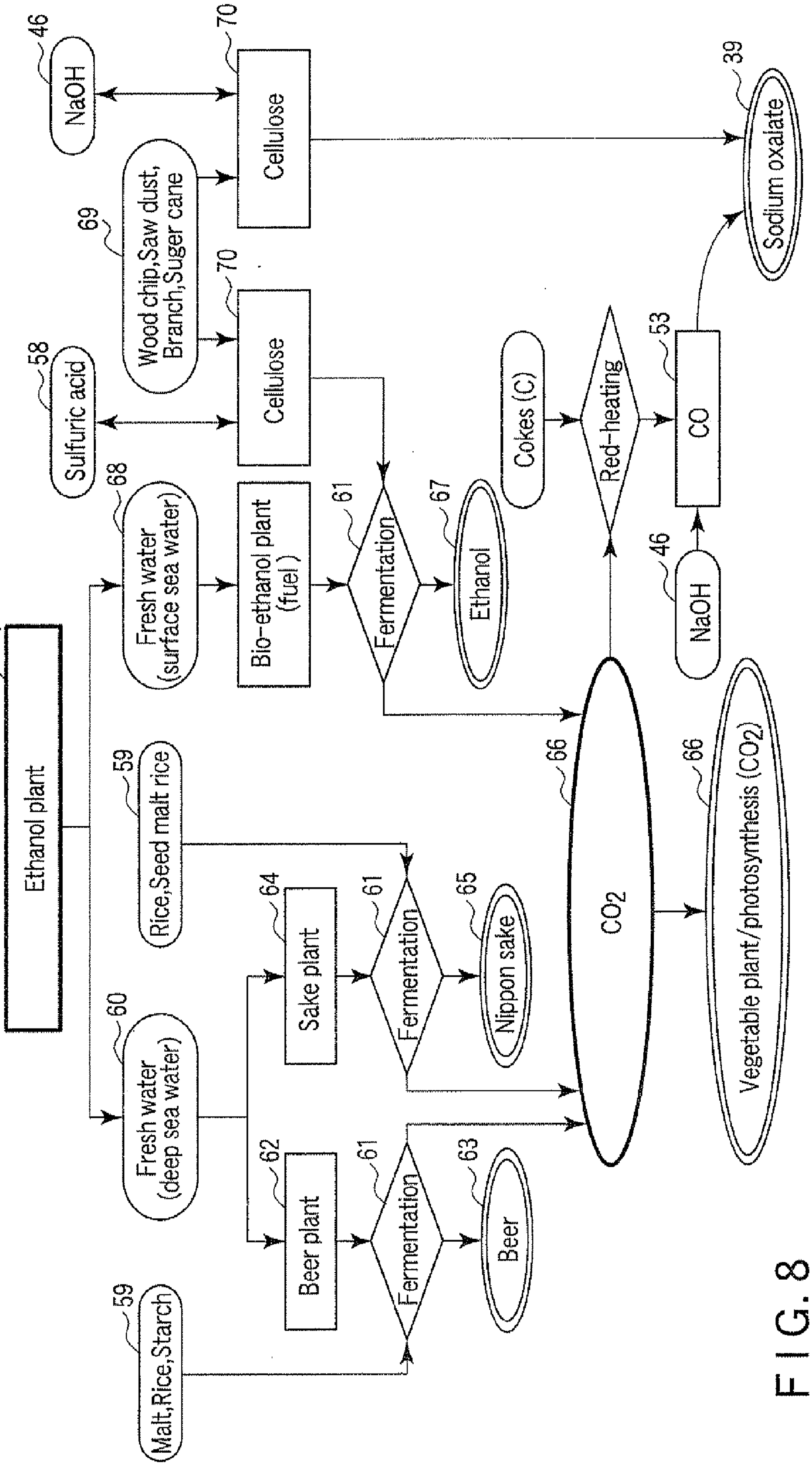
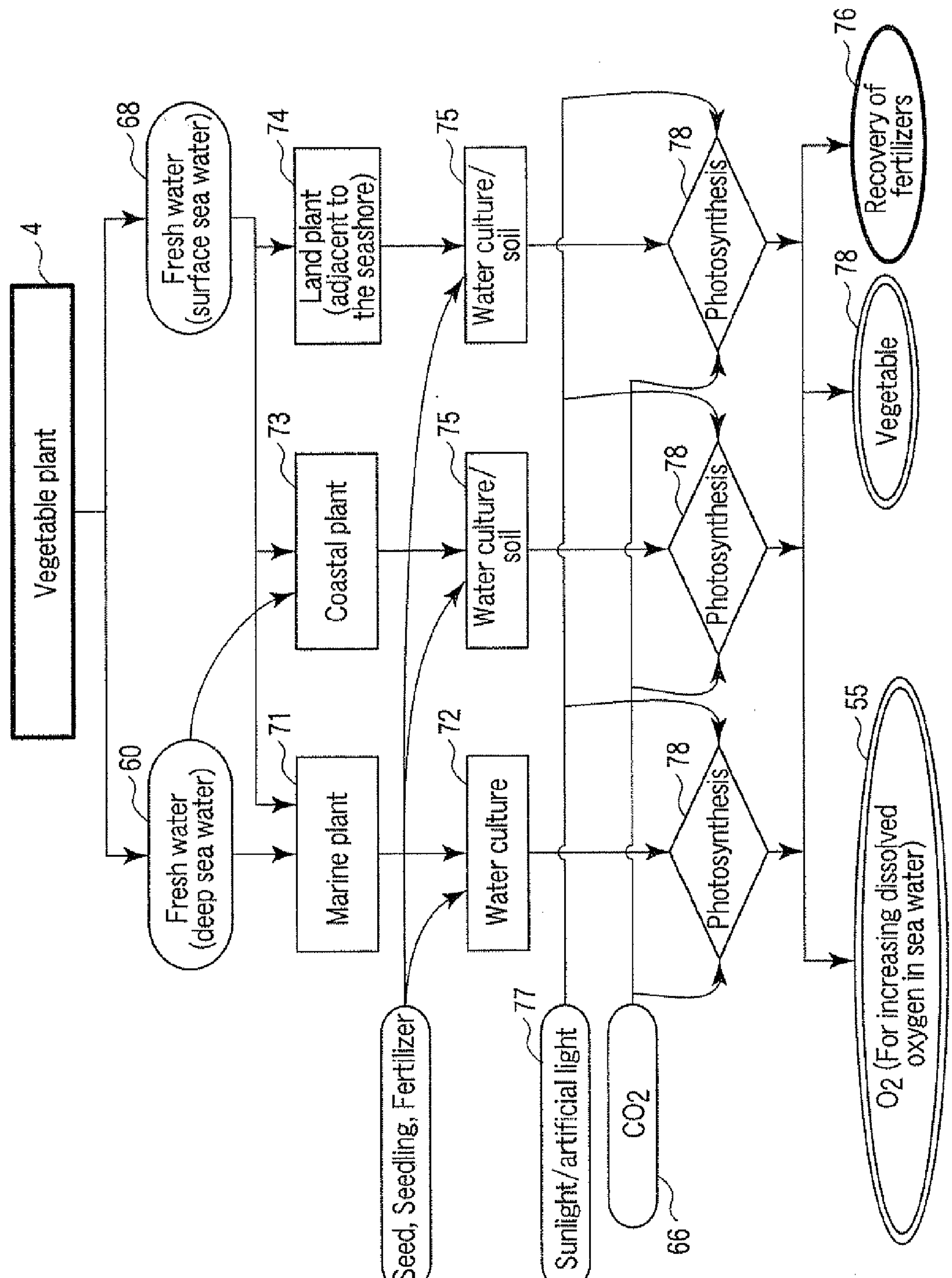

3
Ethanol plant
60
Fresh water
(deep sea water)
59
Rice,Seed malt rice
68
Fresh water
(surface sea water)
58
Sulfuric acid
69
Wood chip,Saw dust,
Branch,Suger cane
46
NaOH
70
Cellulose
70
Cellulose
59
Malt,Rice,Starch
62
Beer plant
64
Sake plant
Bio-ethanol plant
(fuel)
61
Fermentation
61
Fermentation
61
Fermentation
63
Beer
65
Nippon sake
67
Ethanol
Cokes (C)
Red-heating
66
CO$_2$
46
NaOH
53
CO
66
Vegetable plant/photosynthesis (CO$_2$)
39
Sodium oxalate

FIG. 8


Vegetable plant
4
Fresh water (deep sea water)
60
Fresh water (surface sea water)
68
Marine plant
71
Coastal plant
73
Land plant (adjacent to the seashore)
74
Water culture
72
Water culture/soil
75
Water culture/soil
75
Seed, Seedling, Fertilizer
Sunlight/artificial light
77
CO2
66
Photosynthesis
78
Photosynthesis
78
Photosynthesis
78
O2 (For increasing dissolved oxygen in sea water)
55
Vegetable
78
Recovery of fertilizers
76

F I G. 9

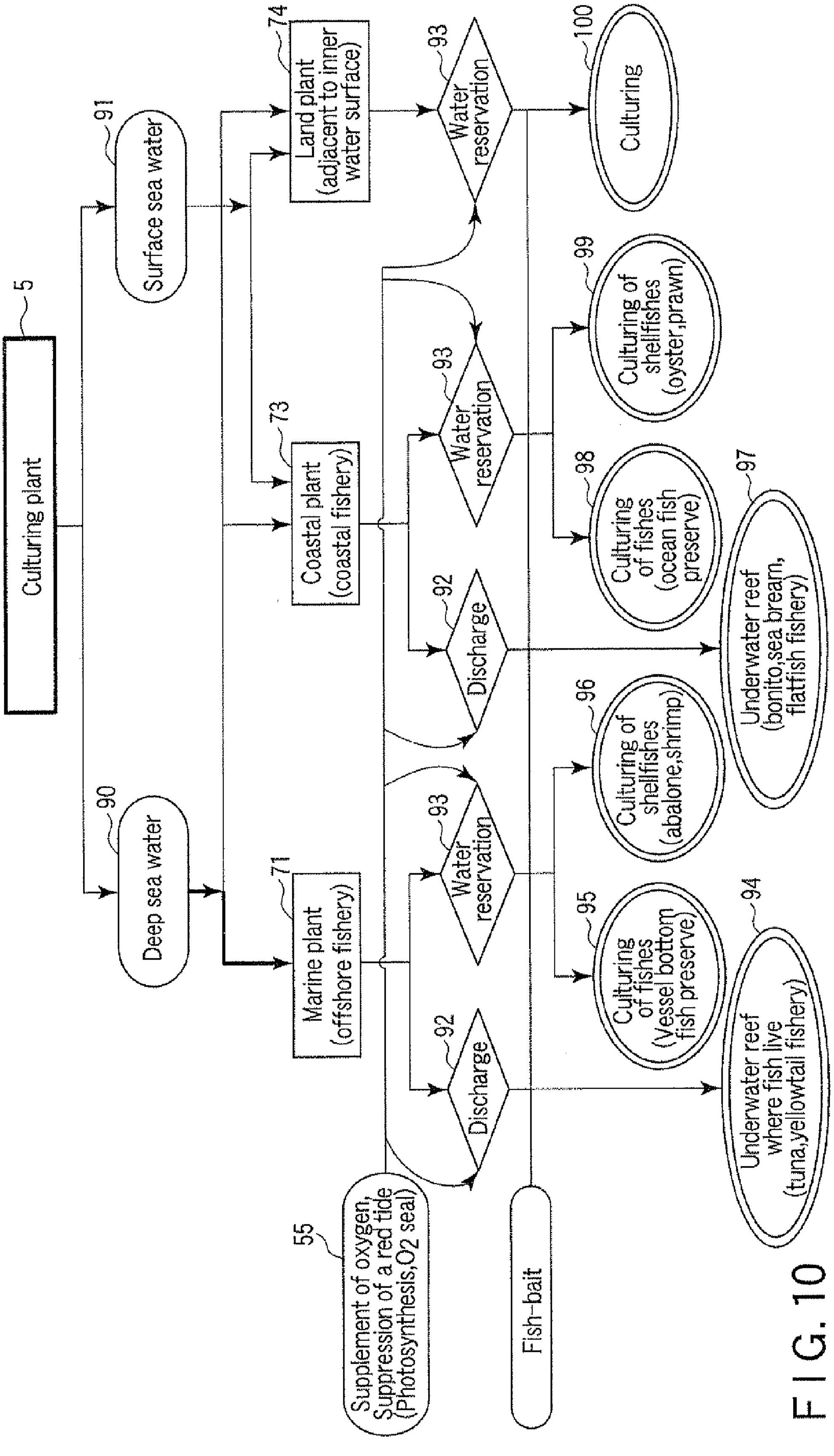

5
Culturing plant
90
Deep sea water
91
Surface sea water
71
Marine plant (offshore fishery)
73
Coastal plant (coastal fishery)
74
Land plant (adjacent to inner water surface)
92
Discharge
93
Water reservation
92
Discharge
93
Water reservation
93
Water reservation
94
Underwater reef where fish live (tuna,yellowtail fishery)
95
Culturing of fishes (Vessel bottom fish preserve)
96
Culturing of shellfishes (abalone,shrimp)
97
Underwater reef (bonito,sea bream, flatfish fishery)
98
Culturing of fishes (ocean fish preserve)
99
Culturing of shellfishes (oyster,prawn)
100
Culturing
55
Supplement of oxygen, Suppression of a red tide (Photosynthesis,O2 seal)
Fish-bait

FIG. 10

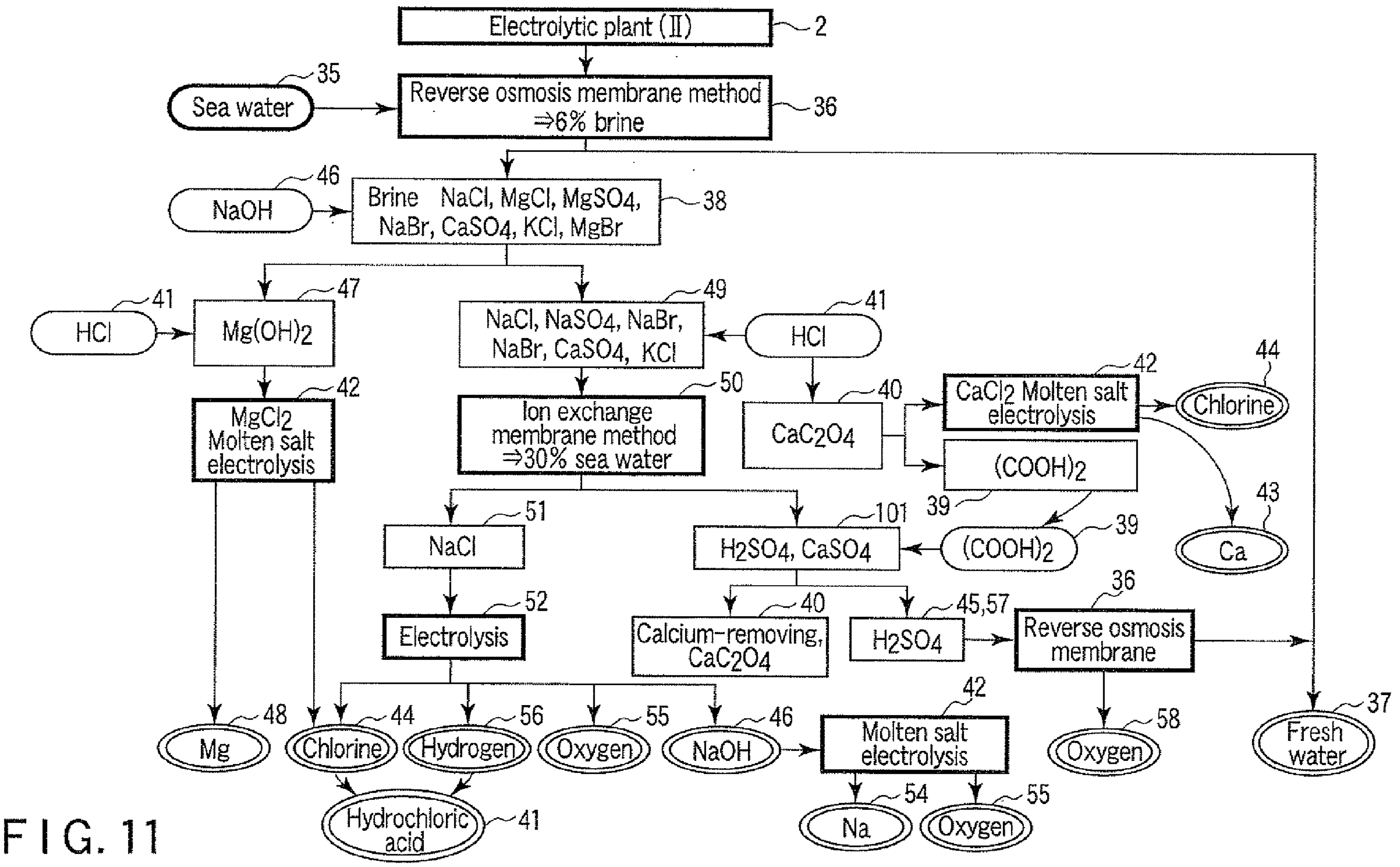
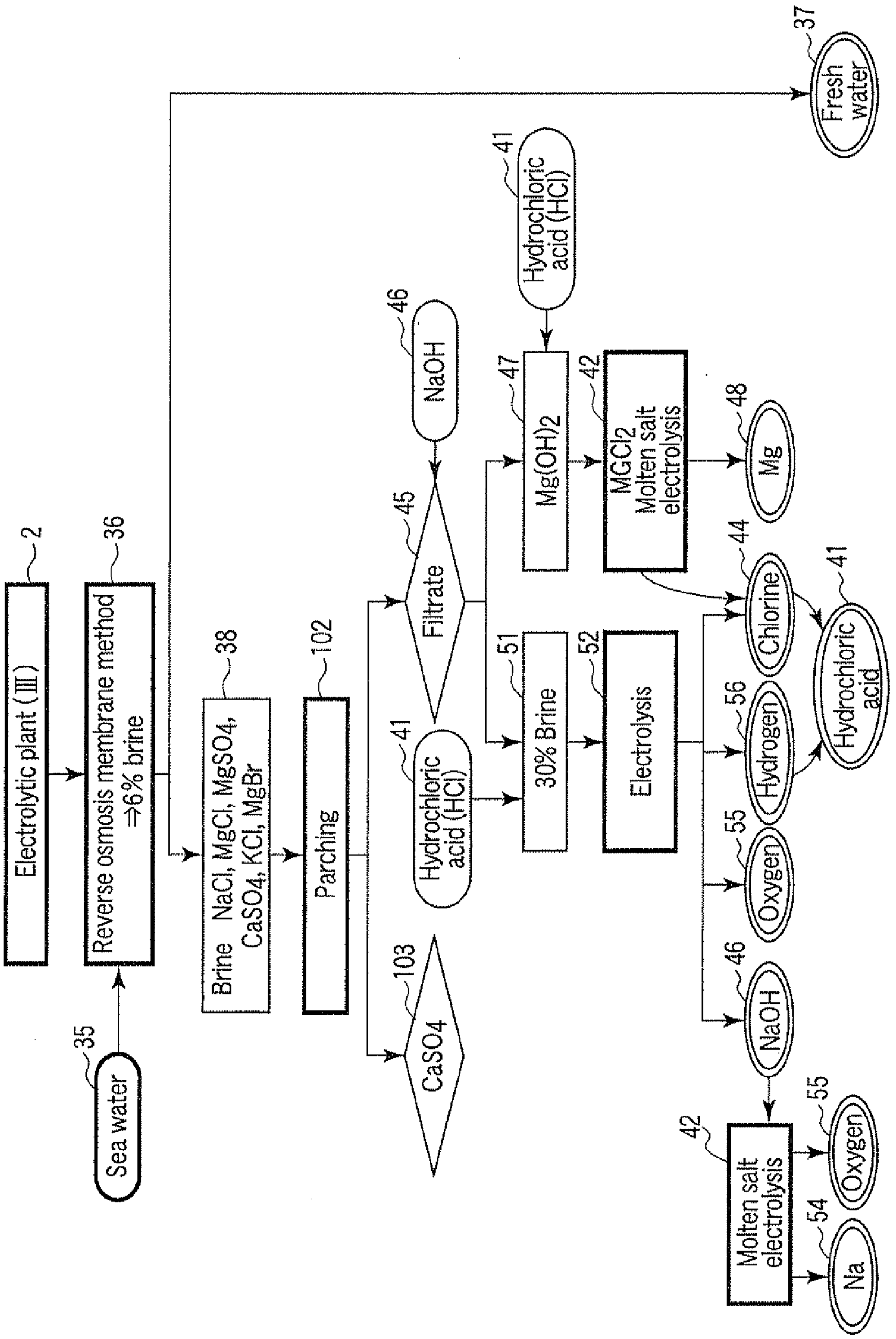

Electrolytic plant (II)
2
Sea water
35
Reverse osmosis membrane method ⇒6% brine
36
NaOH
46
Brine NaCl, MgCl, MgSO4, NaBr, CaSO4, KCl, MgBr
38
HCl
41
Mg(OH)2
47
NaCl, NaSO4, NaBr, NaBr, CaSO4, KCl
49
HCl
41
CaC2O4
40
CaCl2 Molten salt electrolysis
42
Chlorine
44
MgCl2 Molten salt electrolysis
42
Ion exchange membrane method ⇒30% sea water
50
(COOH)2
39
Ca
43
NaCl
51
H2SO4, CaSO4
101
(COOH)2
39
Electrolysis
52
Calcium-removing, CaC2O4
40
H2SO4
45,57
Reverse osmosis membrane
36
Mg
48
Chlorine
44
Hydrogen
56
Oxygen
55
NaOH
46
Molten salt electrolysis
42
Oxygen
58
Fresh water
37
Hydrochloric acid
41
Na
54
Oxygen
55

FIG. 11


Electrolytic plant (Ⅲ)
2
Sea water
35
Reverse osmosis membrane method ⇒6% brine
36
Fresh water
37
Brine NaCl, MgCl, MgSO4, CaSO4, KCl, MgBr
38
Parching
102
CaSO4
103
Filtrate
45
NaOH
46
Hydrochloric acid (HCl)
41
Mg(OH)2
47
Hydrochloric acid (HCl)
41
MGCl2 Molten salt electrolysis
42
Mg
48
30% Brine
51
Electrolysis
52
Chlorine
44
Hydrogen
56
Oxygen
55
NaOH
46
Hydrochloric acid
41
Molten salt electrolysis
42
Na
54
Oxygen
55

F I G. 12

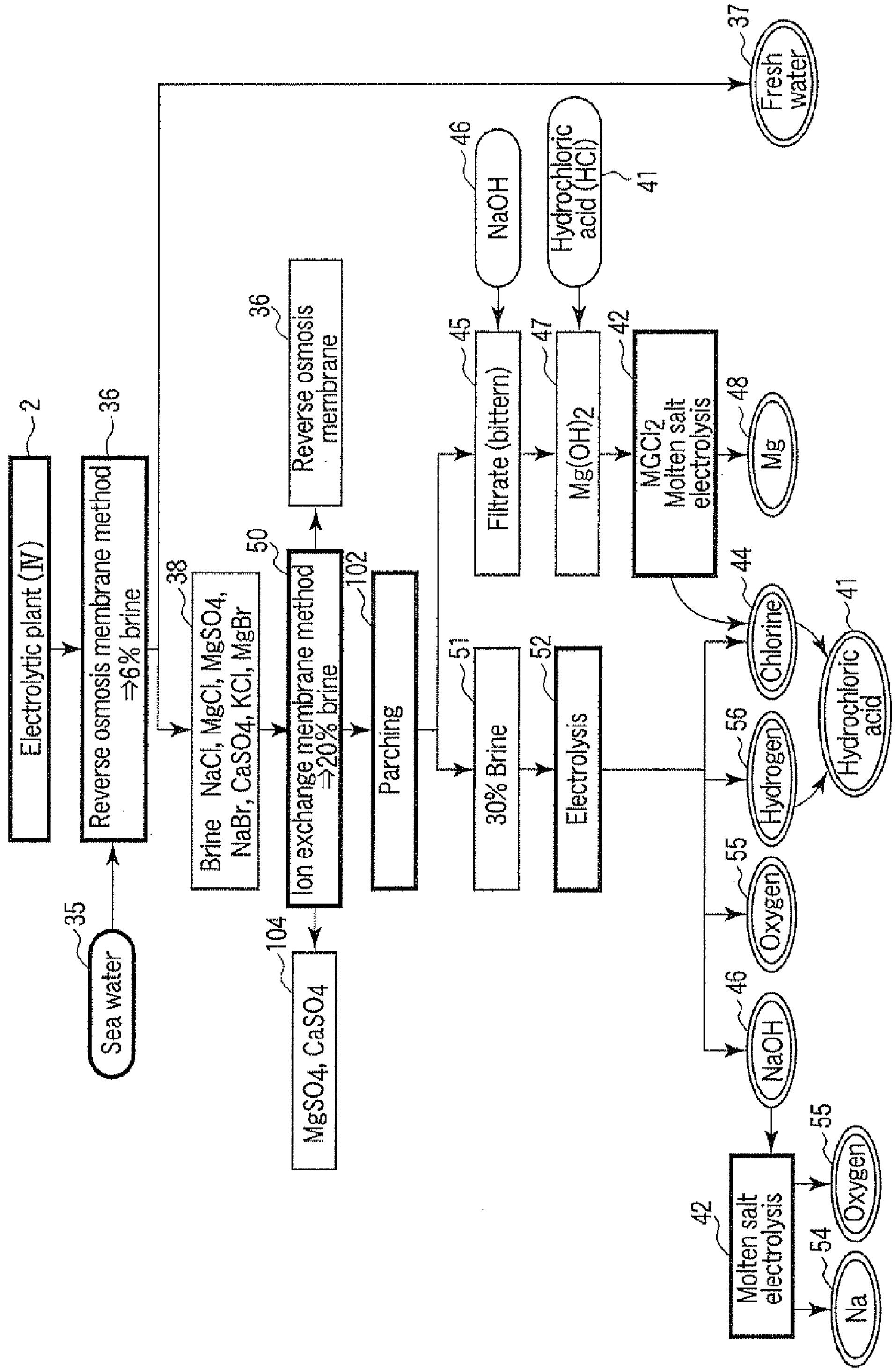

Electrolytic plant (Ⅳ)
2
Sea water
35
Reverse osmosis membrane method ⇒6% brine
36
Fresh water
37
Brine NaCl, MgCl, MgSO4, NaBr, CaSO4, KCl, MgBr
38
Ion exchange membrane method ⇒20% brine
50
Reverse osmosis membrane
36
MgSO4, CaSO4
104
Parching
102
30% Brine
51
Electrolysis
52
Filtrate (bittern)
45
NaOH
46
Mg(OH)2
47
Hydrochloric acid (HCl)
41
MGCl2 Molten salt electrolysis
42
Mg
48
Chlorine
44
Hydrogen
56
Hydrochloric acid
41
Oxygen
55
NaOH
46
Molten salt electrolysis
42
Na
54
Oxygen
55

FIG. 13

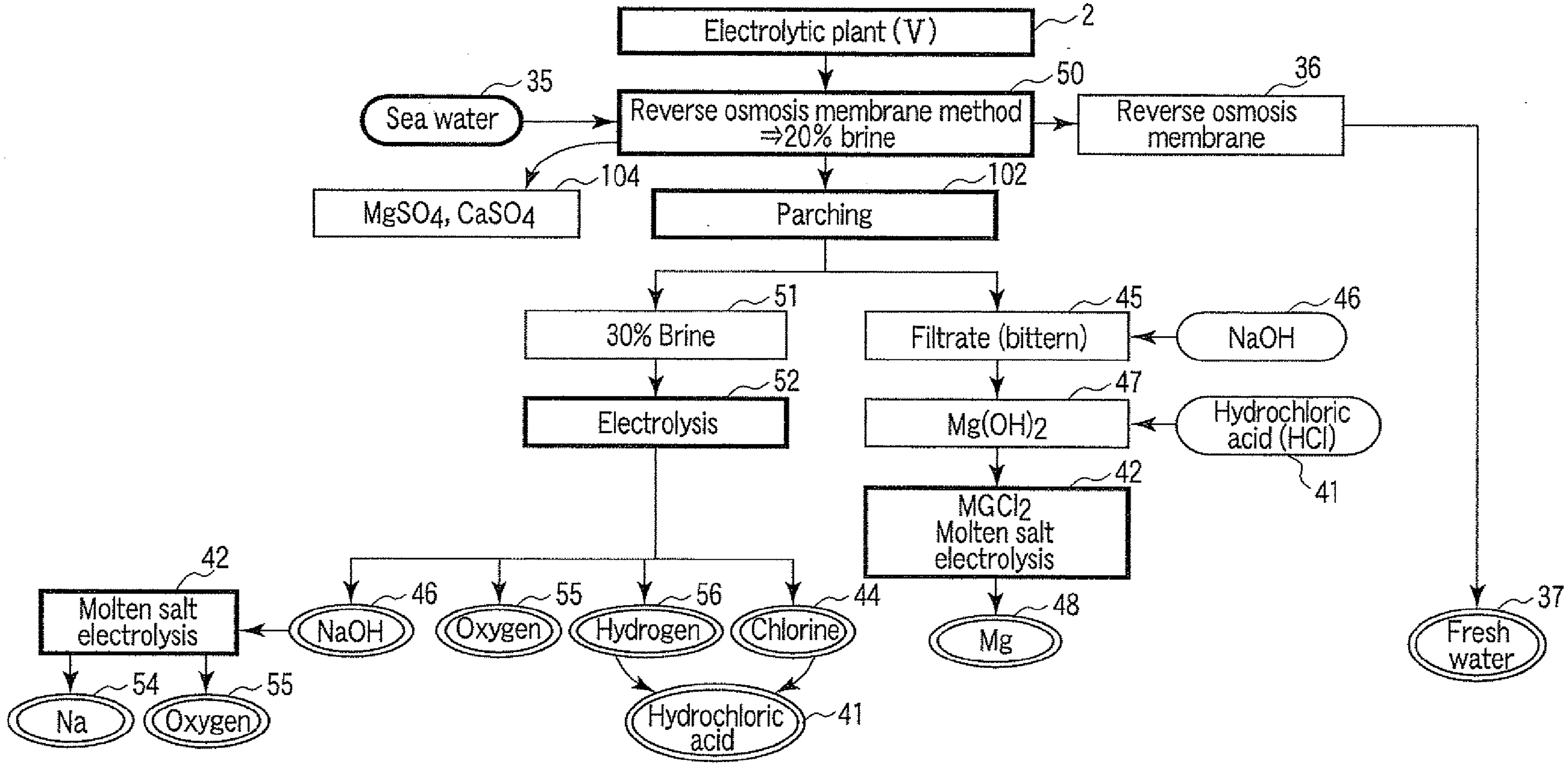

Electrolytic plant (V)
2
35
Sea water
Reverse osmosis membrane method ⇒20% brine
50
36
Reverse osmosis membrane
104
MgSO4, CaSO4
102
Parching
51
30% Brine
45
Filtrate (bittern)
46
NaOH
52
Electrolysis
47
Mg(OH)2
Hydrochloric acid (HCl)
41
42
MGCl2 Molten salt electrolysis
42
Molten salt electrolysis
46
NaOH
55
Oxygen
56
Hydrogen
44
Chlorine
48
Mg
37
Fresh water
54
Na
55
Oxygen
Hydrochloric acid
41

FIG. 14

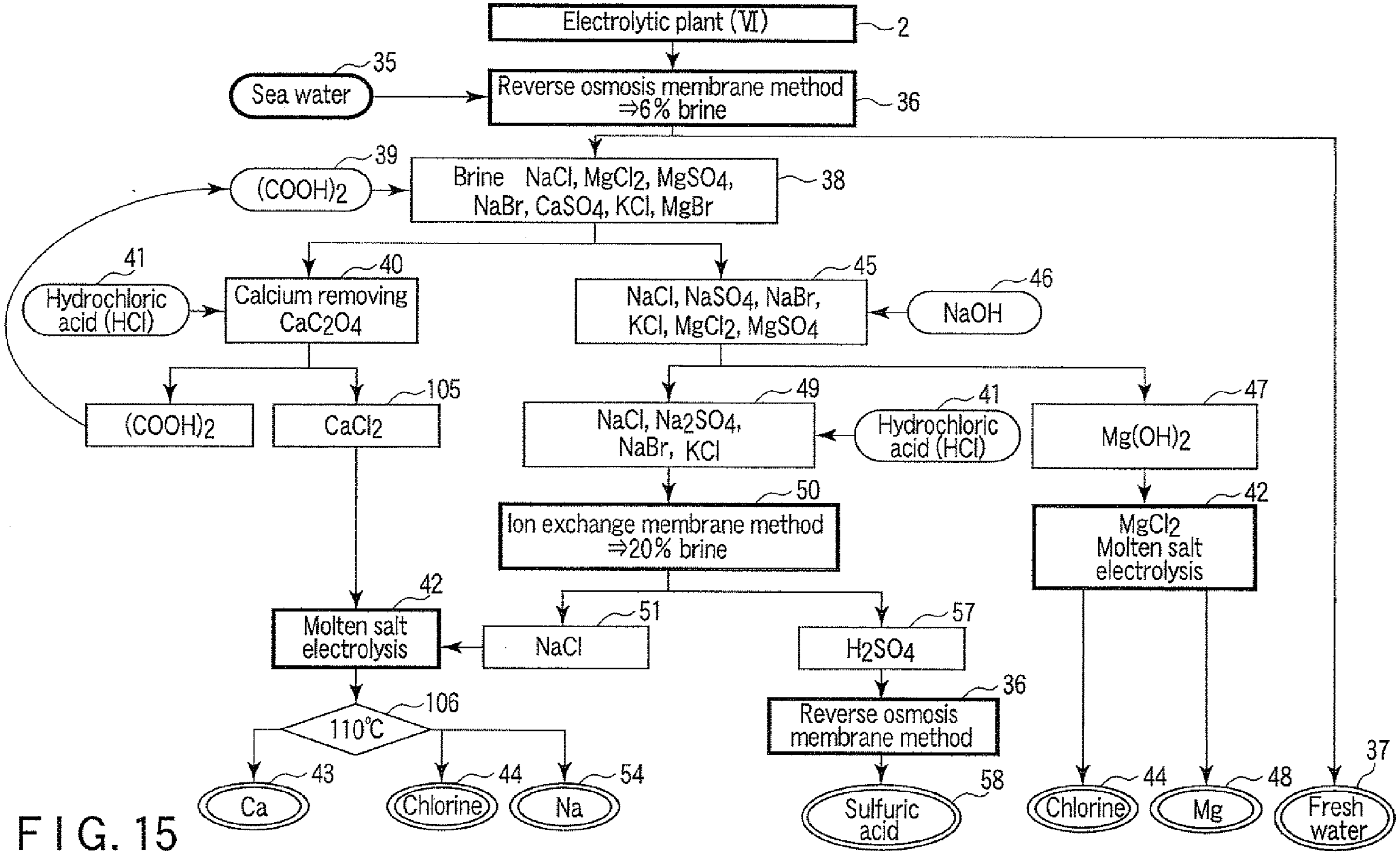

Electrolytic plant (Ⅵ)
2
35
Sea water
Reverse osmosis membrane method
⇒6% brine
36
39
(COOH)2
Brine NaCl, MgCl2, MgSO4,
NaBr, CaSO4, KCl, MgBr
38
41
Hydrochloric acid (HCl)
Calcium removing
CaC2O4
40
NaCl, NaSO4, NaBr,
KCl, MgCl2, MgSO4
45
NaOH
46
(COOH)2
CaCl2
105
NaCl, Na2SO4,
NaBr, KCl
49
41
Hydrochloric acid (HCl)
Mg(OH)2
47
Ion exchange membrane method
⇒20% brine
50
MgCl2
Molten salt
electrolysis
42
Molten salt
electrolysis
42
NaCl
51
H2SO4
57
110℃
106
Reverse osmosis
membrane method
36
37
43
Ca
44
Chlorine
54
Na
58
Sulfuric acid
44
Chlorine
48
Mg
Fresh water

FIG. 15

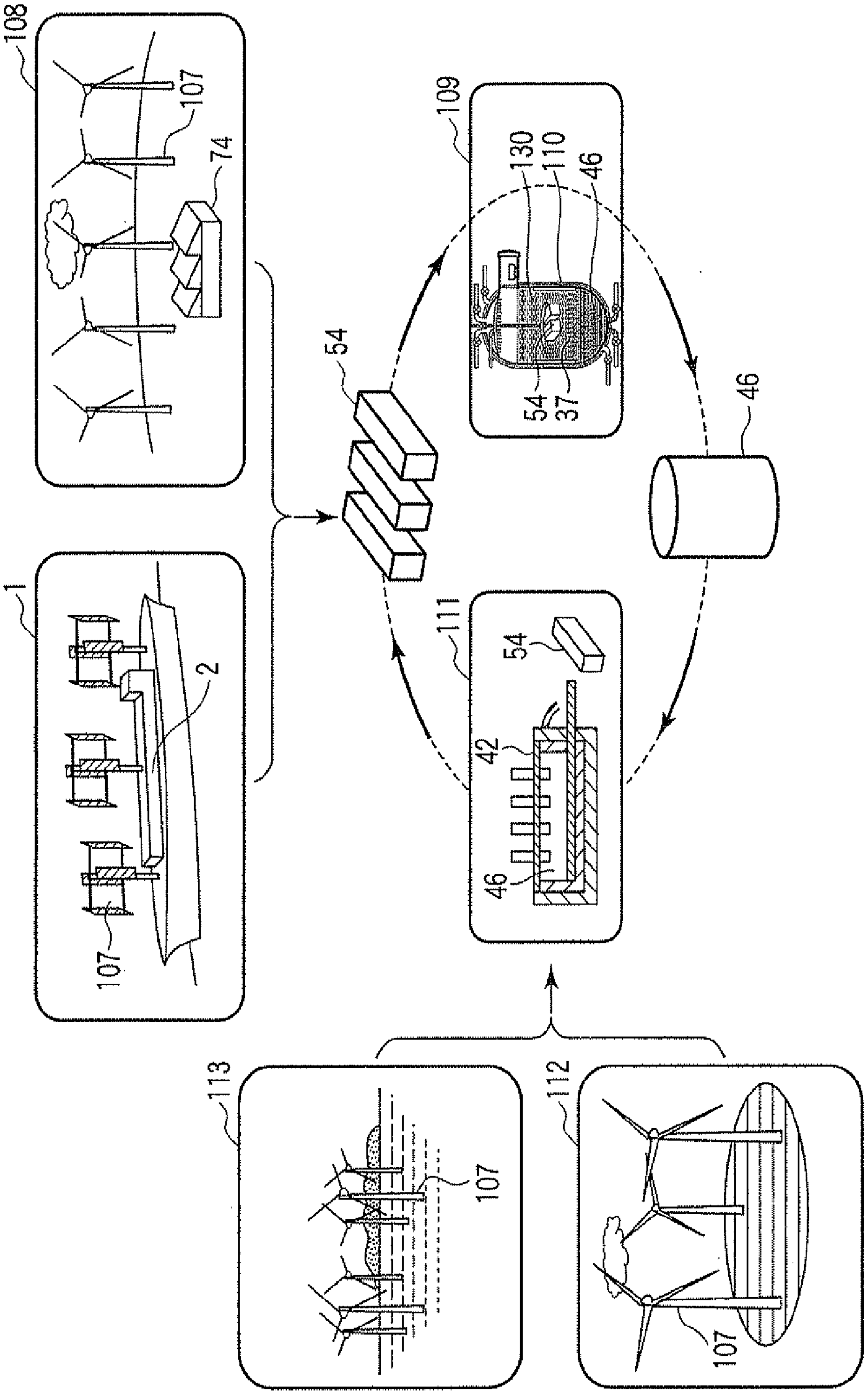

108
107
107
74
1
2
107
54
109
130
110
46
54
37
46
111
54
42
46
113
107
112
107

FIG. 16

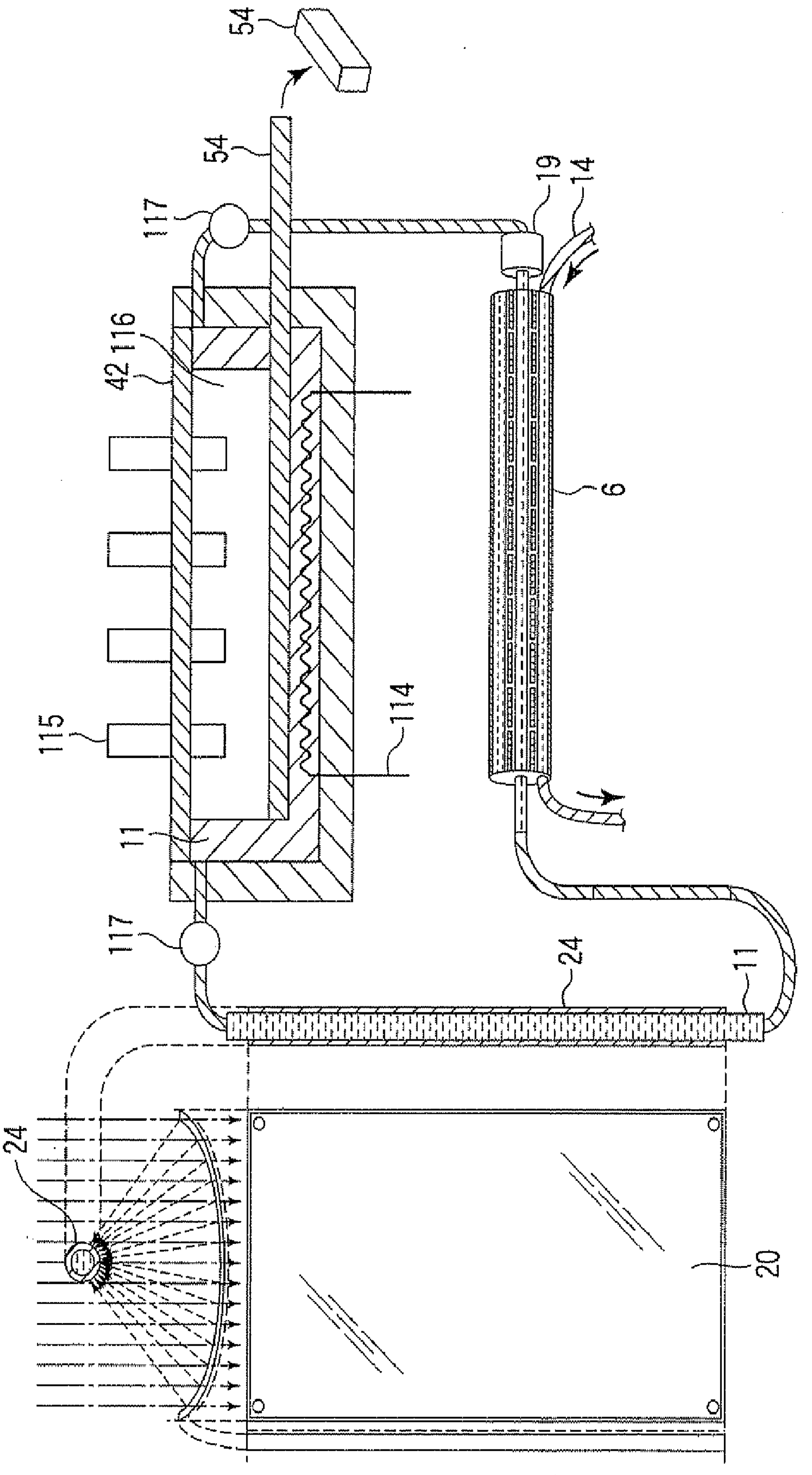
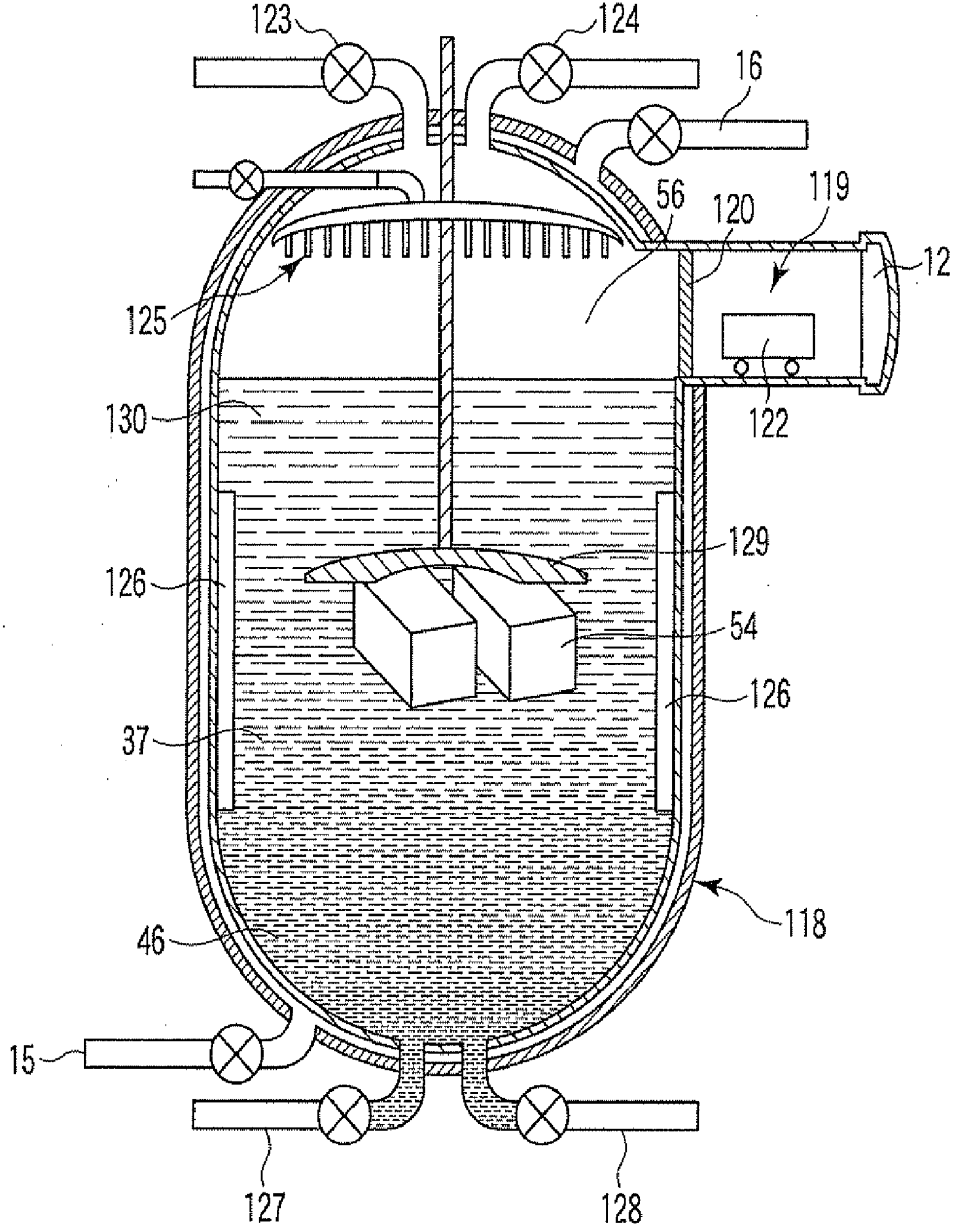


FIG. 17


123
124
16
56
120
119
121
125
122
130
129
126
54
126
37
118
46
15
127
128

F I G. 18

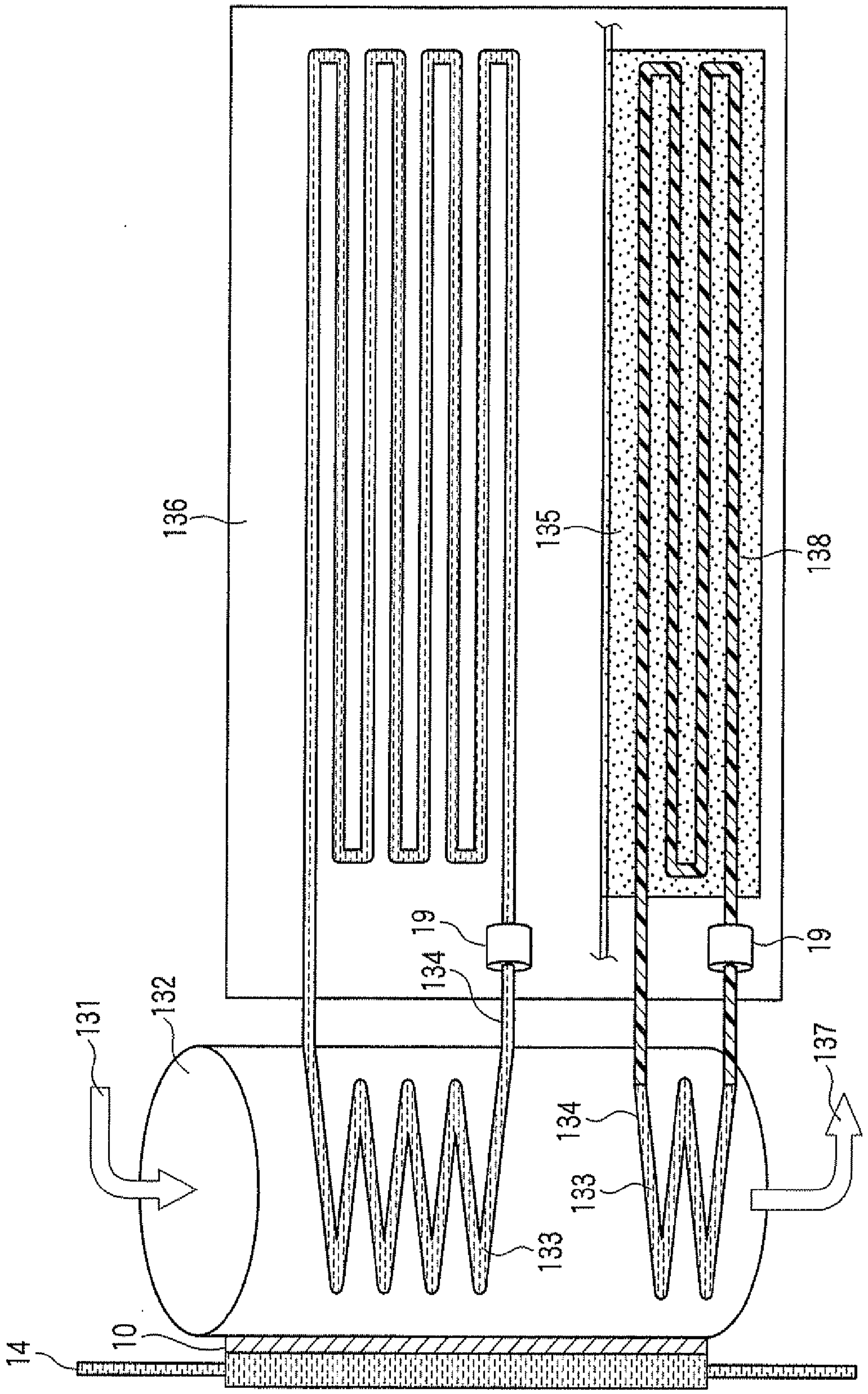
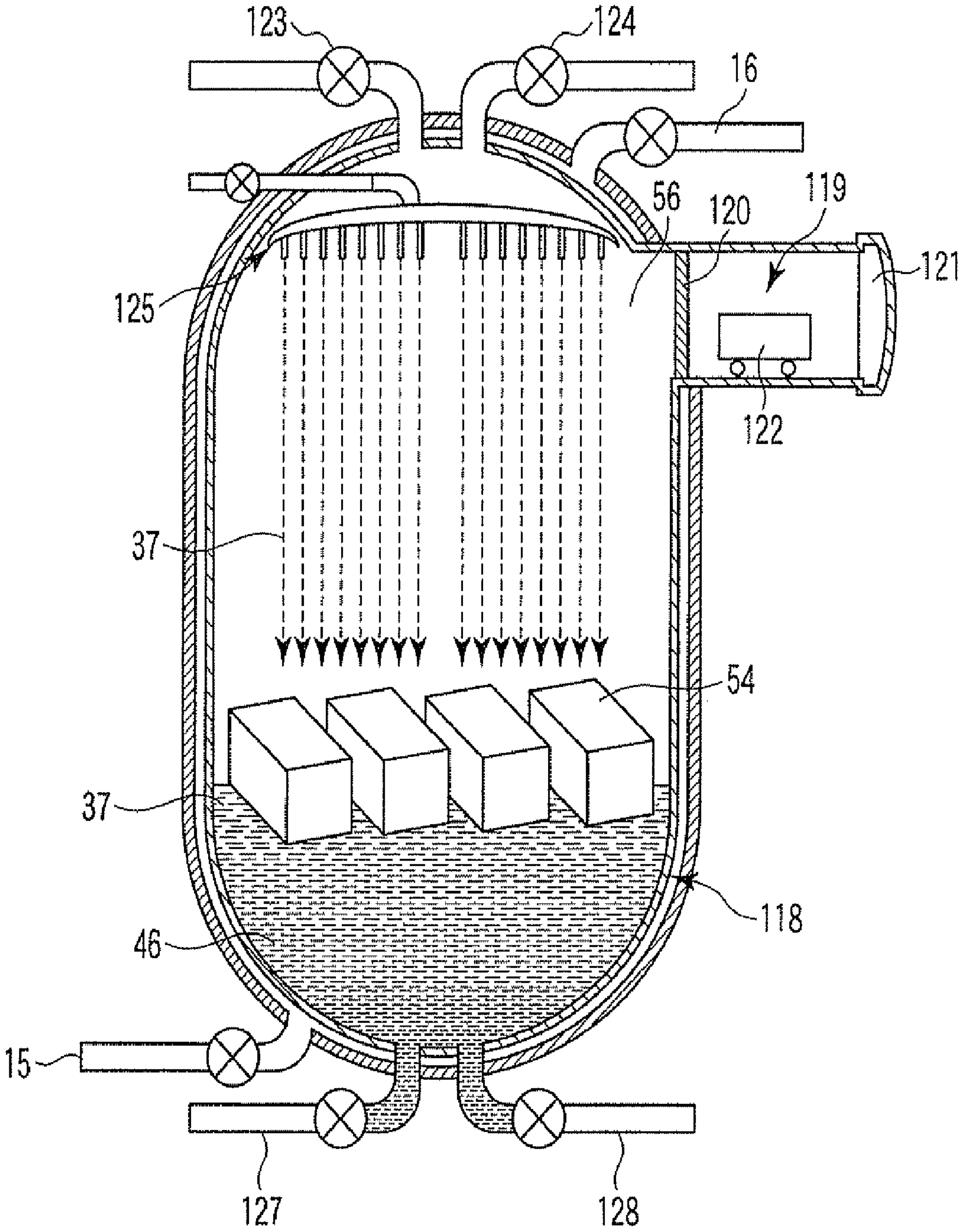


FIG. 19



F I G. 20

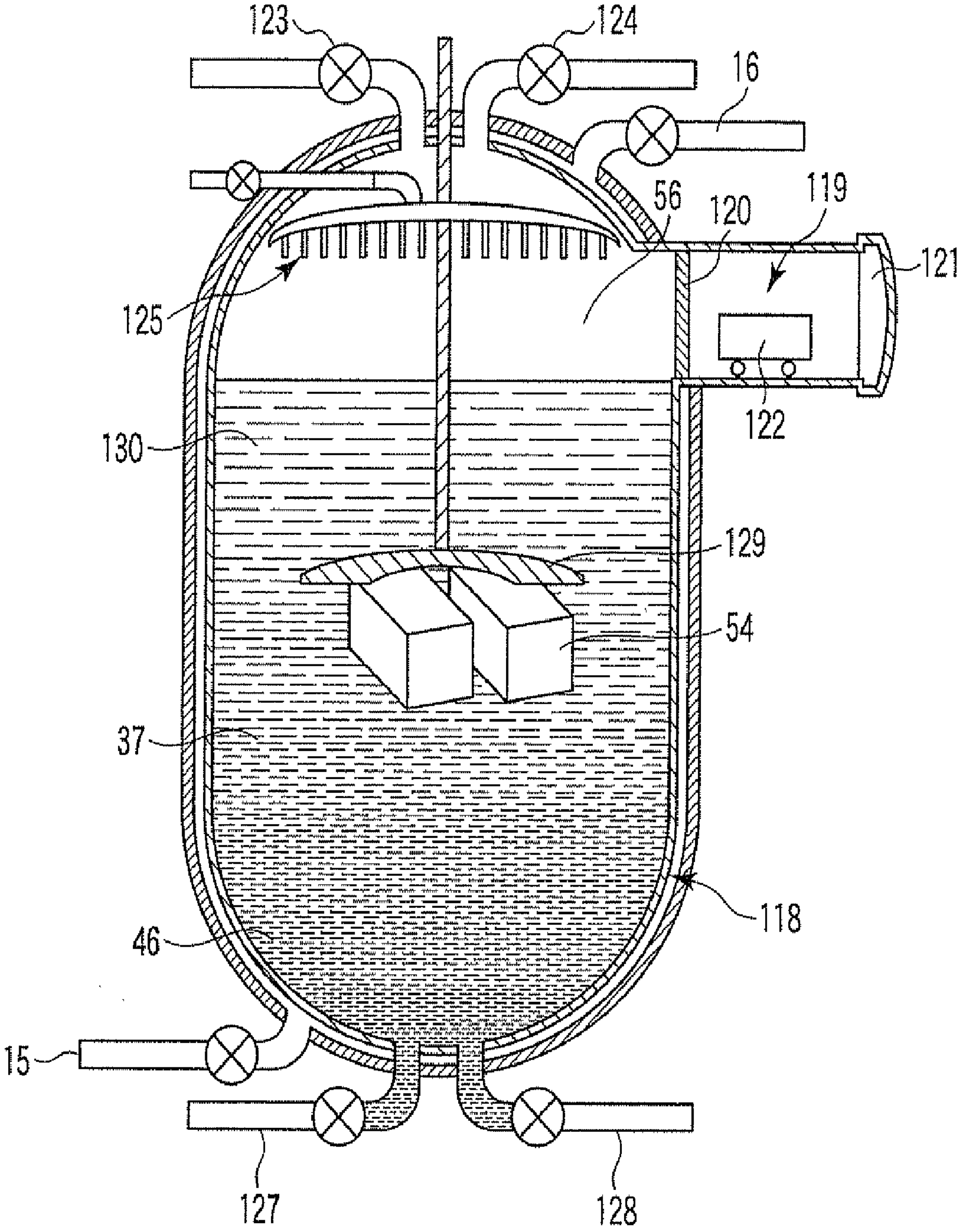


FIG. 21

ONSITE INTEGRATED PRODUCTION FACTORY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. patent application Ser. No. 12/615,437, filed Nov. 10, 2009, which is a Continuation Application of POT Application No. PCT/JP2008/058500, filed May 7, 2008, the entirety of both of which are incorporated herein by reference.

[0002] This application is also based upon and claims the benefit of priority from prior Japanese Patent Applications No. 2007-126324, filed May 11, 2007, and No. 2008-082335, filed Mar. 27, 2008, the entire contents of both of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates to an onsite integrated production factory and particularly to an onsite integrated factory provided with an electric power generating means utilizing natural energy and comprising an electrolysation plant, an ethanol plant, a vegetable plant and a fish/shellfish-culturing plant, which are integrated on a site.

[0005] 2. Description of the Related Art

[0006] In every nation of the world, the reconstruction of industries such as energies, caustic soda and light metals which determine the national power is a matter of urgency. In the Russian Summit held at Sanktopeterburg in 2006, the speech of the leader of each nation emphasizes a plan for controlling the consumption of crude petroleum and refers to atomic energy, natural gas and sun energy and the like as the urgent measures taken for the post-petroleum energy. A desire to rely on natural energy without using fossil fuels is growing greatly. The power generation of natural energy includes those derived from, for example, wind power, water power (tidal power), wave power, sun light, sun heat and geothermal energy. Among these power generations, the wind power generation has a smaller installation area than other natural energy power generations since the windmill can be installed vertically and also can be utilized day and night.

[0007] Patent References 1 and 2 shown below disclose that wind power generation is utilized for the power of a pressure pump used to treat untreated water and sea water in reverse osmosis plants. Also, it is disclosed in the following Patent Reference 3 that wind power generation is used for the power of the pump used to draw sea water with the intention of desalination of sea water. It is also disclosed in the following Patent Reference 4 to make use of wind power generation as the power for producing hydrogen by the electrodialysis of fresh water obtained from equipment for desalination of sea water.

[0008] Tidal electric power generation has higher energy efficiency. The energy (W) obtained from wind power, tidal power and the like is given by the equation: $W=A\rho V^3/2$ (where, A is a flow-receiver area, ρ is the density of the fluid and V is a flow rate). The density of air is 1.2 kg/m^3 whereas the density of water is 1025 kg/m^3. Therefore, if the flow of wind is changed to the flow of water, an energy which is 854 times that obtained in the case of the flow of wind can be obtained. There are, for example, the Kuroshio current (the Japan Current) and Tsushima Current around Japan. The Kuroshio current flowing through the Tokara straight, the Ashizuri Promontory, Muroto Promontory, Shiono Promontory, the Island of Miyake and the Island of Mikura is 250 km in width and 1000 m in depth and has a flow speed of 0.3 to 2 m/sec and is therefore suitable for a tidal power generation source. Because the output of a waterwheel is proportional to the 3rd power of the current, the tidal current power generation is attractive.

[0009] There is a tendency to think the foregoing fluid energies such as wind power and water flow power to be the kinds of energy sources which are mild to the global environment and are free from the exhaustion of resources. However, these energies are all limited by natural and geographical conditions and it is difficult to obtain desirable generated output depending on the meteorological conditions and places. In light of this, many methods are proposed in which these energies are utilized on the ocean where plenty of wind power energy or fluid energy such as a tidal current and ocean current is present. Patent Reference 5 shown below discloses that the generated power obtained by wind power generation to draw deep ocean water up to a pool floated and installed on the ocean. Patent Reference 6 shown below discloses that wind power generation is used for electrolytic desalination of sea water. Patent Reference 7 shown below discloses that power generation facilities utilizing natural energies such as wind power generation, wave power generation and ocean temperature difference power generation are installed on a large floating structure installed on the ocean. The following Patent References 8 and 9 disclose that the water desalinated by the power obtained by steam turbine power generation attained by sun energy, wave power generation and wind power generation is electrolyzed to produce hydrogen and oxygen gas, on the movable floating structure on the sea. The windmill installed on the deck of the drifting on the sea or floating vessels is preferably a non-directional type regardless of wind direction. The inventors of the present invention disclose a vertical axis windmill and water wheel that draw power from the both energies of wind power and tidal power in the following Patent References 10 and 11.

[0010] In Sweden, according to Non-patent Reference 1 shown below, there are the following descriptions. Specifically, the post-atomic power generation policy that atomic power generation is abolished step by step is maintained and high targets are stated as to the introduction of wind power generation. In 1970, the percentage of the dependency of energy demand on petroleum reached 70%. After that, a post-petroleum policy is promoted with the oil crisis, with the result that the percentage of the dependency on petroleum is reduced to the order of 30%. There is also the description that particularly, the percentage of the dependency of heating and hot-water supply in the public welfare section on petroleum has been already reduced to 10% with the spread of a regional heat supply system and with the progress in the conversion of fuel into biomass energy. Then, there is also the description that the ratio of bio-ethanol (5%) to be mixed in gasoline will be increased in a few years, with the result that the use of automobiles using, as the fuel, E85 containing 85% of ethanol or bio-gas obtained by the fermentation of biomass are spread. It is fresh in our memories that there was a sudden rise in grain prices as soon as, on January, 2007, Bush, President of the United States came out with the policy fixed to produce bioethanol by the fermentation of corns to thereby replace 20% of gasoline with the bioethanol by 2017. Japanese government also came out with the plan fixed to increase the production of bio-ethanol up to 6000000 kl by 2030. In Non-patent Reference 2 shown below, it is disclosed from RITE and Honda Motor Co., Ltd. that the gene of Corynebacterium is recombined to convert vegetable fibers such as celluloses into sugars, thereby producing bio-ethanol from wood chips, weeds, rice straws and wheat straws which are not used as foods. In Non-patent Reference 3 shown below, there are descriptions that bacteria which ferments sugars and starches extracted from squeezed residues of sugar canes and wood chips to produce ethanol is increased to 100 times that of usual cases. Patent Reference 12 shown below discloses a method of producing ethanol in which NADH (nicotine amide/adenine/dinucleotide reduction type) is added in a reaction medium from the outside under the ethanol production bacterial enzyme reaction condition to react the ethanol production bacteria under the presence of the compound, thereby producing ethanol production bacteria in the reaction medium, followed by collecting the produced ethanol.

[0011] Non-patent Reference 4 shown below reveals that the Japanese technologies used desalinate sea water by using a reverse osmosis membrane are advanced into all parts of the world. It is, at present, estimated that about 1.1 billion people can utilize water insufficiently in the world and that a shortage of industrial water is a cause of a hindrance to economic growth in China and the Middle East. For this, in these regions, there is a rush to construct a sea water desalinating plant. However, the construction of sea water desalination plant has the purpose of extracting fresh water, so that the brine of sea water having a salt content of about 3% is thrown into the sea as waste fluid at present.

[0012] The production facilities for desalinating sea water and for extracting metals, such as magnesium, dissolved in sea water are placed in limited areas such as the vicinity of thermal power stations in coastal areas and these metals dissolved in sea water have been called fossils of power generation like aluminum so far. As to, particularly, the production of aluminum, as shown in Non-patent Reference 5 shown below, 99% of new ores is dependent on the import in Japan and only Kamahara factory (Shizuoka prefecture) of Nippon Light Metal Co., Ltd. having a private power generation plant carries out the refining of new ores. Metal sodium is the same to the above and there is only Nihongi factory (Niigata prefecture) of NIPPON SODA Co., Ltd. as a manufacturing factory in Japan. About 1700 ton of metal sodium was used in the fast breeder reactor "Monju" in Japan and was all imported. On the other hand, caustic soda industries using salts as starting material are fundamental industries as well as sulfuric acid industries and the chemical industry in Japan and the chemical industry is started from both industries. According to the statistics for fiscal 2005, the throughput of caustic soda in Japan is 4550000 ton showing a satisfactory progress. However, because 100% of the raw salts is dependent on imported salts, a half or more of the imported price is occupied by the cost of transportation. Moreover, because large electric power is required for electrolysis to produce caustic soda from this salt, the profit of fiscal 1999 in caustic soda business department is a deficit of five hundred million, showing that caustic soda/chlorine industries in Japan will lose their international competitive power if they are not improved. This is found from the fact that the working power per ton of a product is as large as about 2500 kW as shown by Non-patent Reference 6. As measures taken for this, there are problems of urgency concerning the promotions of the shift of electric power to midnight power, new construction or extension of a private power plant and development of a large-scale troopships. In Japan, the mercury method is the mainstream of the salt electrodialysis method until the 1955s. However, an overall conversion to the diaphragm method and ion exchange membrane method was completed by June, 1986. However, as shown in Non-patent Reference 7 shown below, the mercury method which is a simple production method and is capable of producing high-purity caustic soda is scarcely abandoned and as shown in Non-patent Reference 5 shown below, the latest world trend shows that the mercury method still occupies the mainstream of the production method.

[0013] With regard to the deep ocean water, the term "deep ocean water" according to Non-patent Reference 8 is sea water which is distributed in deep sea at a depth of 200 m or more and has physical and chemical characteristics different from those of surface water, and means the deep sea water (sub-deep sea water in the North Atlantic and deep sea water in the South Atlantic Pole) which is distributed in deep ocean water and formed in two places (offshore of Greenland in North Atlantic Ocean and the Antarctic Ocean). These deep sea waters move around the oceans in all over the world over 2000 years by the thermal salt circulation and have important relations with the climate of the earth at intervals of 1000 year unit. The physical nature of each deep sea water is as follows: it has low temperatures, a high salt content and a high density and is not almost affected by the atmosphere, so that it is more reduced in change than surface water. As to the chemical characteristics of the deep sea water, sunlight insufficiently reaches the deep sea water, so that no phytoplankton grows and the deep sea water is scarcely mixed with the surface sea water, so that it is lacking in dissolved oxygen. Also, the deep sea water is rich in minerals and nutrient salts because various materials drop from the surface for a long term. There is the case where this sea water rises to the surface in a specific area of sea. This area becomes a sea area having very high biological productivity and is therefore good fisheries. An attempt is made to make use of the deep sea water for culture industries by utilizing such characteristics that the deep sea water is rich in nutrient salts and is very reduced in germs of various sorts. Also, studies are made as to applications to agriculture, applications to fermentation fields and power generation utilizing a difference in temperature between deep sea water and surface water and the like. It is said that particularly in fermented food fields such as liquor, soy sauce and breads, the use of deep sea water brings about such an effect that it promotes fermentation, improves the taste and increases the yield of alcohols in sake. In the case of, particularly, sake, it is disclosed that it has been found that deep ocean water limits the negative action of the yeast to activate the gene important for fermentation and also disclosed that a mechanism which enables the production of sake having good flavor and good taste is scientifically clarified at the gene level through joint research with an enterprise in Kochi prefecture in Japan. Also, there are the following descriptions in Non-patent Reference 9 shown below. Specifically, ocean bacteria acarioculios living in sea water at a depth of 100 m or deeper in a region extending from the tropical region to the South Atlantic Pole undergoes photosynthesis when irradiated with the near-infrared rays having a wavelength of 700 to 800 nm besides the visual rays having a wavelength of 400 to 700 nm which are adaptable to normal chlorophyll so that the synthetic efficiency is increased by 5% and is therefore promising as an absorber of carbon dioxide. Although about 20 billion ton of carbon dioxide has been absorbed every year by the photosynthesis of algae or the like in the sea so far, the above discovery results in additional absorption of about twenty million ton of carbon dioxide, referring to the possibility of the absorption of a larger amount of carbon dioxide in the sea. Patent Reference 13 shown below discloses that carbon dioxide in a vegetable factory is fixed by an artificial moss young seedling grown in a solution, to make it possible to reduce carbon dioxide. Patent Reference 14 shown below discloses that deep sea water is pumped using a windmill as a power source and is then discharged in the surface water to make a fishery. Patent Reference 15 shown below discloses that deep sea water is likewise pumped by the power of a windmill and is then discharged in the surface water to make an ocean farm. Patent Reference 16 shown below discloses that deep sea water is likewise pumped using a windmill as a power source and a holding tank is prepared to hold the deep sea water in the sea for a fixed period of time to make a fishery. Patent Reference shown 17 below discloses that deep sea water is used to produce a beer.

[0014] The above temperature-difference power generation using deep ocean water means a method in which utilizing a difference in temperature between surface ocean water heated by sun heat and cold deep sea water at a depth of 100 m or more which the sun light does not reach, a volatile medium such as Freon and ammonia is used for heat exchange to vaporize by the warm surface ocean water, thereby rotating a turbine to generate power. Patent Reference 18 shown below discloses temperature-difference power generation using deep ocean water and surface ocean water. Patent Reference 19 shown below discloses that deep sea water for temperature-difference power generation is pumped by a storage pump driven by wind power. As to a report referring to the utilization of a thermionic power generation element to the temperature-difference power generation, Patent Reference 20 shown below discloses a production method in which a thermoelement subjected to temperature-difference power generation has a resistance to vibration and impact. Patent Reference 21 shown below discloses a method of producing a portable small thermionic power generation element for temperature-difference power generation. This thermionic power generation element (thermoelement) is called a Pertier element based on the fact that when different types of semiconductors are joined to flow current, heat is generated at one junction and heat is absorbed at another junction. This means that the heat absorbed at one part is released at the other part, wherein if the direction of the current is reversed, the heat generation part and the heat absorption part are reversed. Also, when the both junctions are made to have temperatures different from each other, a potential difference is created, and this works as a temperature-difference power generating element. Non-patent Reference 10 shown below discloses that the inventors of this patent application of this case has made a device for measuring the thermal constant of a rock sample, wherein a sinusoidal wave d.c. voltage is applied to the above thermoelement such that the potential of the thermoelement is changed from plus potential to minus potential to change a temperature difference periodically and the change in heat is given to a rock sample. Patent Reference 22 shown below discloses a device that cools a laser mirror by bringing one side of a thermoelement into close contact with the laser mirror and by flowing d.c. current across the thermoelement in the condition that the other is cooled by cooling water. Non-patent Reference 11 discloses that one side of the thermoelement is heated to 500° C. or less and the other is heated to 1000° C. or less and the obtained temperature difference is utilized in a thermionic power generation element.

[0015] Even in Japan in which the self-support of foods could be relatively procured, the aging of producers, a labor shortage and the like cause an increase in the import of vegetables. China having a huge population is changed to a food-importing country during the course of its economical development and industrialization. Also, in North Europe in winter very decreased in hours of sunshine, a few green vegetables are seen on a table. In the current agriculture relying on natural energy, techniques obtained by drawing on one's resources every district as called right crop for right land have been accumulated. However, in these days of threatening of dangers from a world-wide population increase and food shortage, possible agricultural right lands must be utilized by using proper methods which limit the damages to the natural environment to the minimum. These measures are, however, limited by production area and are dependent on climate. Looking at Non-patent Reference 12 shown below and the home page of Plant Factory Laboratory, a vegetable factory is regarded as “a periodical vegetable production system utilizing high technologies such as environmental control and automation”. Also, it is also described that in the vegetable factory, a vegetable culturing environment, that is, temperature, the quantity of light, and the charges of carbon dioxide, a fertilizer is controlled by a computer to thereby automatically produce crops without any labor regardless of climate. Patent Reference 23 described below discloses that a plant body is grown from a seedling by applying light including near-infrared light relatively in growth period and by applying light reduced in infrared light in the date of ripening to thereby hasten the proper time of harvesting. Patent Reference 24 shown below discloses moisture-proof type lighting equipment that reflects only visible rays so that it can be used for a long period of time even under a high-temperature and high-humidity environment as a photosynthetic light source. Patent Reference 25 shown below discloses that a fuel cell is used for the electric power of a vegetable factory and electric power is supplied to power consumption subjects by solar power generation and wind power generation. It is also disclosed in Patent Reference 26 shown below that a fertilizer blended with a bittern of deep ocean water is supplied to vegetables.

[0016] An international conference on cultured fishes was held in the City of Kobe on Jan. 22, 2007. According to Non-patent Reference 13 shown below, Amami Island has many intricate gulfs and has such a mild climate that sea temperature is not dropped to 20° C. or less all the year round. It is said that industrial officers gather here for culturing tunas. It is natural that sea areas free from, for example, the generation of a red tide are selected as fisheries. According to the State of the World as Non-patent Reference 14 shown below, a huge “dead zone” in which neither fish nor ocean organism can exist occurs in the Gulf of Mexico in every summer. This phenomenon occurs from the reason that marine organisms cannot exist because the level of the concentration of oxygen dissolved in sea water is very low. There are 146 similar oxygen-deficient sea areas in the world, wherein the oxygen-deficient sea area occurs most frequently in a place where water temperature is mild and such an area is centered on the offshore of East Coast of the United State and the seas in Europe. However, it is said that this phenomenon is observed in each coastal offshore of China, Japan, Brazil, Australia and New Zealand. The reason why oxygen-deficient sea areas occur in these coastal areas and fishes and other living bodies die is that phytoplankton and algae are abnormally generated by a stimulation from excessively concentrated nitrogen and phosphorous contained in a fertilizer when this fertilizer is thrown into rivers and sea. When this phytoplankton is dead, it sinks to the bottom of the sea, and is decayed and decomposed. Because whole oxygen around the area is consumed during the course of the above process, a low-oxygen area is produced, so said in the above Reference. Almost all ocean organisms cannot live in the low-oxygen area. Movable fishes and other moveable organisms can be saved only if they leave the oxygen-deficient area. However, there is no time enough for Crustacea and the like to leave the area and Crustacea and the like choke to death. Further, one of the main reasons why the offshore culturing of fishes is prospering is that nutrients are accumulated in coastal areas. To remove this defect, it is a key for the solution of the problem to reduce water pollution caused by the discharged nutrients to thereby restore the function of ecological systems. The Straits of Kattegat between Denmark and Sweden are suffered from a low-oxygen condition, abnormal development of plankton and massive death of fishes after nineteen seventies. In 1986, the Denmark government is touched off by the bankruptcy of lobster fishery in Norway and primarily reduces effluents from a drainage treating station and from industries, to reduce the phosphorous content in water by 80% and to restore coastal damp areas, thereby decreasing the amount of fertilizers to be used in farms. It is reported that the proliferation of plankton came to a stop by this measures, leading to an increase in the amount of oxygen in water.

[0017] Nowadays, there are three ocean wind power generation projects which are advanced in Japan. Among these projects, according to Non-patent Reference 15 shown below, a system using the power generated by a windmill to generate hydrogen is adopted in National Institute for Environmental Studies and National Maritime Research Institute and a system transmitting the power generated by the windmill to the land as it is adopted in The University of Tokyo and The Tokyo Electric Power Company, Incorporated. The system adopted in National Institute for Environmental Studies is based on the plan of a non-mooring system sailing type wind power generation plant on the deep-ocean and is forwarded based on a five-year plan from 2003. In a trial calculation, 288000 windmills will be required and the necessary area will be 124000 km^2, when a 5 MW (rotor diameter: 120 m) windmill is assumed as the windmill, on the premise that the operation rate of the equipment is 25%, hydrogen obtained on the ocean is transmitted to the land to consume the hydrogen by a fuel cell and that, in this case, the hydrogen conversion efficiency is 50% and the energy efficiency of the fuel cell is 60%.

[0018] The system adopted in National Maritime Research Institute is a mooring system floating type wind power generation system in which a mooring type floating body (length: 187 m and width: 60 m) is installed on the sea near the shore at a surface depth of 100 to 200 m where no fishery right is created, to carry out wind power generation. Two windmills are installed on one floating body. As the windmill, one having a rated output of 5 MW (rotor diameter: 120 m) is assumed and sea water is directly electrolyzed to produce hydrogen. However, in its immediate plan, sea water is desalinated and the resulting water is electrolyzed to produce hydrogen. Furthermore, this hydrogen is reacted with CO_2 transported from the land to convert these compounds into methane. The obtained methane is liquefied or is made into compressed gas, and the obtained liquid or gas is transported to the land. Actual data of wind conditions indicates that the sea area where the annual utilization factor of the equipment is 40% is four places, that is, the west coast of Hokkaido, offshore of Tohoku of Japan Sea, offshore of Boso and offshore of Izu, and these areas having a total of 15000 km^2 correspond to the above sea area. The wind power generation equipment in which one floating body has an output of 10 MW generates a total annual power generation of 35,040 MWh, making it possible to produce about 835 ton of hydrogen a year (conversion efficiency: 99%). The above hydrogen can be made to produce about 1,650 ton of methane (conversion efficiency: 99%). This corresponds to the amount of fuel to be used for about 4,300 cars covering a running distance of 10000 km in one year. Because the methanization reaction of hydrogen is an exothermic reaction, a heat of 6.94×10^6 kWh is produced. This produced heat is utilized to generate electricity by using a steam power generator to reuse the obtained electricity as the power for electrolysis. In a trial calculation, the construction cost per floating body is about 4.9 billion Yen, and the cost of electricity is 11.7 Yen/kWh for 30 years of amortization period.

[0019] The system adopted in The University of Tokyo and The Tokyo Electric Power Company, Incorporated is a mooring system floating type ocean wind power generation system on the sea near the shore. It is intended to carry out an operation of a floating body type ocean wind power generation at a place about 10 km apart from the offshore of the Pacific Ocean in Kanto district, wherein the evaluation of wind conditions on the ocean, the development of the floating body and economical evaluation of the equipment and the like will be made in fiscal 2005 to 2006. Three windmills each having a rated output of 2.4 MW (rotor diameter: 92 m) will be constructed on one floating body, wherein the distance between the windmills is 180 m, and the floating body is constituted of a fundamental floating body made of RC, connecting members made of steel pipes and tension cables. The mooring will be furnished at a windmill tower and four places in the center part.

CITED REFERENCES

[0020] Patent Reference 1: Jpn. Pat. Appln. KOKOKU Publication No. 2004-537668

[0021] Patent Reference 2: Jpn. Pat. Appln. KOKAI Publication No. 2000-202441

[0022] Patent Reference 3: Jpn. Pat. Appln. KOKAI Publication No. 2004-290945

[0023] Patent Reference 4: Jpn. Pat. Appln. KOKAI Publication No. 2005-069125

[0024] Patent Reference 5: Jpn. Pat. Appln. KOKAI Publication No. 2002-059893

[0025] Patent Reference 6: Jpn. Pat. Appln. KOKAI Publication No. 2001-213388

[0026] Patent Reference 7: Jpn. Pat. Appln. KOKAI Publication No. 2002-255091

[0027] Patent Reference 8: Jpn. Pat. Appln. KOKAI Publication No. 2002-303454

[0028] Patent Reference 9: Jpn. Pat. Appln. KOKAI Publication No. 2005-145218

[0029] Patent Reference 10: Jpn. Pat. Appln. KOKAI Publication No. 2003-206848

[0030] Patent Reference 11: Jpn. Pat. Appln. KOKAI Publication No. 2003-206849

[0031] Patent Reference 12: Jpn. Pat. Appln. KOKAI Publication No. 2004-344107

[0032] Patent Reference 13: Jpn. Pat. Appln. KOKAI Publication No. 2006-254900

[0033] Patent Reference 14: Jpn. Pat. Appln. KOKAI Publication No. 2007-2721

[0034] Patent Reference 15: Jpn. Pat. Appln. KOKAI Publication No. 2005-52136

[0035] Patent Reference 16: Jpn. Pat. Appln. KOKAI Publication No. 2003-333955

[0036] Patent Reference 17: Jpn. Pat. Appln. KOKAI Publication No. 2003-169657

[0037] Patent Reference 18: Jpn. Pat. Appln. KOKAI Publication No. 2005-280581

[0038] Patent Reference 19: Jpn. Pat. Appln. KOKAI Publication No. 7-63155

[0039] Patent Reference 20: Jpn. Pat. Appln. KOKAI Publication No. 2006-278352

[0040] Patent Reference 21: Jpn. Pat. Appln. KOKAI Publication No. 2004-296960

[0041] Patent Reference 22: Jpn. Pat. Appln. KOKAI Publication No. 54-118196

[0042] Patent Reference 23: Jpn. Pat. Appln. KOKAI Publication No. 2001-57816

[0043] Patent Reference 24: Jpn. Pat. Appln. KOKAI Publication No. 5-89710

[0044] Patent Reference 25: Jpn. Pat. Appln. KOKAI Publication No. 5-135783

[0045] Patent Reference 26: Jpn. Pat. Appln. KOKAI Publication No. 2005-126278

[0046] Non-patent Reference 1: Greener World 2006-07-14: greenerw.exblog.jp

[0047] Non-patent Reference 2: The Nikkei, Mar. 30, 2007, Morning paper, "All fiber components of wood chips and weeds, to ethanol"

[0048] Non-patent Reference 3: The Nikkei, Mar. 8, 2007, Evening paper, "Ebara CORPORATION, will take his share in bioethanol"

[0049] Non-patent Reference 4: The Nikkei, Jan. 14, 2007, front page of Morning paper, "Water-making is spread worldwide"

[0050] Non-patent Reference 5: NIPPON KOKUSEI ZUKAI, Foundation, Yano Kota Kinenkai, Jun. 1, 2006

[0051] Non-patent Reference 6: TAKAHASHI Takehiko, INTRODUCTION TO ELECTROCHEMISTRY, Maki Shoten, Feb. 20, 1991, New edition 4

[0052] Non-patent Reference 7: The Latest Chemistry of Products, (k.k.) Kokusei (she), p79. Dec. 20, 1973

[0053] Non-patent Reference 8: Free Encyclopedia "Wikipedia"

[0054] Non-patent Reference 9: The Nikkei, Apr. 10, 2007, third page of Evening paper, "Photosynthesis by New-infrared rays/Ocean Bacteria"

[0055] Non-patent Reference 10: MURAHARA Masataka, Measurement of the thermal diffusivity of a rock by using a thermal semiconductor, THE NIKKAN KOGYO SHINBUN, Mar. 30, 1997

[0056] Non-patent Reference 11: Toshiba Press Release, the Mar. 29, 2004 issue, "As to the development of a heat conductive module generating electricity by utilizing a difference in temperature between the upper and lower surfaces"

[0057] Non-patent Reference 12: TAKATSUJI Masaki, "Fundamental and Actual Vegetable Factory", SHOKABO

[0058] Non-patent Reference 13: The Nikkei, Jan. 22, 2007, Morning paper, "Fishery regulation will be strengthened, Excitement over Culturing of Tuna"

[0059] Non-patent Reference 14: State of the World 2006-7, Eco-Economy-Update 2004-10, World Watch Institute

[0060] Non-patent Reference 15: Ocean Policy Research Foundation, News Letter No. 140 (Jun. 5, 2006)

BRIEF SUMMARY OF THE INVENTION

[0061] The current procurement of energy sources is limited to places rich in resources from an economical point of view and the problem is how to transport the energy resources economically to a consumer place. However, the development of modern industries brings about indiscriminate acquisition of resources and the worldwide deficiency of resources caused by the indiscriminate acquisition of resources brings about a steep rise in the prices of the resources. Fortunately, Japan is surrounded by the ocean and has the possibility of being a country rich in resources taking the outskirts of the 200-mile continental shelf. Mineral resources dissolved in sea water, fluid energy resources such as oceanic current and tide, solar heat, thermal energy resources such as submarine hot spring or a difference in temperature between submarine hot spring and sea water, drinking water and industrial water are marine resources. It is a problem to be solved by the present invention to build an integrated system in which these inexhaustible marine resources are economically recovered without using fossil fuels, and cellulose and grain which are landed are allowed to ferment by combining them with these marine resources, to produce fuel ethanol or deep sea water beer. Also, in the integrated system, carbon dioxide generated by the alcohol fermentation is used as a raw material to grow vegetables and oxygen generated by photosynthesis is supplied by bubbling from the seabed or undersea to the marine surface to increase the concentration of oxygen in the sea water, thereby promoting the growth of fishery products and also reducing low-oxygen areas on the ocean to thereby suppress the generation of red tides.

[0062] As the electric power in the integrated production factory, no fossil fuel is used but natural energy such as wind power, hydraulic power (tidal force), wave power, sunlight, solar heat or geothermal heat is used. Among these powers, the wind power generation is more reduced in installation area than other natural energy power generations because the windmill can be installed vertically to the surface of the earth and the sea, it can be utilized day and night. Particularly, tidal power generation utilizing the Kuroshio current has a significantly high generation efficiency. To mention in more detail, because water has a higher density than that of wind when comparing water wheel power generation with windmill power generation, an 854-fold increase of energy is obtained by changing the flow of wind to the flow of water. For this, the tide having a flow speed of 1 m/s, this equals to wind having a flow speed of 9.5 m/s and the tide having a flow speed of 2 m/s, this equals to wind having a flow speed of 19 m/s. Therefore, if the floating vessel on the ocean factory is moored on the ocean having the fast-flowing tide such as the Kuroshio current, the power generation efficiency can be improved. Also, the temperature-difference power generation using the deep ocean water is currently conducted by using a volatile medium such as Freon or ammonia is used for heat exchange to vaporize by the surface ocean water, thereby rotating a turbine to generate electric power. If this mechanical turbine is changed to a thermionic power generation element, power generation free from the operation part can be accomplished. Specifically, the electric power can be supplemented by, for example, temperature-difference power generation equipment having the following structure. In order to obtain a high difference in temperature, a high-temperature circulation liquid consisting of petroleum products, aromatic compounds, molten salts, meltable metals, silicone oil, sulfuric acid or oil or the like as a heating medium heated by solar heat or factory waste heat or water, hot waster water from an electrolytic plant or warm water circulation liquid such as submarine hot spring and coastal hot spring as the hot spring or hot spring water of volcanic hot spring is used on the high-temperature side, and deep sea water, surface marine water or river water is used on the low-temperature side. The solar water heater is made of either plural heat-collecting pipes arranged on the deck or a heat-collecting pipe placed on the focus line of sunlight converged by a ray-converging means such as a lens and mirror. A salt in the course of the electrolysis of the molten salts and molten salts of a salt and calcium chloride, magnesium chloride, potassium chloride, calcium chloride or caustic soda or the like are preheated by the heating medium circulated in the heat-collecting pipe prior to the heating by electric power. Then, the electric power can be supplied by the heated molten salt and cool water including the pumped deep sea water, surface ocean water or river water are made to flow in the inner tube and outer tube of a double or triple pipe structure respectively and semiconductor thermionic power generation elements are arranged in the middle tube between these inner and outer tubes.

[0063] Researches and developments are being made in wide fields such as power generation, fuel for transportation and city gas by using a hydrogen combustion turbine, by using hydrogen converted from clean and reproducible energy such as sunlight and wind power. Particularly, sea water is desalinated by the power obtained by wind power generation on the ocean and the obtained water is electrolyzed to produce hydrogen, which is then stored in a bomb in a liquid state. Therefore, developments and researches are being made concerning hydrogen absorbing metals for transporting to the land and reduction in the weight of a bomb for storing hydrogen. In an electric power station and facilities such as city gas plant and factories for charging fuel cells which need a large amount of hydrogen in a short time, solid hydrogen is suitable. Metal sodium has a specific gravity of 0.971 and is hence lighter than water and is also safe when stored in petroleum. Therefore, if hydrogen is produced on the ocean, transportation cost and costs of a storage tank and the like can be reduced. Combustion energy generated by liquefying the metal sodium and by reacting this metal sodium with steam or oxygen can be used to generate electricity. However, if hydrogen generated by spraying water on this metal sodium as a simple method is used in an electric power station, and facilities such as city gas plant and factories for charging fuel cells, caustic soda as its waste may be supplied as economic raw material to be used in soda industries. On the other hand, caustic soda is subjected to molten salt electrolysis performed using the electric power obtained by wind power generation to constitute a sodium fuel cycle for reproducing metal sodium in consideration of the balance between the demand and supply of caustic soda and metal sodium for generation of hydrogen. This sodium fuel cycle is a system in which fuel is produced endlessly to reproduce it in the same manner as in the nuclear fuel cycle for reproducing uranium and plutonium by retreating spent nuclear fuel in an atomic power plant. However, the sodium fuel cycle recommended by the present invention is safe because no radioactive waste is produced unlike the nuclear fuel cycle. Also, in contrast with uranium that is deposited only in limited areas in a small amount in the world, sodium is present inexhaustively as salts in sea water and also exists as a rock salt abundantly on the land. Although sodium is fuel which is abundant in the sense of resource and can be supplied in every nation of the world, it must be very carefully treated. This metal sodium reacts with water explosively to generate hydrogen, which is burned by its reaction heat. When water is added to sodium which is contained in oils to limit the combustion and oxidation, by spraying, instillation or pulse-wise addition from above, water having a higher specific gravity than the oil passes at a high speed in the oil. Water is brought into contact with metal sodium while it passes to cause a chemical reaction. Or, the water layer in contact with the lower layer of the oil may be stirred by ultrasonic vibration to bring the mixture of oil and water into contact with metal sodium to cause the reaction of water with metal sodium. Moreover, water may be sprayed toward metal sodium in the oil layer from plural high-pressure water spray nozzles. In order to run the reaction directly with water, metal sodium floated in the oil layer may be pushed down by a control bar from the above to react metal sodium with water under the oil layer. In order to cause the reaction more violently, water may be added to metal sodium by spraying, instillation or pulse-wise addition after the oil is withdrawn under hydrogen or an atmosphere of inert gas such as argon or nitrogen. Hydrogen and caustic soda can be drawn from the top and bottom of the reactor. A structure may be adopted in which a cooling jacket is provided on the outside periphery of the reactor to make cooling water flow in the case where a rise in temperature by the reaction heat is steep. Anti-corrosion materials such as stainless, polyethylene and polypropylene may be used for the reactor. It is a problem to be solved by the present invention to make such a circulating system.

[0064] When the amount of water to be supplied to metal sodium is small, and specifically, when water is added to metal sodium from the water spray nozzle located on the upper part of the reactor after the oil is withdrawn, the temperature becomes higher by the reaction heat and reaches a temperature higher than the flash point (500° C.) of produced hydrogen. Particularly, when oxygen is poured into the reaction system, hydrogen is burned to raise the temperature of the system. In order to utilize this heat, a heating medium as a primary cooling agent is circulated in the cooling jacket around the outer periphery of the reactor to boil water as a secondary cooling water by this heat, thereby rotating the steam turbine, making it possible to supply electric power. When the amount of water to be supplied to metal sodium is large on the other hand, and specifically when metal sodium floated in the oil layer is pushed down by the control bar from above to react a large amount of water under the oil layer with metal sodium, the temperature is not so much raised because the heat capacity of water is large, ensuring that hydrogen can be stably produced. Of course, hydrogen is not burned because no oxygen is supplied in water.

[0065] In view of the above problems, the present invention has been made. Specifically, it is an object of the present invention to provide an onsite integrated production factory as a measure which is not limited by natural and geographical conditions, climatic conditions and places. In the integrated system, desired electric power and raw materials are obtained in one defined area to thereby produce fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, oxygen or the like by using sea water, salt lake water or rock salt as a raw material, cellulose materials and grains which are landed are allowed to ferment by combining them with these produced materials, to produce fuel ethanol or deep sea water beer, and carbon dioxide generated by the alcohol fermentation is used as a raw material to grow vegetables. Hot spring water is utilized to produce tropical or subtropical plants in the vegetable plant. For this, a metal pipe in which water as a secondary heat water is circulated is arranged around the periphery of a warm water passage and a warm water container in which hot spring primary hot water flows and the secondary hot water is utilized for heating to raise the soil temperature and culture temperature in the vegetable plant to culture tropical or subtropical vegetables. Oxygen generated by photosynthesis in the vegetable plant is provided to keep the concentration of oxygen in the sea water to thereby grow fisheries. Namely, the onsite integrated production factory is provided as an ocean composite plant to reduce the energy loss in the production, storage and transportation and also, to improve the efficiency of the whole system. With regard to, particularly, the supply of metal sodium as the energy source, a rock salt and a salt lake are exist on the land besides enormous sea water on the ocean. The rock salt occupies ¾ of the amount of the salts produced in the world. These salts on the land and natural energy on the land, for example, wind power generation, sunlight power generation, solar power generation and solar heat are used to produce metal sodium directly by molten-salt electrolysis or indirectly by further subjecting sodium hydroxide produced by the electrolysis of an aqueous salt solution, to molten-salt electrolysis. In the world, there is an area in which the salt concentration of the sea water is 1% or less though the area is blessed with ocean wind force like Baltic sea, and also, a fresh water lake. A rock salt is transported to these areas, where metal sodium is produced. In the continent, there are rock salt areas and salt lakes in South America, North America and Europe and many of the lands are also wind power generation areas. The rock production countries in 2003 are United State of America 16300000 ton, Germany 15000000 ton, Italy 3000000 ton, Spain 2000000 ton, England 1500000 ton, Brazil 1300000 ton and Pakistan 1300000 ton. Also, the rock production countries are distributed widely and these countries are typified by Russia, China, Mongolia, Iran, Morocco, Algeria, Libya, Yemen, Argentina, Columbia, Ecuador, Peru and Chile. As the salt lake, Lake Michigan and Salt Lake in America, The Dead Sea in Israel, and Lake Lefroy and the like are famous. Metal sodium may be produced in lakes and rock salt drilling sites and the like in these areas and transported to consumer places. A production system in such an area having raw materials and power sources jointly can reduce an energy loss in production, storage and transportation and enables the provision of an energy production plant capable of improving the efficiency of the whole system.

[0066] The above object is attained by an onsite integrated production factory according to the present invention, the production factory being provided with a power generating means utilizing natural energy including fluid energy power generation using wind or tide, temperature-difference thermionic power generation using solar heat and sea water or optical power generation using a solar battery, and comprising an electrolytic plant producing fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, oxygen, or the like by using sea water, salt lake water or rock salt as a raw material, an ethanol plant producing fuel bioethanol or alcohol drinks including deep sea water beer and sake together with oxalic acid or sodium oxalate by fermenting cellulose materials or grains by using fresh water, sulfuric acid or caustic soda produced in the ethanol plant, wherein oxalic acid or sodium oxalate produced in the ethanol plant is used as an agent for removing calcium contained in sea water in the electrolytic plant, a vegetable plant producing vegetables by photosynthesis using carbon dioxide generated in the fermentation process in the ethanol plant, fresh water produced in the electrolytic plant, sunlight or artificial light, and a culturing plant growing fisheries in a fishery farm or underwater reef where fish live which are formed by introducing oxygen generated in the photosynthesis, into sea water to supplement the concentration of oxygen in the sea water or to suppress the generation of a red tide and by discharging the sea water obtained by supplementing oxygen to deep sea water pumped in the electrolytic plant, in the surface sea water, on a site. The onsite integrated production factory of the present invention may be installed in a floating body vessel or lifting vessel constituted of a multi- or mono-hull or a megafloat floating on the sea, a littoral structure or a structure on the land.

[0067] The onsite integrated production factory of the present invention is an integrated factory in which the electrolytic plant, ethanol plant, vegetable plant and culturing plant are installed in a large catamaran, multihull or monohull, submarine, megafloat, littoral structure or a structure disposed on the land adjacent to the seashore. For example, in order to obtain a large amount of electric power on the ocean from fluid energy, the integrated structure is provided with plural non-directional vertical axis wind or water wheels or propeller type horizontal axis wind or water wheels are disposed on or under the deck and can be navigated on the ocean, floated on a resource collecting site or moored while continuing production. Particularly, in ocean current power generation utilizing ocean current such as the Kuroshio current, the vessel is moored. Also, a multihull is preferable to a monohull to carry out ocean current power generation, and plural non-directional vertical axis wind wheels are installed on the deck made by combining two or more vessels and plural ocean current power generation vertical axis water wheels or propeller horizontal water wheels to carry out water wheel power generation under the ocean surface under the deck. Moreover, as the power generation utilizing sunlight, high-density sunlight converged by a strip plane mirror which works as a convex mirror and an objective mirror is introduced into a system provided with mirrors having a bandpass filter or cold filter film which transmits light having a wavelength range of 600 to 700 nm and reflects infrared rays having a wavelength higher than the above wavelength range, and a solar cell improved in power generation efficiency by cooling its back with sea water, and the infrared rays reflected on the bandpass filter film are converged to thermionic power generation element and subjected to temperature-difference power generation using sea water. Here, if the objective mirror which converges sunlight is provided with a cold filter film which transmits light having a wavelength range of 600 nm or less and reflects the rays having a wavelength higher than the above wavelength range, the visible rays transmitted through the objective mirror are used for the photosynthesis in the vegetable plant. Warm water circulated in solar heater pipes stretched around the surface of the deck, or high-temperature circulating liquids of oil petroleum products such as light gas oil and kerosene, aromatic compounds such as diphenyl ether, dichlorobenzene and alkylbenzene, dissolved salts such as sodium nitrate and potassium nitrate, metal sodium, mercury, lead or easily dissolvable metals such as sodium and potassium, silicone oil, sulfuric acid and oil as heating mediums circulated in a heat-collecting pipe arranged on the focus line of the sunlight converged by a ray-converging means such as a lens or mirror may be used as auxiliaries for the heating of the molten salt in the molten salt electrolytic plant. Moreover, wastes of these heating mediums and cool water consisting of pumped deep sea water or surface ocean water are made to flow in the inner tube and outer tube of a double or triple pipe structure respectively and a semiconductor thermionic power generation elements are arranged between these inner and outer tubes, to constitute a temperature-difference power generation. Natural energies such as this temperature-difference power generation and temperature-difference power generation equipment having a structure in which the converged sunlight is applied to one surface of a thermionic power generation element through a heat absorbing layer and sea water is made to flow on the other surface of the thermionic power generation element are the electric power of the onsite integrated production factory. A difference in temperature between high-temperature liquid such as submarine hot spring, coastal hot spring or volcanic hot spring and river water or sea water is utilized for a thermionic power generation element to generate electricity. There are many high-temperature hot springs having a temperature of 45° C. or more in Japan: examples of these hot springs include submarine hot springs scattered in Okinawa Trough sandwiched between East China Sea including the main island of Okinawa and Ishigaki island and Ryukyu islands gushes with hot water having a temperature of 300° C. or more, coastal hot springs such as Ibusuki Onsen in Kagoshima prefecture, Shirahama Onsen in Wakayama prefecture, and Shimogamo Onsen and Toi Onsen in Izu peninsula, and volcano type hot springs including hot springs having a temperature of about 98° C. such as Arima Onsen in Hyogo prefecture, Tamagawa Onsen in Akita prefecture, Matsunoyama Onsen in Niigata prefecture and hot springs having a temperature of about 90° C. such as Yunomine Onsen in Wakayama prefecture and Kusatsu Onsen Bandai in Gunma prefecture and Kirishima Onsen in Kagaoshima prefecture. Temperature-difference power generation using these hot spring waters and cool river water is also effective as thermal energy power generation. The hot spring water which has been subjected to the temperature-difference power generation can be utilized as dashing type hot springs having 100% of the head spring without adding water. Particularly in the case of a hot spring, the content of calcium is as large as 10 to 20 times that of marine water and therefore, the hot spring water is not made to flow in the outer tube but to flow in a round inner tube as the pipe for flowing high-temperature hot spring water, to make easy to remove precipitate. When a super water-repellent material such as graphite or a fluororesin is used for the inner wall, the adhesion of crystals to the tube wall can be limited. As other method, metal pipes in which water as the secondary hot water is circulated are stretched around the periphery and inside of a river, warm-water passage and warm-water storage tank in which high-temperature hot spring water to be used as the primary hot water is made to flow. That secondary hot water is supplied for heating to raise the temperatures of a soil and the culture temperature in the vegetable plant, and is also supplied to the vegetable plant for culturing tropical or subtropical vegetables and for room heating.

[0068] In the electrolytic plant producing fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, oxygen and the like by using sea water as the raw material, the sea water is treated with a reverse osmosis membrane to produce fresh water and then, oxalic acid or sodium oxalate produced in the ethanol plant is poured into the remainder 6% salt brackish water to remove calcium. Then, caustic soda produced in the electrolytic plant is poured into the filtrate to precipitate only a magnesium salt, and then, the solution is neutralized by hydrochloric acid produced in the electrolytic plant to form magnesium chloride, which is then subjected to molten salt electrolysis to produce metal magnesium. Hydrochloric acid produced in the electrolytic plant is poured into the filtrate, on the other hand, to convert sodium sulfate into sodium chloride and the resulting filtrate including sodium chloride is subjected to an ion exchange membrane to produce brine having a concentration 20% or more and then, the brine is electrolyzed to produce caustic soda and byproducts including chlorine, hydrogen and oxygen. On the other hand, waste sulfuric acid is concentrated by a reverse osmosis membrane and concentrated sulfuric acid is used for cellulose decomposition in the ethanol plant. Here, hydrochloric acid is poured into calcium oxalate precipitated after oxalic acid or sodium oxalate is added to the brine, and produced calcium chloride and sodium chloride concentrated by the ion exchange membrane are respectively further concentrated under heating to produce a mixed salt containing about 60% of sodium chloride and about 40% of calcium chloride is subjected to molten salt hydrolysis at about 600° C. Then, the obtained mixture is cooled down to 110° C. to directly produce metal sodium without the treatment using caustic soda for separating sodium from calcium.

[0069] In the ethanol plant, deep ocean water pumped in the electrolytic plant, and landed starch and malt and the like are used as the raw materials to undergo alcohol fermentation, thereby manufacturing deep sea water beer or sake, and cellulose materials such as landed wood chips and scrap wood are decomposed by sulfuric acid produced in the electrolytic plant and combined with fresh water manufactured in the electrolytic plant to ferment, thereby manufacturing fuel bioethanol. Carbon dioxide generated by these alcohol fermentation is supplied as photosynthetic raw material in the vegetable plant. Also, carbon dioxide generated by pouring caustic soda manufactured in the electrolytic plant into a part of the cellulose material, or carbon dioxide obtained by the alcohol fermentation, and carbon monoxide generated by red-heating cokes are absorbed by caustic soda to produce sodium oxalate or oxalic acid, which is then used as an agent for removing calcium in the sea water used in the electrolytic plant.

[0070] In the vegetable plant, carbon dioxide generated in the ethanol plant, fresh water obtained by desalinating deep ocean water or surface ocean water in the electrolytic plant, visible rays which are eliminated by the bandpass filter and are not supplied for sunlight power generation, a fluorescent lamp which is artificial light and a light emitting diode and the like are used to run photosinthesis. Oxygen generated at the unexposed time is supplied for the supplement of oxygen concentration in sea water in the culturing plant and for suppressing the generation of a red tide, and also supplied to the deep see water pumped in the electrolytic plant for growing fishes in fisheries or underwater reefs where fish live. An oxygen discharge pipe extended to a fish preserve, underwater reef where fish live, or the bottom or middle of the sea is installed as a measures for dissolving oxygen in the sea water and a water-repellent porous film or a sponge is applied and stretched on the interface of the sea water at the gas outlet of the pipe to press oxygen gas into the sea in the condition that the sea water and gas are separated from each other by adjusting the water depth and oxygen gas seal pressure. The gas pressure of oxygen depends on the depth of the sea water, and water pressure rises at a rate about 1 atm every 10 m in depth. Therefore, it is necessary to apply a pressure of 2 atm or more $(1+1+\alpha)$ at a surface depth of 10 m, 11 atm or more $(1+10+\alpha)$ at a surface depth of 100 m and 31 atm or more $(1+30+\alpha)$ at a surface depth of 300 m. Here, α is a pressure decided by the hole diameter of the porous film. On the other hand, the deep ocean water pumped in the electrolytic plant is, after it is subjected to the temperature-difference power generation, used to cool for cold district farm room of the vegetable plant and then, the deep sea water is divided into two lines. The deep sea water in one of these lines is subjected to desalination in the electrolytic plant and is then used as the raw material of beer or sake in the ethanol plant or as the raw material used for the water culture method in the vegetable plant, and the other is discharged into a cold current fishery preserve or discharged into the surface ocean water as it is to form fisheries having an enclosure for warm current fisheries, bottom-water fishes or shrimps and crabs and the like or natural fisheries and underwater reefs for migratory fishes which cluster around the deep sea water rich in nutrients around the fisheries.

[0071] In the present invention, two methods are adopted as the method of producing metal sodium. One of these methods is a method in which a salt water solution containing a salt or rock salt or salt lake water is electrolyzed to produce caustic soda, which is then subjected to molten salt electrolysis to produce metal sodium. This reason is that this method of producing metal sodium through the production of caustic soda is more decreased in total cost and there are larger demands for caustic soda and hydrochloric acid produced as byproducts in other processes in the factory. Although caustic soda is usually a starting material of soda industries, metal sodium is produced via caustic soda in the present invention because abundant electric power can be supplied by water wheel/windmill power generation on the ocean or wind power generation on the land. The other method is a method in which a common salt is directly subjected to molten salt electrolysis to produce sodium. Particularly, in the present invention, sodium oxalate produced in the ethanol plant is poured into the brine to remove calcium in the brine, and hydrochloric acid is poured into the precipitate calcium oxalate to recover oxalic acid and make calcium chloride free. However, when a mixed salt prepared by adding about 40% of calcium chloride to sodium chloride as a catalyst is subjected to molten salt electrolysis, the temperature of the electrolytic bath is dropped to about 600° C. from about 800° C. Though caustic soda and hydrogen are not produced as byproducts, it is hard to abandon this method because this method is superior in workability and safety. Both the metal sodium products obtained in these two methods are transported to the hydrogen supply facilities on the land, where water and sodium are reacted with each other to generate hydrogen, and caustic soda which is a reaction residue obtained after the production of hydrogen is supplied as it is as the raw material of soda industries. Specifically, this implies that caustic soda which is the raw material of soda industries can be supplied without cost. The annual consumption of caustic soda in our country is as large as 4450000 ton which is the third in rank. When comparing this with the annual power consumption (1.1 trillion kWh), the power consumption is incredibly larger. For this, it is considered that if the equipment of the present invention is in such a situation that it is fully operated, the supply of caustic soda is excessive. For this, the supply of caustic soda to soda industries is limited taking the balance between the demand and supply into account, a sodium fuel cycle for reproducing metal sodium can be established by subjecting caustic soda of the reaction residue to molten salt electrolysis by using the electric power obtained wind power generation. This sodium fuel cycle is a system in which fuel is produced endlessly to reuse it in the same manner as in the nuclear fuel cycle for reproducing uranium and plutonium by retreating spent nuclear fuel in an atomic power plant. However, the sodium fuel cycle recommended by the present invention is safe because no radioactive waste like the nuclear fuel cycle is produced. Also, uranium is deposited only in limited areas in the world and is limited in reserve like fossil fuels so that there is a fear that it is exhausted in dozen years or so in the future. In contrast with these small resources, sodium is present inexhaustively as salts in sea water and also exists as a rock salt on the land abundantly. The sodium is a fuel in rich resources and can be supplied all over the world. Also, metal sodium has a specific gravity of 0.971, so that it is lighter than water and it can be stored in petroleum oil, making it possible to reduce energy loss when its products are stored and transported. Because a large amount of hydrogen can be instantly generated according to the need by reacting this metal sodium with water in electric power stations, city gas factories and factories for charging fuel cells or the like, it is unnecessary to fill it in a heavy bomb in a liquid state to transport it by land unlike hydrogen obtained by the electrolysis of water. For this, the cost of transportation can be reduced and the residual caustic soda can be supplied as the raw material for soda industries. However, this metal sodium reacts with water explosively to generate hydrogen, which is burned by its reaction heat. Particularly, it reacts violently with, for example, water, moistened air, carbon dioxide and hydrocarbon halides. In particular, it is necessary to take meticulous care for the reaction control and safety of a hydrogen generator in which water is added to metal sodium to generate hydrogen. Therefore, the structure of the hydrogen generator must be designed to hinder the combustion and oxidation of hydrogen produced by the reaction and reaction heat of metal sodium with water. For this, sodium may be stored in oils and water mists may be dropped from above on the oil layer while sodium is kept in the oils to mild the reaction. When water is dropped by instillation from plural nozzles (taps), the amount of hydrogen to be generated is increased. When water is sprayed pulse-wise from plural pressure water jetting nozzles toward metal sodium in the oil layer, the contact area between sodium and water is increased in a short time, a sharp reaction is caused. However, if water is added to sodium stored in oil, water which does not participate in the reaction is collected under the oil layer. Therefore, in order to react the water with sodium, the whole reactor is stirred by ultrasonic vibration to thereby the mixture solution of oil and water into contact with metal sodium to activate the reaction between water and metal sodium. In order to react the water directly with sodium, metal sodium floated in the oil phase may be pushed down by a control bar from the above to react metal sodium directly with water under the oil phase. In order to cause the reaction more violently, water may be directly added to metal sodium by spraying, instillation or pulse-wise addition after the oils for protecting metal sodium are withdrawn from the reactor under an atmosphere of dry inert gas such as argon or nitrogen or of hydrogen gas and hydrogen and caustic soda can be drawn from the top and bottom of the reactor respectively. A structure may be adopted in which a cooling jacket is provided on the outside periphery of the reactor to make cooling water flow in the case where a rise in temperature by the reaction heat is steep. Anti-corrosion materials such as stainless, polyethylene or polypropylene may be used for the reactor. Though metal magnesium which can produce hydrogen by reacting with hot water is produced by the molten salt electrolysis in the same manner as in the case of metal sodium, the amount of magnesium to be produced from sea water is as small as 11.2% of that of sodium. If this metal magnesium is used as a hydrogen-generating source, it entails an enormous cost further to reduce an oxide which is the residue of magnesium. In the mean time, a metal sodium residue after hydrogen is produced can be used as the raw material for soda industries as it is. Therefore, if metal sodium is specialized as a material for generation of hydrogen and metal magnesium is used as a light metal alloy material, the both respectively have a far-reaching economic effect.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0072] FIG. **1** is a schematic structural view showing one embodiment of the present invention.

[0073] FIG. **2** is a typical view of a temperature-difference thermionic power generator.

[0074] FIG. **3** is a schematic view of a temperature-difference thermionic power generation system using a solar heater.

[0075] FIG. **4** is a schematic view of a temperature-difference thermionic power generation system using a cylinder type spherical mirror.

[0076] FIG. **5** is a schematic view of a temperature-difference thermionic power generator and a solar battery power generation system using a strip type plane mirror.

[0077] FIG. **6** is a schematic view of a high thermionic power generator and a solar battery power generation system using a strip type plane mirror.

[0078] FIG. **7** is a production process diagram (I) in an electrolytic plant.

[0079] FIG. **8** is a production process diagram in a methanol plant.

[0080] FIG. **9** is a production process diagram in a vegetable plant.

[0081] FIG. **10** is a production process diagram in a fishery product-culturing plant.

[0082] FIG. **11** is a production process diagram (II) in an electrolytic plant.

[0083] FIG. **12** is a production process diagram (III) in an electrolytic plant.

[0084] FIG. **13** is a production process diagram (IV) in an electrolytic plant.

[0085] FIG. **14** is a production process diagram (V) in an electrolytic plant.

[0086] FIG. **15** is a production process diagram (VI) in an electrolytic plant.

[0087] FIG. **16** is a metal sodium fuel cycle system diagram.

[0088] FIG. **17** is a molten salt preheating auxiliary system diagram for molten salt electrolysis utilizing sunlight.

[0089] FIG. **18** is a schematic view of a hydrogen generator.

[0090] FIG. **19** is a heating system diagram of a vegetable plant utilizing dashing hot spring water.

[0091] FIG. **20** is a steam power generation heat collecting container utilizing reaction heat.

[0092] FIG. **21** is a schematic view of hydrogen generating equipment which no oil exists.

DETAILED DESCRIPTION OF THE INVENTION

[0093] Several embodiments of the present invention will be explained in detail with reference to FIG. **1** to FIG. **21**.

[0094] FIG. **1** is a schematic view showing an embodiment of the present invention. As shown in FIG. **1**, an onsite integrated production factory **1** according to the present invention includes an electrolytic plant **2**, an ethanol plant **2**, a vegetable plant **3** and a culturing plant **4** and these factories **2** to **4** are installed in a floating body vessel floated on the ocean, a structure on the coast or a structure on the land adjacent to the seashore. The energy obtained by fluid energy power generation utilizing wind and tide, temperature-difference power generation utilizing hot water heated by the infrared ray of sunlight or high-temperature hot spring water such as submarine hot spring and coastal hot spring, and sea water or river water, or solar cell power generation utilizing the visible rays of sunlight or the like are supplied to the integrated production factory **1**. The main raw materials of the products of integrated production factory **1** of the present invention is sea water such as deep sea water and surface sea water. The sea water is decomposed in the electrolytic plant **2** to produce fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, oxygen and the like. In electrolytic plant **2**, first, sea water pumped by a storage pump is treated with a reverse osmosis membrane to produce fresh water and then, oxalic acid or sodium oxalate produced in the ethanol plant **3** is poured into the remainder 6% salt brackish water to remove calcium. Then, caustic soda produced in the electrolytic plant **2** is poured into the filtrate to precipitate only a magnesium salt, and then, the solution is neutralized by hydrochloric acid produced in the ethanol plant **2** to form magnesium chloride, which is then subjected to molten salt electrolysis to produce metal magnesium. Hydrochloric acid produced in the electrolytic plant **2** is poured into the filtrate, on the other hand, to convert sodium sulfate into sodium chloride and the resulting filtrate including sodium chloride is subjected to an ion exchange membrane to produce brine having a concentration 20% or more and then, the brine is electrolyzed to produce caustic soda and byproducts including chlorine, hydrogen and oxygen. On the other hand, waste sulfuric acid is concentrated by a reverse osmosis membrane and concentrated sulfuric acid is used for cellulose decomposition in the ethanol plant **3**. In the ethanol plant **3**, deep ocean water pumped in the electrolytic plant **2**, landed starch and malt, rice, mold starter, millet and the like are used as the raw materials to run alcohol fermentation, thereby manufacturing deep sea water beer or sake, and cellulose materials such as landed wood chips, scrap wood and marc of cane are decomposed by sulfuric acid produced in the electrolytic plant **2** and combined with fresh water manufactured in the electrolytic plant **2** to ferment, thereby manufacturing fuel bioethanol. Here, carbon dioxide generated by pouring caustic soda manufactured in the electrolytic plant **2** into a part of the cellulose material landed for producing bioethanol, or carbon dioxide obtained by the alcohol fermentation, and carbon monoxide generated by red-heating landed cokes are absorbed by caustic soda to produce sodium oxalate or oxalic acid, which is then used as an agent for removing calcium in the sea water or brine used in the electrolytic plant **2**. The purity of magnesium chloride or sodium chloride to be supplied as the raw material of the molten salt electrolysis can be improved in advance by this calcium-removing treatment. Also, carbon dioxide generated by the alcohol fermentation in the ethanol plant **3**, fresh water obtained from deep ocean water or surface sea water by desalination in the electrolytic plant **2**, 350 to 800 nm visible rays removed by the bandpass filter or cold filter during daylight hours and is not supplied for sunlight power generation or artificial light including lamp light and light emitted from a light emitting diode are used to undergo photosynthesis, wherein the day and night are switched artificially to produce vegetables day and night. Oxygen generated at the unexposed time is supplied for the supplement of oxygen concentration in sea water in the culturing plant **5** and for suppressing the generation of a red tide, and also supplied to the deep see water pumped in the electrolytic plant **2**. The deep sea water increased in oxygen concentration is discharged in surface sea water for growing fishes in fisheries or underwater reefs where fish live. The deep ocean water pumped in the electrolytic plant **2** is supplied for the temperature-difference power generation, is then used to cool for cold district farm room of vegetable plant **4** and then, the deep sea water is divided into two lines. The deep sea water in one of these lines is subjected to desalination in the electrolytic plant **2** and is then used as the raw material of beer or sake in the ethanol plant **3** or as the raw material used for the water culture method in the vegetable plant **4**, and the other is discharged into a cold current fishery preserve or discharged into the surface ocean water as it is to form fisheries having an enclosure for warm current fisheries, bottom-water fishes or shrimps and crabs and natural fisheries and underwater reefs for migratory fishes which cluster around the deep sea water rich in nutrients around the fisheries.

[0095] FIG. **2** is a schematic view of a temperature-difference thermionic power generator. A temperature-difference power generator **6** has a triple tube structure and consists of an inner tube **7**, a middle tube **8** and an outer tube **9**, wherein thermionic thermoelements **10** are arranged in the middle tube **8**. A high-temperature liquid **11** such as warm water heated by a solar heater, hot oil or water heated in heat collecting pipe arranged on the focus line of sunlight converged by a light condensing means such as a lens or mirror, heat waste water in the electrolytic plant **2** and high-temperature spring water such as a submarine hot spring and coastal hot spring is introduced from a tap **12**, discharged from a tap **13** and returned to a heat collecting section. At the same time, a cool water **14** including deep sea water and surface ocean water pumped in the electrolytic plant **2** is introduced from a tap **15** and discharged from a tap **16**. A thermionic thermoelement used here has a plane square shape, and therefore, the outside wall of the inner tube **7** is made into a polygon tubular surface to apply one surface of the thermionic thermoelement in close contact with the outside wall of the inner tube **7** and to stick the other to the inside surface of the middle tube **8** through a heat conductive adhesive. Then, the deep sea water which has been subjected to the temperature-difference thermionic power generation **6** is used to cool the cold district farm room of vegetable plant **4** and then, the deep sea water is divided into two lines. The deep sea water in one of these lines is subjected to desalination in the electrolytic plant **2** and is then used as the raw material of beer or sake in the ethanol plant **3**, and the other is discharged into a cold current fishery preserve in the culturing plant **5** or discharged into the surface ocean water as it is to form fisheries having an enclosure for warm current fisheries, bottom-water fishes or shrimps and crabs and natural fisheries and underwater reefs for migratory fishes which cluster around the deep sea water rich in nutrients around the fisheries.

[0096] FIG. **3** is a schematic view of temperature-difference thermionic power generating equipment using a solar heater. A heat collecting pipe **17** of a solar heater stretched around the surface of the deck is irradiated with a sunlight **18** to be a warm water **11** which is circulated in the heat collecting pipe **17**, introduced from a high-temperature liquid port **12** of the temperature-difference thermionic generator **6** and then discharged from a high-temperature liquid outlet port **13**. Then, the warm water **11** is returned to the heat collecting pipe of the solar heater through a circulating pump **19**. On the other hand, a cool water **14** including deep ocean water or surface ocean water is introduced from a cold water port **15** and discharged from a cold water discharge port **16**. Thermionic power generation is accomplished by a temperature difference between the high-temperature liquid **12** and the cold water **14**.

[0097] FIG. **4** is a schematic view of a temperature-difference thermionic power generation system using a cylinder type spherical mirror. A cylinder type spherical mirror **20** is set as a light incident skylight introducing light as a light source of photosynthesis in the vegetable plant and is provided with a cold filter film **23** which transmits visible rays **21** and reflects light having a wavelength **22** of 800 nm or more. Here, this film is applied to the room side so that the outside air surface side glass surface can be easily washed with water though this film may be applied to the outside air side or the room side. The cylinder type spherical mirror **20** is manufactured by the method disclosed in Jpn. Pat. Appln. KOKAI Publication No. 53-5647 by the inventors of the patent application of this case. The visible rays having a wavelength of 800 nm or less among the incident sunlight **18** is transmitted through the skylight **20** and used for the photosynthesis of vegetables. A heat ray **22** reflected by the cold filter film **23** is converged to a heat collecting pipe **24** arranged on the focus line of sunlight and the high-temperature liquid **11** such as hot water and hot oil heated by heat conversion using sunlight is circulated in the heat collecting pipe **24**, is introduced from the high-temperature liquid introduction port **12** of the temperature-difference thermionic power generating equipment **6**, discharged from the high-temperature liquid discharge port **13** and then returned to the heat collecting pipe **24** through the circulating pump **19**. The cold water **14** including deep ocean water or surface ocean water is introduced from the cold introduction port **15** and discharged from the cold water discharge port **16**. Thermionic power generation is accomplished by a temperature difference between the high-temperature liquid **12** and the cold water **14**. For the tracking of sunlight, each flapping angle of the four corners of the skylight **20** (mirror with a cylindrical mirror surface) is given by an operating device **25** controlled by a computer. The heat rays **22** which are the reflected light are always ray-converged to the heat collecting pipe **24**. With regard to the light to be used for the photosynthesis in the vegetable plant, the quantity of light and irradiation position are not almost changed because a meniscus structure lens is used.

[0098] FIG. **5** is a schematic view of a temperature-difference thermionic power generation and a solar battery power generation system using a strip type plane mirror. A plane glass plate **26** is placed as a skylight for incident of light as a light source for photosynthesis in the vegetable plant and a strip-like mirrors **27** provided with a cold filter film which reflects heat rays having a wavelength of 600 nm or more and transmits light having a wavelength less than 600 nm are arranged in parallel on the plane glass plate **26**. A flapping angle is set to each strip by a flapping angle operating device controlled by a computer, and the incident sunlight **18** is reflected on each strip type plane mirror **27**, converged to the focus line surface and forms high-density light. Here, a solar battery array **28** is arranged, and a strip-like two-axis concave mirror **29** with a cold filter which reflects light having a wavelength of 800 nm or more is stuck to the front surface of this solar battery array **28** and a radiator **30** (cooling water) is attached to the backside of the solar battery array **28**.

[0099] The electric power of this solar battery power generation is supplied to a part of the electric power of the integrated production factory. The infrared rays **31** which are reflected on the strip-like two-axis concave mirror **29** with a cold filter form parallel rays and are converged to the heat collecting pipe **24** placed on the center of the plane glass plate **26**. The high-temperature liquid **11** such as hot water and hot oil heated by heat conversion using sunlight is circulated in the heat collecting pipe **24**, introduced from the high-temperature introduction port **12** of the temperature-difference thermionic power generating equipment **6**, discharged from the high-temperature discharge port **13**, and set back to the heat collecting pipe **24** through the circulation pump **19**. The cold water **14** including deep ocean water or surface ocean water is introduced from the cold introduction port **15** and discharged from the cold water discharge port **16**. Thermionic power generation is accomplished by a temperature difference between the high-temperature liquid **12** and the cold water **14**. In the method in which electric power is obtained from a solar battery like that of this embodiment, it is necessary to irradiate the solar battery with light having a wavelength of 600 to 750 nm and therefore, light having a wavelength of 600 to 800 nm is supplemented by artificial light in the culture of vegetables according to the need.

[0100] FIG. **6** is a schematic view of a high thermionic power generation and a solar battery power generation system using a strip type plane mirror. A plane glass plate **26** is placed as a skylight for incident of light as a light source for photosynthesis in the vegetable plant and strip-like mirrors **27** provided with a cold filter film which reflects heat rays having a wavelength of 600 nm or more and transmits light having a wavelength less than 600 nm are arranged in parallel on the plane glass plate **26**. A flapping angle is set to each strip mirror by a flapping angle operating device controlled by a computer, and the incident sunlight **18** is reflected on each strip type plane mirror **27**, converged to the focus line surface and forms high-density light. Here, a solar battery array **28** is arranged, and a cold filter film **32** which reflects light having a wavelength of 800 nm or more is vapor-deposited on the front surface of the solar battery array **28** and a radiator **30** (cooling water) is attached to the backside of the solar battery array **28**. The electric power of this solar battery power generation is supplied to a part of the electric power of the integrated production factory. The infrared rays **31** which are reflected on the cold filter film **32** are further converged to conduct about 500° C. heat to the high-temperature thermionic thermoelement **34** through the heat collecting plate **33** placed on the center of the plane glass plate **26**. The cold water **14** is introduced from the cold water introduction port **15** into the backside of the high-temperature thermionic thermoelement **34** and discharged from the cold water discharge port **16**. Thermionic power generation is caused by the temperature difference between the heat collecting plate **33** and the cold water **14**. In the method in which electric power is obtained from a solar battery like that of this embodiment, it is necessary to irradiate the solar battery with light having a wavelength of 600 to 750 nm and therefore, light having a wavelength of 600 to 800 nm is supplemented by artificial light in the culture of vegetables according to the need.

[0101] FIG. **7** is a view of a production process diagram in the electrolytic plant. A sea water **35** having a salt content of about 3% such as deep sea water and surface sea water is pumped by a storage pump and the sea water to which high pressure is applied is allowed to pass through a reverse osmosis membrane **36** to produce fresh water **37**. Here, sodium oxalate or oxalic acid **39** produced in the ethanol plant **3** is poured into a brine **38** for the purpose of removing Ca in the brine **38** which has not been passed through the reverse osmosis membrane **36** and has a salt content of about 6% and in which NaCl, $MgCl_2$, $MgSO_4$, NaBr, $CaSO_4$, KCl, $MgBr_2$ and the like to precipitate and remove calcium oxalate (CaC_2O_4) **40**. A hydrochloric acid **41** produced in the electrolytic plant **2** is poured into this calcium oxalate to recover oxalic acid **39** and concentrated $CaCl_2$ is subjected to molten salt electrolysis **42** to produce a metal calcium **43** and a chlorine **44**. On the other hand, in order to make magnesium free from the filtrate **45** from which Ca has been removed, a caustic soda **46** produced in the electrolytic plant **2** is poured into the filtrate **45** to precipitate and remove magnesium hydroxide **47**. The hydrochloric acid **41** produced in the electrolytic plant **2** is poured into the magnesium hydroxide to make magnesium chloride **41**, which is then subjected to molten salt electrolysis **42** to produce metal magnesium **48**. On the other hand, in order to remove sulfuric acid from the filtrate **49** from which Mg has been removed, the filtrate neutralized by the hydrochloric acid **41** produced in the electrolytic plant **2** is subjected to transmission/separation by using an ion exchange resin electrodialysis **50**. On the other hand, a brine **51** having a salt content of about 20% is further concentrated to a salt content of 30% by heating and is then subjected to solution electrolysis **52** to produce caustic soda **46**. A large part of this caustic soda **46** is further subjected to molten salt electrolysis **42** to produce metal sodium **54**, which is then stored in petroleum. An oxygen **55** is produced as a byproduct of this molten salt electrolysis **42**. Also, in the solution electrolysis **52**, chlorine **44**, hydrogen **54** and oxygen **55** are produced. Chlorine gas **44** is reacted with hydrogen gas **54** to produce hydrochloric acid **41**. On the other hand, a dilute sulfuric acid **57** removed by the electrodialysis **50** using an ion exchange membrane **36** is concentrated by the ion exchange resin to separate a concentrated acid **58** from a fresh water **37**. A large part of oxygen gas **55** produced here is bubbled in the sea water from the culturing plant **5**. Though oxalic acid or sodium oxalate **39** is poured into the brine **38** which has not been passed through the reverse osmosis membrane **36** here, the brine **38** may be first poured into sea water **35** to carry out calcium-removing treatment. If so, the amount of fresh water to be obtained through the reverse osmosis membrane **36** is increased and also, brine having a salt content of 6% or more can be obtained.

[0102] FIG. **8** is a production process diagram in the ethanol plant. The major purpose of the ethanol plant **3** is to secure a large amount of carbon dioxide which is necessary and essential for photosynthesis in the vegetable plant **4** with the intention of furnishing the source of carbon dioxide by alcohol fermentation. A deep fresh water **60** obtained by desalinating deep ocean water by the reverse osmosis membrane pumped in the electrolytic plant **2** is used for, particularly, drinking beer and sake and brewing grains **59** such as landed malt, rice, mold starter, corn, starch and the like and particularly, starch is treated with yeast contained therein to convert starch into glucose, fructose, cane sugar, maltose or the like by amylase and maltase secreted from the yeast. Then, these sugars are subjected to an alcohol fermentation **61** made by an alcoholic decomposition enzyme zymase, thereby brewing deep sea water beer **63** in a beer plant **62** and deep water sake **65** in a sake plant **64**. A carbon dioxide **66** generated by this alcohol fermentation **61** is supplied for the photosynthesis in the vegetable plant **4**. On the other hand, a surface fresh water **68** obtained by desalinating surface ocean water pumped in the electrolytic plant **2** by a reverse osmosis membrane is used for this fuel bio-ethanol **67**. The concentrated sulfuric acid **58** produced in the electrolytic plant **2** is added to a ligneous biomass such as landed wood, wood chip, branches, squeezed residues **69** of canes to solubilize a cellulose **70** and the solubilized cellulose is decomposed into sugars by a dilute sulfuric acid **58**. The alcohol fermentation **61** is caused by an alcohol decomposition enzyme excreted from yeast to produce a bio-ethanol **67** through a distillation dehydration process. Here, the sulfuric acid **58** is recovered and reused. The carbon dioxide **66** generated by the alcohol fermentation **61** is supplied for the photosynthesis of vegetable plant **4**. In the ethanol plant **3**, on the other hand, sodium oxalate and oxalic acid **39** are produced as agents used to remove calcium in sea water in the electrolytic plant **2**. Also, carbon dioxide generated by using the surface fresh water **68** obtained by desalinating surface ocean water pumped in the electrolytic plant **2** by a reverse osmosis membrane and by pouring caustic soda **46** manufactured in the electrolytic plant **2** into the landed wood/wood chip **69** or the like or carbon dioxide obtained by the alcohol fermentation, and carbon monoxide generated by red-heating cokes are absorbed by caustic soda to produce sodium oxalate **39**, which is then used as an agent for removing calcium in the electrolytic plant **2**.

[0103] FIG. **9** is a view of a production process in the vegetable plant **4**. The main object of vegetable plant **4** is to provide a large amount of fresh vegetables to consumer places. However, it is important to supply oxygen to surface sea water poor in dissolved oxygen to suppress the generation of red tides, thereby eliminating ocean dead zones. For this, the oxygen gas generated by the photosynthesis in the vegetable plant **4** is returned to sea water from the culturing plant **5**. Necessary elements in the vegetable production are a temperature, water, light, carbon dioxide and fertilizers for photosynthesis. As the water, the deep fresh water **60** and the surface fresh water **68** are used. In a plant **71** in the vegetable plant **4**, it is important to secure water because a solution culture method **72** is used. A soil culture method **75** may be used in a coastal plant **73** and a land plant **74** adjacent to the seashore. The recovery **76** of fertilizers is also important to suppress such a phenomenon that fertilizers are washed away in sea water and that is one of the causes of deficiency of oxygen concentration in sea water. Because the culture circumstance is controlled by a computer in the vegetable plant, deep ocean water is supplied through a pipe and, according to the case, electric cooling is combined to limit the temperature of a vegetable room to 15° C. or less in the place where cold district vegetables or cold upland vegetables are produced, and the high-temperature liquid used in the temperature-difference power generation is supplied through a pipe to settle a growing circumstance kept at about 25° C. in the case of tropical vegetables. Electric cooling and a refrigerator are necessary to store harvested vegetables. In vegetable plant **4** utilizing fluid energy power generation using wind, tide and the like, vegetables can be produced day and night even in the weather with wind and rain. This is a perfectly controlled vegetable plant utilizing an artificial light **77** such as a fluorescent lamp and a light emitting diode without utilizing sunlight. Vegetables are made to proceed with photosynthesis **77** by light having a wavelength of 400 to 700 nm. There are a strong light reaction which is run by light having a peak at a wavelength of 430 nm and a peak at a wavelength of 630 nm and a weak light reaction which is run by light having a peak at a wavelength of 650 nm and a peak at, a wavelength of 700 to 750 nm, such as seed sprouting, flower differentiation, blooming, development of a cotyledon, chlorophyll synthesis and internode elongation. It is necessary to select the wavelength of the irradiation corresponding to the condition of growth. In order to exactly secure the irradiation **77** of light, the amount of carbon dioxide **66** to be supplied and also to always produce oxygen **55** generated when the irradiation of light is stopped, ON-OFF of the artificial light **77** and the installation of plural vegetables production rooms are necessary. It is possible to produce the vegetables **79** which are independent of climate and weather and need no labor by controlling by a computer the circumstance of the culturing of vegetables.

[0104] FIG. **10** is a production process diagram in the culturing plant. The main object of the culturing plant **5** is to make a fishery rich in nutrients and a fish preserve and an underwater reef where fish live which are rich in dissolved oxygen by supplying oxygen **55** generated in the vegetable plant to deep ocean water **90** pumped in the electrolytic plant by bubbling and by discharging (**92**) deep ocean water **90** on surface sea water **91**. Also, the generation of red tides can be suppressed and the coastal area dead zones that are being spread in seashores and gulfs can be eliminated by increasing dissolved oxygen of the surface water by bubbling oxygen from the underwater. An oxygen discharge pipe extended to the fish preserve, to underwater reef where fish live, an to the bottom or middle of the sea is installed as a measures for dissolving oxygen in the sea water and a water-repellent porous film with 3 μm of pore diameter is applied and stretched on the interface of the sea water at the gas outlet of the pipe. When 1 atm oxygen gas is sealed in the pipe, the oxygen gas puffs out by a water depth of 5 m, but the sea water flows backward to the pipe at a depth larger than 5 m. Therefore, an oxygen seal pressure higher than the pressure at which sea water flow backward is necessary. α is a pressure decided by the hole diameter of the porous film. Therefore, when α is set to 0.5 atm from the actual value obtained in the case where the pore diameter is 3 μm, it is necessary to apply a pressure of 2.5 atm or more ($1+1+\alpha$) at a surface depth of 10 m, 11.5 atm or more (1+10+α) at a surface depth of 100 m and 31.5 atm or more (1+30+α) at a surface depth of 300 m. When, in the offshore marine plant **71**, oxygen **55** produced in the vegetable plant **4** is added to deep ocean water **90** pumped in the electrolytic plant **2** to discharge (**92**) deep ocean water **90** under the sea while taking this oxygen seal pressure and the sea depth of the pipe into account, this results in the formation of the natural underwater reef **94** for warm current fishes such as tunas, bonitos, mackerels and sardines in sea water having a temperature of 10° C. or more, and cold current fishes such as herrings, codfishes, trout and yellowtails and migratory fishes such as tunas, herrings and sauries in sea water having a temperature less than 10° C. The culturing **95** of fishes and the culturing **96** of shellfishes and crustaceans such as abalones and lobsters is carried out in a fish preserve with water **93** preserved at the ship bottom of the marine plant **71**. When, in the coastal plant **73** located in a place where the sea bottom is relatively shallow, oxygen **55** produced in the vegetable plant **4** is added to deep ocean water **90** pumped in the electrolytic plant **2** to discharge (**92**) deep ocean water **90** to the sea bottom, this results in the formation of an underwater reef **97** for bottom water fishes such as flatfishes, codfishes and flounders. Yellowtails and tunas are cultured in a natural fish preserve **98** of which the surroundings are enclosed by a fence on the marine around the coastal plant **73**, and shellfishes and crustaceans such as prawns and ormers are cultured in a ship bottom fish preserve **99**. Eels and sweet fishes and the like are cultured by inland water culturing **100** in a fish preserve on a land plant **93**.

[0105] FIG. **11** is a production process diagram in the electrolytic plant (II). In the electrolytic plant (I) shown in FIG. **7**, first oxalic acid **39** is used to undergo a calcium-removing process. However, in this electrolytic plant (II), first magnesium is separated. Specifically, the sea water **35** having a salt content of about 3% such as deep sea water and surface sea water is pumped by a storage pump and the sea water to which high pressure is applied is allowed to pass through the reverse osmosis membrane **36** to produce fresh water **37**. Here, in order to remove magnesium from the brine which has not been passed through the reverse osmosis membrane **36** and has a salt content of about 6% and in which NaCl, $MgCl_2$, $MgSO_4$, NaBr, $CaSO_4$, KCl, $MgBr_2$ and the like are dissolved, caustic soda **46** produced in the electrolytic plant **2** is poured into the brine to precipitate and remove magnesium hydroxide **47**. Hydrochloric acid **41** produced in the electrolytic plant **2** is poured into this magnesium hydroxide to obtain magnesium chloride, which is then subjected to molten salt electrolysis **42** to produce metal magnesium **48** and chlorine gas **44**. In order to remove sulfuric acid from the filtrate **49** from which magnesium has been removed, the filtrate neutralized by hydrochloric acid **41** produced in the electrolytic plant **2** is subjected to ion exchange resin electrodialysis **50** and the separated brine **51** having a salt content of about 20% is further thermally concentrated by heating to a concentration of 30%, followed by solution electrolysis **52** to produce caustic soda **46**. A large part of this caustic soda **46** is further subjected to molten salt electrolysis **42** to produce metal sodium **54**, which is then stored in petroleum. Oxygen **55** is produced as a byproduct of this molten salt electrolysis **42**. Also, in the solution electrolysis **52**, chlorine **44**, hydrogen **54** and oxygen **55** are produced. This chlorine gas **44** is reacted with hydrogen gas **54** to produce hydrochloric acid **41**. On the other hand, sodium oxalate or oxalic acid **39** which is produced for the purpose of separating Ca in the ethanol plant **3** is poured into a mixture solution **101** of sulfuric acid and calcium sulfate removed by the ion exchange electrodialysis **50** to precipitate and remove calcium oxalate (CaC_2O_4) **40**. Hydrochloric acid **41** produced in the electrolytic plant **2** is poured into this calcium oxalate to recover oxalic acid **39**, and the concentrated $CaCl_2$ is subjected to molten salt electrolysis **42** to produce metal calcium **43** and chlorine **44**. On the other hand, filtrate **45** and dilute sulfuric acid **58** from which Ca has been removed are concentrated by the reverse osmosis membrane **36** and separated into concentrated sulfuric acid **58** and fresh water **37**. A large part of oxygen gas **55** is charged from a culturing plant in the sea water by bubbling.

[0106] FIG. **12** is a production process diagram in the electrolytic plant (III). In electrolytic plant (I) shown in FIG. **7**, first, oxalic acid **39** is used to undergo a calcium-removing process **40**. However, in this electrolytic plant (III), the brine having a salt content of about 6% and removed by the reverse osmosis membrane method is parched (**102**) by the conventional salting process to isolate calcium sulfate based on a difference in solubility. Specifically, the sea water **35** having a salt content of about 3% such as deep sea water and surface sea water is pumped by a storage pump and the sea water to which high pressure is applied is allowed to pass through the reverse osmosis membrane **36** to produce fresh water **37**. Here, the brine **38** which has not been passed through the reverse osmosis membrane **36** and has a salt content of about 6% and in which NaCl, $MgCl_2$, $MgSO_4$, NaBr, $CaSO_4$, KCl, $MgBr_2$ and the like are dissolved is parched (**102**) to remove calcium sulfate **103** which is first precipitated. In order to remove magnesium from the filtrate **45** from which Ca ions have been removed, caustic soda **46** which is produced in the electrolytic plant **2** is poured into the filtrate to precipitate and separate magnesium hydroxide **47**. Hydrochloric acid **41** produced in the electrolytic plant **2** is poured into magnesium hydroxide **47** to produce magnesium chloride, which is then subjected to molten salt electrolysis **42** to produce metal magnesium **48** and chlorine gas **44**. On the other hand, the NaCl/KCl mixture filtrate from which Mg has been removed is neutralized by hydrochloric acid **41** produced in the electrolytic plant **2** and brine **51** concentrated to about 30% is subjected to solution electrolysis **52** to produce caustic soda **46**. A large part of this caustic soda **46** is subjected to molten salt electrolysis **42** to produce metal sodium **54**, which is then stored in petroleum. Oxygen **55** is produced as a byproduct of this molten salt electrolysis **42**. Also, in the solution electrolysis **52**, chlorine **44**, hydrogen **54** and oxygen **55** are produced. This chlorine gas **44** is reacted with hydrogen gas **54** to produce hydrochloric acid **41**. A large part of oxygen gas **55** produced here is charged in the sea water by bubbling from the culturing plant **5**.

[0107] FIG. **13** is a production process diagram in the electrolytic plant (IV). In electrolytic plant (I) shown in FIG. **7**, first, oxalic acid **39** is used to undergo a calcium-removing process **40**. However, in this electrolytic plant (IV), the brine having a salt content of about 6% and removed by the reverse osmosis membrane method is further concentrated by ion exchange resin electrodialysis **50** to prepare a concentrated brine having a salt content of about 20% and then, the concentrated brine is parched (**102**) by the conventional salting process to isolate a salt from magnesium. Specifically, the sea water **35** having a salt content of about 3% such as deep sea water and surface sea water is pumped by a storage pump and the sea water to which high pressure is applied is allowed to pass through the reverse osmosis membrane **36** to produce fresh water **37**. Here, the brine **38** which has not been passed through the reverse osmosis membrane **36** and has a salt content of about 6% and in which NaCl, $MgCl_2$, $MgSO_4$, NaBr, $CaSO_4$, KCl, $MgBr_2$ and the like are dissolved is treated by ion exchange resin electrodialysis **50** to remove sulfuric acid ions, thereby removing magnesium sulfate and calcium sulfate **104**. The brine which has a concentration of about 2% and is extracted from ion exchange resin electrodialysis **50** is made to pass through reverse osmosis membrane **36** to produce fresh water **37**. On the other hand, the brine having a salt content of about 20% is parched (**102**) to prepare a brine **51** having a salt concentration of about 30%, which is then subjected to solution electrodialysis **52** to produce caustic soda **46**. A large part of this caustic soda **46** is subjected to molten salt electrolysis **42** to produce metal sodium **54**, which is then stored in petroleum. Oxygen **55** is produced as a byproduct of this molten salt electrolysis **42**. Also, in the solution electrolysis **52**, chlorine **44**, hydrogen **54** and oxygen **55** are produced. This chlorine gas **44** is reacted with hydrogen gas **54** to produce hydrochloric acid **41**. On the other hand, in order to remove magnesium from the filtrate **45** (bittern), caustic soda **46** produced in the electrolytic plant **2** is poured into the filtrate to precipitate and remove magnesium hydroxide **47**, into which hydrochloric acid **41** produced in the electrolytic plant **2** is then poured to prepare magnesium chloride, which is then subjected to molten salt electrolysis **42** to produce metal magnesium **48** and chlorine gas **44**. A large part of oxygen gas **55** produced here is charged in the sea water by bubbling from the culturing plant **5**.

[0108] FIG. **14** is a production process diagram in the electrolytic plant (V). In electrolytic plant (I) shown in FIG. **7**, first, oxalic acid **39** is used to undergo a calcium-removing process **40**. However, in this electrolytic plant (V), first, sea water **35** is concentrated by ion exchange resin electrodialysis **50** to prepare concentrated brine having a salt content of about 20%, which is parched by the usual salt production method to isolate salt from magnesium. Specifically, the sea water **35** having a salt content of about 3% such as deep sea water and surface sea water is pumped by a storage pump and the sea water is treated by ion exchange resin electrodialysis **50** to separate sulfuric acid ions, thereby removing magnesium sulfate and calcium sulfate **104**. The brine which has a concentration of about 2% and is extracted from ion exchange resin electrodialysis **50** is made to pass through the reverse osmosis membrane **36** to produce fresh water **37**. On the other hand, the brine having a salt content of about 20% is parched (**102**) to prepare brine **51** having a salt concentration of about 30%, which is then subjected to solution electrodialysis **52** to produce caustic soda **46**. A large part of this caustic soda **46** is subjected to molten salt electrolysis **42** to produce metal sodium **54**, which is then stored in petroleum. Oxygen **55** is produced as a byproduct of this molten salt electrolysis **42**. Also, in the solution electrolysis **52**, chlorine **44**, hydrogen **54** and oxygen **55** are produced. This chlorine gas **44** is reacted with hydrogen gas **54** to produce hydrochloric acid **41**. On the other hand, in order to remove magnesium from the filtrate **45** (bittern), caustic soda **46** produced in the electrolytic plant **2** is poured into the filtrate to precipitate and remove magnesium hydroxide **47**, to which hydrochloric acid **41** produced in the electrolytic plant **2** is then poured to prepare magnesium chloride, which is then subjected to molten salt electrolysis **42** to produce metal magnesium **48** and chlorine gas **44**. A large part of oxygen gas **55** produced here is charged in the sea water by bubbling from the culturing plant **5**.

[0109] FIG. **15** is a production process diagram in the electrolytic plant (VI). In electrolytic plant (I) shown in FIG. **7**, first, sodium oxalate or oxalic acid **39** is used to undergo a calcium-removing process to precipitate calcium oxalate **40**, to which hydrochloric acid **41** is added, and obtained calcium chloride **105** is subjected to molten salt electrolysis **42** to produce metal calcium. In this electrolytic plant (VI), calcium chloride **105** is used as an electrolytic bath temperature dropping agent for producing metal sodium. The sea water **35** having a salt content of about 3% such as deep sea water and surface sea water is pumped by a storage pump and the sea water to which high pressure is applied is allowed to pass through the reverse osmosis membrane **36** to produce fresh water **37**. Here, in order to remove Ca in the brine **38** which has not been passed through the reverse osmosis membrane **36** and has a salt content of about 6% and in which NaCl, $MgCl_2$, $MgSO_4$, NaBr, $CaSO_4$, KCl, $MgBr_2$ and the like are dissolved, sodium oxalate or oxalic acid **39** which is produced in ethanol plant **3** is poured into the brine to precipitate and remove calcium oxalate (CaC_2O_4) **40**. Hydrochloric acid **41** produced in the electrolytic plant **2** is poured into this calcium oxalate to recover oxalic acid **39** and concentrated calcium chloride **105** and sodium chloride **51** concentrated by ion exchange membrane **50** are respectively concentrated under heating. A mixture salt of about 60% of sodium chloride and about 40% of calcium chloride is subjected to molten salt electrolysis **42** carried out at about 600° C. Then, produced calcium-containing sodium is cooled (**106**) to 110° C. by utilizing the fact that the melting point (97.81° C.) is extremely lower than that (839° C.) of calcium, to separate metal sodium **54** from metal calcium **43** and metal sodium **54** is stored in petroleum. On the other hand, in order to make magnesium free from filtrate **45** from which Ca has been removed, caustic soda **46** is poured into filtrate **45** to precipitate and remove magnesium hydroxide **47**. Hydrochloric acid **41** is poured into magnesium hydroxide **47** to make magnesium chloride, which is then subjected to molten salt electrolysis **42** to produce metal magnesium **48**. On the other hand, sulfuric acid **57** which does not pass the ion exchange membrane **50** is concentrated by a reverse osmosis membrane and also distilled to produce concentrated sulfuric acid **58**.

[0110] In an embodiment of the present invention, the integrated production factory **1** is a marine factory and has a structure of a floating body vessel. When the floating body vessel is moored in a sea area where the tidal current is faster, such as the Kuroshio area near Miyake island in Japan, a power generating system is installed in which wind wheel impeller is set to the surface of the floating vessel and a water wheel impeller is set to the underside of the floating vessel to thereby drive a power generator. Also, when the floating body vessel is fixed to a prescribed position by a mooring mechanism, a vertical rotation axis type wind or water wheel is used as the wind or water wheel. Two or more of these vertical rotation axis type wind or water wheels are installed on the floating body vessel. One wind or water wheel of a pair of wind or water wheels and the other are selected such that the directions of the rotations of the both are opposite to each other to drive the power generator by the rotation axis of each wind or water wheel. In this case, the turning forces in opposite directions cancel the reaction force which acts on the floating body vessel. Therefore, it is unnecessary to enforce the mechanical strength of the mooring mechanism for mooring the floating body vessel. Accordingly, because this floating body vessel can be installed not only in a sea area of shallows but also in a sea area having a relatively higher depth, it produces large economical effects. A marine integrated production factory can be made in which such a floating body vessel plant is used as a mother ship and deep ocean water plays a key role.

[0111] In another embodiment of the present invention, the integrated production factory shown in FIG. **1** is a marine factory utilizing a crude oil tanker. Marine wind force is converted into electric power by a vertical rotation axis type wind wheel. This integrated production factory is designed to be a nautical and open ocean factory using this electric power to produce fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, oxygen and the like. Hydrogen produced in this factory is used for the fuel of the vessel. The marine factory is only constituted of the electrolytic plant and the ethanol plant, vegetable plant and culturing plant do not exist. For example, this factory leaves Japan and comes to anchor in East China Sea to produce fresh water and to unload the produced fresh water including Na, Mg, Cl_2 produced at the same time at a port of China. Then, after fresh water, Na, Mg, Cl_2 are again produced in South China Sea and the Indian Ocean and these products are unloaded at ports in the countries in the Middle East. Crude oil is filled in the fresh tank at ports in the Middle East and the factory returns to Japan. While the factory comes back to Japan, the storing of fresh water is limited and produced fresh water is electrolyzed to produce hydrogen, which is supplied for the fuel of the factory itself, and also, hydrochloric acid is produced from hydrogen and chlorine. Hydrogen and Cl_2 are unloaded at ports in Sri Lanka, Singapore, Manila or Taiwan. Then, in Japan, hydrogen, Cl_2, Na and Mg produced on the voyage and the petroleum are unloaded at ports. This factory is a trading ship type nautical and open ocean factory.

[0112] In a further embodiment of the present invention, the integrated production factory in FIG. **1** is a coastal factory and ocean wind force is converted into electric force by using a horizontal rotation axis windmill and a vertical rotation axis windmill. In the horizontal rotation axis windmill, the rotations of a pair of front and back propellers rotated reversely are connected directly to the rotor and stator of the generator and in the vertical rotation axis windmill, the rotations of a pair of vertical propellers rotated reversely are connected directly to the rotor and stator of the generator, ensuring that electric energy equivalent to a flow rate twice the actual flow rate can be extracted by their relative rotations. This coastal integrated production factory is the integrated production factory **1** including the electrolytic plant **2**, ethanol plant **3**, vegetable plant **4** and culturing plant **5** which use the electric power obtained by these windmills. If the coastal integrated production factory is located at Sweden, the following situation is considered. In Northern Europe, daylight hours are extremely short particularly in winter, and this is a hindrance to the growth of vegetables and, of course, to solar power generation. Particularly, Sweden forwards the post-petroleum policy and also, maintains the policy of post-nuclear power generation. Then, Sweden promotes the utilization of forests and therefore, energy crops are cultured in cultivated lands and unused lands to forward the generation of fuel and power generation using biomass. Abundant energy sources in Sweden are water and forests and sunlight cannot be expected. However, there is abundant wind force in Baltic Sea and particularly, in the vicinity of Gotland Islands. Because the seashore is shallow, not a floating structure but a structure having its foundation on the bottom of the sea is suitable to the integrated production factory **1**. However, because the salt concentration of Baltic Sea is as low as 1%, imported rock salts may be used for the production of metal sodium. In light of this, fresh water, sodium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, oxygen and the like are produced from surface sea water pumped from the electrolytic plant and the fresh water produced simultaneously is electrolyzed to produce hydrogen which is then fed to a coastal power generating plant through a pipeline. On the other hand, cellulose materials such as woods, branches and grasses produced on the land are treated with sulfuric acid and then fermented to brew bio-ethanol. Carbon dioxide generated in this alcohol fermentation is used for photosynthesis and the electric power obtained by the wind power generation is used to culture vegetables by using a light emitting diode or a fluorescent lamp as the light source. The oxygen generated in this photosynthesis is supplied to fish preserves and under reefs where fish live to culture fishes, and also, returned to sea water reduced in the concentration of oxygen to use it for suppressing the generation of a crown-of-thorns star and the generation of a red tide.

[0113] In a still further embodiment of the present invention, the integrated production factory in FIG. **1** is a land factory and ocean wind force is converted into electric power by using a horizontal rotation axis windmill and a vertical rotation axis windmill in the same manner as in the embodiment mentioned just before. Also, sunlight power generation and solar power generation may be utilized. High-density sunlight converged by a strip plane mirror which works as a convex mirror and an objective lens is introduced into a system provided with mirrors having a bandpass filter or cold filter film which transmit light having a wavelength range of 600 to 700 nm and reflects infrared rays having a wavelength higher than the above wavelength range, and a solar cell improved in power generation efficiency by cooling its back with sea water, and the infrared rays reflected on the bandpass filter are converged to thermionic power generation element are subjected to temperature-difference power generation using sea water as the cold source. Here, if the objective mirror which converges sunlight is provided with a cold filter film which transmits visible rays having a wavelength range of 600 nm or less and reflects the rays having a wavelength higher than the above wavelength range, the visible rays transmitted through the objective mirror are used for the photosynthesis in the vegetable plant. Warm water circulated in solar heater pipes stretched around the roof of the factory, hot oil or hot water circulated in a heat-collecting pipe arranged on the focus line of the sunlight converged by a ray-converging means such as a lens or mirror, or high-temperature liquids such as hot waste water or cooled oil in the electrolytic plant, and cool water consisting of pumped deep sea water or surface ocean water are made to flow in the inner tube and outer tube of triple pipe structure respectively and a semiconductor thermionic power generation elements are arranged between these inner and outer tubes to obtain temperature-difference power generation. Also, converged sunlight is applied to one surface of a thermionic power generation element through a heat absorbing layer and sea water is made to flow on the other surface to obtain temperature-difference power generation. Then, the electric power obtained by solar power generation such as above temperature-difference power generations and by the windmill is used to operate the integrated production factory **1** including the electrolytic plant **2**, the ethanol plant **3**, the vegetable plant **4** and the culturing plant **5**. Because the factory is installed on the land near the seashore, a soil culturing **75** can be accomplished in the vegetable plant **4**. Here, it is supposed that the factory is installed on Iki. Fresh water, caustic soda, hydrogen, chlorine, hydrochloric acid, sulfuric acid, hydrogen chloride, magnesium, sodium and the like are produced there from surface sea water pumped in the electrolytic plant. On the other hand, malts and wood chips produced on the land are fermented to brew deep sea water beers and bio-ethanol. Carbon dioxide generated in this alcohol fermentation is used for photosynthesis to culture open-field vegetables and oxygen generated in this photosynthesis is supplied to a fish preserve and under reef where fish live to culture fishes.

[0114] The metal sodium produced in the electrolytic plant **2** or metal sodium produced from a rock salt and salts of salt lakes are transported, as it is stored in a petroleum container, to power generation stations, city gas factories or factories for charging fuel cells or the like, and reacted with water to generate a large amount of hydrogen instantly according to the need. It is therefore unnecessary to fill it in a heavy bomb in a liquid state to transport it by land unlike hydrogen obtained by the electrolysis of water. For this, the cost of transportation can be reduced and the residual caustic soda can be supplied as the raw material for soda industries. Particularly, in mass-consumption places such as a power generation station, soda industries may be established around the power generation station. Moreover, if nuclear fuel used in an atomic power plant is replaced with metal sodium, effects on both of the stable supply of raw material and safety can be expected. It must be considered that the fuel wastes from the power generation station is the starting material of soda industries. Though, on the other hand, metal magnesium which can produce hydrogen by reacting with hot water is produced by the molten salt electrolysis in the same manner as in the case of metal sodium, the amount of magnesium to be produced from sea water is as small as 11.2% of that of sodium. If this metal magnesium is used as a hydrogen-generating source, it entails an enormous cost further to reduce an oxide which is the residue of magnesium. In the mean time, a metal sodium residue after hydrogen is produced can be used as the raw material for soda industries as it is. An endless fuel cycle can be constructed by producing metal sodium by subjecting this residue caustic soda again to the molten salt electrolysis. Therefore, if metal sodium is specialized as a material for generation of hydrogen and metal magnesium is used as a light metal alloy material, the both respectively have a far-reaching economical effect.

[0115] FIG. **16** is a metal sodium fuel cycle system diagram. A salt is extracted from sea water pumped at that place in the marine integrated production factory **1** floated on the ocean. Then, the salt is subjected to molten salt electrolysis **42** by the electric power obtained by wind power generation **107** on the deck to produce metal sodium **54**. Or, in a metal sodium production facility **108**, a rock salt is subjected to molten salt electrolysis **42** by the electric power obtained by wind force power generation **107** in the vicinity of a rock salt area to produce metal sodium **54**. This metal sodium is transported to a hydrogen power generation station **109**, where fresh water **37** is poured into metal sodium **54** in a hydrogen generator **110**, the generated hydrogen gas **56** is burned to generate electricity, and caustic soda **46** generated as a waste is fed to a sodium regenerating plant **111**. The caustic soda **46** is subjected to molten salt electrolysis (in the caustic soda electrolytic plant **112** by the power obtained in the land wind force power generation facility **112** or a coastal wind force power generation facility **113** in the vicinity of the regenerating plant to reproduce metal sodium, which is then used for hydrogen power generation fuel.

[0116] FIG. **17** is a molten salt preheating auxiliary system diagram for molten salt electrolysis utilizing sunlight. Using temperature-difference power generation system (FIG. **4**) using a cylinder type spherical mirror. A high-temperature liquid **11** constituted of light gas oil or an easily meltable metal such as sodium or potassium as a heating medium circulated in a heat collecting pipe **24** installed on the focus line of sunlight converged by the cylinder type spherical mirror **20** is made to flow in a molten salt electrolysis furnace **42** and current is made to flow across an electrode **115** in the condition that the molten salt **116** is preheated and further heated by electric elements **114** to undergo molten salt electrolysis, thereby producing metal sodium **54**. Furthermore, temperature-difference power generation is conducted by a temperature-difference thermal power generating system **6** having a structure in which these waste heating mediums and cool water **14** constituted of pumped deep sea water or surface ocean water are made to flow in the inner tube and outer tube of a double or triple pipe structure respectively and semiconductor thermionic power generation elements are arranged between these inner and outer tubes. Then, the heating medium is again fed to the heat collecting pipe **24** of a sunlight heating collecting device by a circulating pump **19**. When no sunlight is expected, a shield valve **117** is closed to stop the circulation of the heating medium.

[0117] FIG. **18** is a schematic view of a hydrogen generator. This hydrogen generator is an apparatus used to react water with a metal sodium safely either in oils such as light gas oil or kerosene or in a dried atmosphere of gas such as hydrogen, argon or nitrogen. This hydrogen generator **118** is made of a stainless reactor and is provided with a metal sodium introduction door **121** having a shutter **120** isolating the reactor from a pre-room **119** on the upper part of the reactor and also with an introduction door **122** which continuously supplies metal sodium which is fuel protected by the oil on the upper port of the reactor. A hydrogen gas discharge port **123**, a gas seal port **124** for hydrogen, argon or nitrogen and a nozzle **125** that supplies water by spraying, instillation or pulse-wise addition are disposed on the ceiling part of the inside wall of the hydrogen generator **118**. A ultrasonic vibrator **126** is disposed on the periphery of the inside wall of the reactor, and an aqueous caustic soda solution discharge valve **127** and an oil discharge valve **128** are disposed on the bottom of the reactor. Moreover, a control bar **129** for pushing metal sodium contained in the oil phase, down to the water phase. The densities of sodium, water, caustic soda and hydrogen relating to the reaction in this reactor are as follows: hydrogen: 0.09, light gas oil: 0.8, metal sodium: 0.97, water: 1.0, and caustic soda: 2.13. The materials in the reactor are vertically disposed in the order of specific gravity from the bottom of the reactor as follows: caustic soda is heaviest and collected at the lower layer in the reactor, water is collected on the caustic soda, sodium is collected on the water, a light gas oil is floated on the sodium, and finally, the lightest gas hydrogen is disposed on the light gas oil. Taking these natures into account, a water phase is formed on the aqueous caustic soda solution and the light gas oil phase is formed on the water phase, wherein metal sodium is not in contact with water but is floated safely in the light gas oil and the produced hydrogen gas is collected on the light gas oil layer by comparatively increasing the amount of the light gas oil. It becomes easy to control a chemical reaction like this by utilizing a small difference in specific gravity. Metal sodium **54** and light gas oil **130** are put in the reactor **118**. When water **131** is poured into the reactor **118** from a nozzle **125** disposed above, a part of fresh water **37** passing through the light gas oil **130** is brought into contact with the metal sodium **54** to undergo a reaction, thereby producing hydrogen gas **56**, which then rises through the light gas oil **130**. The hydrogen gas **56** is discharged from a hydrogen gas discharge port **123** to the outside of the system and recovered. On the other hand, caustic soda **46** which is another reaction product is sunk to the bottom of the container and recovered from the discharge valve **127** to the outside of the reaction system. In order to control the quantity of reaction of water with metal sodium, the reaction becomes more violent when water is supplied in the atomized state from the nozzle **125** and is added dropwise in the case where the reaction is mild. When pressure is applied to spray water or water is sprayed pulse-wise, the reaction becomes more violent. However, in any case, the poured water is not all reacted and therefore, the water phase **131** and the light gas oil phase **130** are stirred by a ultrasonic vibrator **126** to bring a mixture solution of oil and water into contact with metal sodium, thereby activating the reaction of water with metal sodium. Moreover, in order to cause a direct reaction with water, metal sodium **54** floated in the oil phase may be pushed down by the control bar **129** to react directly with the water phase **37** under the oil phase **130**. If water is reacted with sodium in the condition free of oils, the most violent reaction is expected. For this, (to protect metal sodium from humidity, dry inert gas such as argon or nitrogen, hydrogen gas or the like is introduced from a gas seal port **124** and sealed in the reactor **118** and at the same time, the oils **130** such as light gas oil in the reactor **118** are excluded by the oil discharge valve **128**. Under this condition, water is supplied by spraying, instillation or pulse-wise addition in metal sodium **54** from the nozzle **25** to recover hydrogen gas **56** from the hydrogen gas discharge port **123** at the ceiling part of the reactor and to recover caustic soda **46** from the of the aqueous caustic soda solution discharge valve **127** at the bottom part of the reactor. Or, metal sodium **54** may be poured in the condition that fresh water **37** is filled in the reactor. Also, a cooling jacket is provided on the outside periphery of the reactor and cooling water is circulated through cooling water charge and discharge ports **15** and **16** when a rise in temperature is sharp because of reaction heat. This reaction heat may be utilized for steam power generation as shown in FIG. **20**. When the amount of water **37** to be supplied to metal sodium **54** is small, that is, when water is added to metal sodium from the water spray nozzle **125** located on the upper part of the reactor after the oil is withdrawn, the temperature becomes higher by the reaction heat and reaches a temperature higher than the flash point (500° C.) of produced hydrogen. Particularly, when oxygen is poured into the reaction system from the gas seal port **124** into the reaction system, hydrogen is burned to raise the temperature of the system. In order to utilize this heat, a heating medium **11** as a primary cooling agent is circulated in the cooling jacket **118** through the heating medium discharge port **16** and the heating medium charge port **15** to boil water as a secondary cooling water (though not shown) to rotate a steam turbine, making it possible to supply electric power. When the amount of water to be supplied to metal sodium is large on the other hand, and, specifically when metal sodium **54** floated in the oil layer **130** is pushed down from above by the controller **129** to react a large amount of water **37** under the oil phase with metal sodium **54**, the temperature is not so much raised because the heat capacity of water is large, ensuring that hydrogen can be stably produced. Of course, hydrogen is not burned because no oxygen is supplied in water.

[0118] FIG. **19** is a heating system diagram of a vegetable plant utilizing dashing hot spring water. A metal pipe **134** in which warm water as a secondary hot water **133** is circulated is stretched around a warm water passage or a warm water container **132** in which a primary hot water **131** as high-temperature spring water flows. The secondary hot water **133** is supplied by a circulating pump **19** for heating to raise the culture temperature in a soil **135** and a vegetable culturing house **136** in a tropical or subtropical vegetable plant and a waste warm water **137** dropped in temperature and discharged from the warm water container **132** is used as dashing hot spring water. Particularly, the temperature of a soil **135** and the temperature of a culture house **136** are computer-controlled by controlling the temperature of the secondary hot water **133** according to the date of sprouting, growing season or the time of harvesting. Also, in hot spring places in a cold district, a heavy snowfall area or the uplands, hot spring water is utilized to culture an asparagus, a sugarcane, corn or the like. Also, thermionic thermoelements **10** are disposed around the warm water container **132** and cold water **14** such as river water and melted snow is made to flow on the backside of the thermionic thermoelements **10** to carry out temperature-difference power generation and the generated electric power is utilized for illumination to conduct the photosynthesis in the culturing house **136**. Because water and fertilizers are supplied, particularly, to the soil for the growth of vegetables, the use of a metal pipe **133** which is easily corroded is avoided and it is recommended to use a plastic pipe **138** such as a vinyl chloride pipe as the section of soil **135**.

[0119] As explained above, according to the present invention, large electric power is efficiently produced from natural energies such as ocean tide and wind force or land wind force and sunlight. The obtained electric power ensures, for example, the following processes and production of products. Specifically, metal sodium can be produced at the site where sea water is collected and rock salt collecting site or salt collecting site of salt lakes. Also, fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen and oxygen and the like can be produced at the sea water collecting site. At the same time, unloaded malts, wood chips and the like are fermented to brew a deep sea water beer and bio-ethanol, carbon dioxide generated by this alcohol fermentation is used for photosynthesis to culture vegetables, and oxygen generated by the photosynthesis is supplied to a fish preserve and underwater reef where fish live to culture fishes and also returned to sea water reduced in the concentration of oxygen to thereby suppress the generation of a red tide. Namely, as mentioned above, the present invention so considers that environmental problems take precedence and the present invention can also, of course, reduce energy loss in the storage and transportation of products. Moreover, the energy efficiency of the whole system can be improved. Therefore, the effects of the present invention are not confined to the activation of the industries of the countries which depend on foreign countries for their resources but are extended over the activation of the energy economy of the world.

[0120] The present invention provides an integrated production factory in which, for example, effectively using electric power produced from an ocean tide and wind force on the sea water collecting site, fresh water, sodium, magnesium, calcium, potassium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen and oxygen and the like can be produced at the sea water collecting site, at the same time, unloaded malts, wood chips and the like are fermented to brew a deep sea water beer and bio-ethanol, carbon dioxide generated by this alcohol fermentation is used for photosynthesis to culture vegetables, and oxygen generated by the photosynthesis is supplied to a fish preserve and underwater reef where fish live to culture fishes and also returned to sea water reduced in the concentration of oxygen to thereby suppress the generation of a red tide, ensuring that in each section, products are united to effectively utilize their interactions. The integrated factory of the present invention is provided as a marine factory/cargo ship carrying on all of these productions, as a mother ship which stays at the site to continue productions or as a land factory adjacent to the coast or seashore. Then, in the integrated factory of the present invention, metal sodium is produced by the electric power obtained by using rock salts or salts in salt lakes and wind force power generation adjacent to the site where these salts are collected, or marine or land wind force power generation, and also, energy losses during production, storage and transportation are reduced and the efficiency of the whole system can be improved. This onsite integrated production factory is not restricted in its effect to the dissolution of the problems concerning worldwide exhaustion of resources and high cost of resources but produces an effect extended over economical production of clean and reproducible marine resources without using any fossil fuel, showing that the onsite integrated production factory of the present invention has a large industrial applicability.

What is claimed is:

1. An onsite integrated production factory comprising:

an electrolytic plant having a means for producing and outputting at least fresh water, sodium, magnesium, calcium, caustic soda, chlorine, hydrochloric acid, sulfuric acid, hydrogen, and oxygen from raw materials comprising sea water, salt lake water or rock salt;

an ethanol plant having a means for producing and outputting at least fuel bioethanol, alcohol drinks, and oxalic acid or sodium oxalate including a means for fermenting cellulose materials or grains using the fresh water, sulfuric acid or caustic soda produced by and received from the electrolytic plant,

means for using the oxalic acid or sodium oxalate produced in and received from the ethanol plant as an agent for removing calcium contained in sea water in the electrolytic plant, and for generating and outputting carbon dioxide during the fermenting of the cellulose materials or grains;

a vegetable plant having a means for producing vegetables by photosynthesis that generates and outputs oxygen and that receives and uses the carbon dioxide generated in the fermentation process in the ethanol plant, fresh water produced in the electrolytic plant, and sunlight or artificial light;

a culturing plant having a fishery farm or underwater reef configured in a way such that fish are grown therein by having a means for introducing oxygen received from the vegetable plant into sea water to supplement a concentration of oxygen in the sea water or to suppress a generation of a red tide or by discharging the sea water supplemented with oxygen into sea water in the electrolytic plant; and

a power generation unit configured in a way such that the power generation unit uses natural energy to generate energy supplied to at least one of the electrolytic plant, ethanol plant, vegetable plant, or culturing plant.

2. The onsite integrated production factory according to claim **1**, wherein the power generation unit comprises temperature-difference power generation equipment comprising:

a double or triple pipe structure having an inner and outer tube;

semiconductor thermionic power generation elements arranged between said inner and outer tubes,

wherein said temperature-difference power generation equipment is arranged to produce and output energy by having a means for circulating in said inner tube heated water selected from the group consisting of warm water circulated from solar heater pipes, high-temperature liquids of petroleum products, aromatic compounds, dissolved salts, easily meltable metals, silicone oil, sulfuric acid and oil, heated waste water from the electrolytic plant, and warm water circulation liquids selected from the group consisting of submarine hot spring, coastal hot spring, and a volcanic hot spring, and circulating in said outer tube cool water selected from the group consisting of pumped deep sea water, surface ocean water, and river water,

wherein the means for circulating heated water includes a heat collecting pipe arranged to be heated by converging sunlight using a light converging means; and

a cold filter or bandpass filter arranged to divide sunlight according to wavelength and supplied to the vegetable plant for photosynthesis, and

wherein the vegetable plant has a means for receiving and using the sea water which has been subjected to the temperature-difference power generation equipment to cool a cold district farm room and a means for dividing the received sea water into two lines with a means for sending the deep sea water in one of the two lines for desalinization in the electrolytic plant to output desalinated water and received in the ethanol plant having a means for using desalinated water as a raw material for making beer or sake, and wherein the other line is arranged to discharge into a cold current fishery preserve or into the surface ocean water to form fisheries in the culturing plant.

3. The onsite integrated production factory according to claim **1**, including means for generating and outputting carbon dioxide from fermentation of alcohol, and means for generating and outputting carbon monoxide including means for red-heating coking, and means for absorbing said carbon monoxide using caustic soda to thereby produce and output oxalic acid or oxalate soda in the ethanol plant, and

wherein said electrolytic plant has a means for receiving and using said oxalic acid or oxalate soda to precipitate calcium oxalate to produce a filtrate, and a means for receiving and concentrating said filtrate using a reverse osmosis membrane or heater to produce sulfuric acid, and means for receiving and precipitating said calcium oxalate by pouring hydrochloric acid into the calcium oxalate to produce calcium chloride from said oxalic acid, and means for receiving and using said calcium chloride as a raw material for molten salt electrolysis used to produce metal calcium or as a catalyst for molten salt electrolysis to produce metal sodium.

4. The onsite integrated production factory according to claim **1**, having a means for producing and introducing into a body of water the oxygen produced from said vegetable plant using an oxygen discharge pipe.

5. The onsite integrated production factory according to claim **1**, having hydrogen producing equipment, wherein said hydrogen producing equipment has means for receiving and reacting said metal sodium produced in the electrolytic plant with water to produce hydrogen.

6. The onsite integrated production factory according to claim **5**, wherein the hydrogen producing equipment comprises a reactor having an introduction port for metal sodium embraced in light gas oil or oils forming an oil phase and a water phase, a hydrogen discharge port, a nozzle and a tap configured in a way to supply water by spraying, instillation or pulse-wise addition at an upper part, a ultrasonic piezoelectric transducer around a periphery of said reactor, a discharge valve for an aqueous caustic soda solution at a bottom of said reactor, a control bar configured to push down metal sodium in the oil phase toward the water phase under the oil phase, a gas seal port and a hydrogen discharge port at an upper part of said reactor, and a jacket around the periphery of said reactor.

7. The onsite integrated production factory according to claim **2**, including a means for using the heating medium circulated in the heat collecting pipe as an auxiliary heat supply for heating molten salt in a molten salt electrolytic plant installed in the electrolytic plant.

8. The onsite integrated production factory according to claim **2**, further comprising metal pipes for circulating secondary hot water around a periphery of a warm-water passage or a warm-water tank which flows a high-temperature hot spring water, having a means for supplying the secondary hot water to raise temperatures of a soil or to culture temperature in the vegetable plant, and to culture tropical or subtropical vegetables or for room heating.

9. The onsite integrated production factory according to claim **1**, wherein the electrolytic plant, the ethanol plant, the vegetable plant or the culturing plant is installed in a floating body vessel or drifting vessel of a multi- or mono-hull or a megafloat, a littoral structure or a structure on the land.

10. The onsite integrated production factory according to claim **1**, wherein the power generation unit uses natural energy selected from the group consisting of wind power, hydraulic power, tidal power, sunlight, solar heat, or geothermal heat to produce said energy.

11. The onsite integrated production factory according to claim **1**, comprising:

hydrogen power generation station where fresh water is added to the metal sodium produced in the electrolytic plant to produce hydrogen gas and caustic soda and the produced hydrogen gas is burnt for generating electricity; and

sodium regenerating plant where the caustic soda is subjected to molten salt electrolysis to regenerate metal sodium, which is then transported to the hydrogen power generation station for producing hydrogen gas, which is used for generating electricity.

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5F151 JA23　JA25　JA29

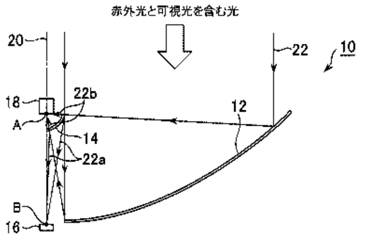
(54)【発明の名称】光エネルギー収集装置

(57)【要約】

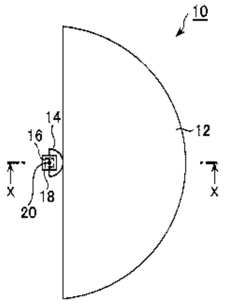
【課題】太陽電池等の設置面積が小さくても大きな光電変換出力を取り出すことができ、しかも光電変換素子の温度上昇を抑制することができ、さらには入射光に含まれる熱エネルギーを有効利用できる光エネルギー収集装置を提供する。

【解決手段】凹面鏡１２は太陽光２２を反射して集光する。コールドミラー１４は集光された光２２を入射して該光２２に含まれる可視光２２ａを反射し、赤外光２２ｂを透過する。太陽電池１６は可視光２２ａを受光して光起電力を発生する。熱電変換素子、スターリングエンジン、温水器、蒸気タービン発電機等の熱利用素子１８は赤外光２２ｂを受光して該赤外線２２ｂの熱エネルギーを利用する。

【選択図】図１



(a) 断面



(b) 平面

【特許請求の範囲】

【請求項1】

赤外光と可視光を含む光源からの光を反射して集光する凹面鏡と、

前記集光された光を入射して該光に含まれる可視光と赤外光とを分離する波長選択素子と、

前記分離された可視光を受光して光起電力を発生する光電変換素子と、

前記分離された赤外光を受光して該赤外線の熱エネルギーを利用する熱利用素子と

を具備してなる光エネルギー収集装置。

【請求項2】

前記波長選択素子が可視光を反射し赤外光を透過するコールドミラーであり、

前記光電変換素子が前記コールドミラーで反射された可視光を受光し、

前記熱利用素子が前記コールドミラーを透過した赤外光を受光する請求項１記載の光エネルギー収集装置。

【請求項3】

前記波長選択素子が可視光を透過し赤外光を反射するコールドフィルターであり、

前記光電変換素子が前記コールドフィルターを透過した可視光を受光し、

前記熱利用素子が前記コールドフィルターで反射された赤外光を受光する請求項１または２記載の光エネルギー収集装置。

【請求項4】

前記凹面鏡の鏡面形状が放物面、球面、楕円面のいずれかである請求項１から３のいずれか１つに記載の光エネルギー収集装置。

【請求項5】

前記波長選択素子の入射面形状が凸面または平面である請求項１から４のいずれか１つに記載の光エネルギー収集装置。

【請求項6】

前記凸面が双曲面または球面である請求項５記載の光エネルギー収集装置。

【請求項7】

前記凹面鏡の鏡面形状が半筒状凹面であり、前記波長選択素子が半筒状凸面または平面である請求項１から３のいずれか１つに記載の光エネルギー収集装置。

【請求項8】

前記波長選択素子の凸面または半筒状凸面が連続面またはフレネル面で構成されている請求項５から７のいずれか１つに記載の光エネルギー収集装置。

【請求項9】

前記凹面鏡の凹面が連続面またはフレネル面で構成されている請求項１から８のいずれか１つに記載の光エネルギー収集装置。

【請求項10】

前記熱利用素子が熱電変換素子、スターリングエンジン、温水器、蒸気タービン発電機のいずれかである請求項１から９のいずれか１つに記載の光エネルギー収集装置。

【発明の詳細な説明】

【技術分野】

【0001】

この発明は太陽等の光源から放射される赤外光と可視光を含む光からエネルギーを収集する装置に関し、太陽電池等の光電変換素子の設置面積が小さくても大きな光電変換出力を取り出すことができ、しかも光電変換素子の温度上昇を抑制することができ、さらには入射光に含まれる熱エネルギーを有効利用できるようにしたものである。

【背景技術】

【0002】

太陽光を受けて発電すると同時に温水を生成する従来の太陽光エネルギー収集装置として下記特許文献１～４に記載されたものがあった。特許文献１記載の装置は太陽電池と温水器を横に並べて配置したものである。太陽電池側で受光した太陽光のうち発電に寄与し

なかった長波長側の光は温水器側に反射されて利用される。

【0003】

特許文献２記載の装置は温水器の上に太陽電池を重ねて配置したものである。太陽電池は太陽光に含まれる可視光を利用して発電し、赤外光を透過する。温水器は太陽電池を透過した赤外光を利用して温水を生成する。

【0004】

特許文献３記載の装置は太陽光を集光レンズで集光して太陽電池に照射するものである。集光した太陽光を太陽電池に照射すると太陽電池の温度が上昇して発電効率が低下するので、冷媒を通した配管中に太陽電池の受光面を露出させ、該配管に形成した光透過窓を透過して太陽光を太陽電池の受光面に照射する。

【0005】

特許文献４記載の装置は凹面状に配列された太陽電池の表面に波長選択反射透過膜を配置したものである。波長選択反射透過膜を透過した波長の短い光は太陽電池で受光され、波長選択反射透過膜で反射され集光された波長の長い光は熱電発電素子で受光され、それぞれ発電が行われる。太陽電池および熱電発電素子はそれぞれ冷却水で冷却され、該冷却水は該冷却の過程で暖められて温水となり給湯に利用される。

【0006】

【特許文献1】実開平０５－６６４７３号公報
【特許文献2】特開２００６－３１７１２８号公報
【特許文献3】特開平９－２１３９８０号公報
【特許文献4】特開平１１－３１８３５号公報

【発明の開示】

【発明が解決しようとする課題】

【0007】

特許文献１記載の装置によれば太陽電池と温水器を並べて配置するので、設置スペースが限られている場合（例えば家屋の屋根上）には、それぞれを単独で設置する場合に比べて個々に割り当て可能な設置スペースが狭くなっていた。この場合太陽電池側で受光した太陽光のうち発電に寄与しなかった長波長側の光は温水器側に反射されて利用されるが、温水器側で受光した太陽光のうち水の加熱に寄与しなかった短波長側の光は発電に利用されないので太陽光エネルギーの利用効率が悪かった。

【0008】

特許文献２記載の装置によれば温水器と太陽電池を重ねて配置するので特許文献１の装置に比べて個々の設置スペースを広くとることができる。しかし太陽電池で得られるエネルギーは該太陽電池の設置面積で決まるため、大きなエネルギーを得るには高価な太陽電池を多数設置する必要があった。また特許文献１，２のいずれの装置も太陽電池に直接太陽光が照射されるため、該太陽電池の温度上昇は避けられず、発電効率が低下する問題があった。

【0009】

特許文献３記載の装置によれば太陽光を集光レンズで集光して太陽電池に照射するので、小面積の太陽電池で大きな出力を取り出すことができる。しかし太陽電池の冷却によって加熱された冷媒の熱エネルギーは利用されないので太陽光エネルギーの利用効率が悪かった。

【0010】

特許文献４記載の装置によれば太陽電池の表面に波長選択反射透過膜を配置して波長の長い光（熱線）を反射するので、太陽電池の温度上昇を抑えることができる。しかし太陽電池で得られるエネルギーは該太陽電池の設置面積で決まるため、大きなエネルギーを得るには高価な太陽電池を多数設置する必要があった。特にこの装置では太陽電池を曲面状に配置するので、太陽電池を平面状に配置する場合に比べて、同じ断面積の太陽光を受けるのに要する太陽電池の設置面積が広くなり、その分高価な太陽電池を多く設置する必要があった。

【0011】
　この発明は上述の点に鑑みてなされたもので、太陽電池等の光電変換素子の設置面積が小さくても大きな光電変換出力を取り出すことができ、しかも光電変換素子の温度上昇を抑制することができ、さらには入射光に含まれる熱エネルギーを有効利用できる光エネルギー収集装置を提供しようとするものである。

【課題を解決するための手段】

【0012】
　この発明は赤外光と可視光を含む光源からの光を反射して集光する凹面鏡と、前記集光された光を入射して該光に含まれる可視光と赤外光とを分離する波長選択素子と、前記分離された可視光を受光して光起電力を発生する光電変換素子と、前記分離された赤外光を受光して該赤外線の熱エネルギーを利用する熱利用素子とを具備してなるものである。

【0013】
　この発明によれば、光源からの光を凹面鏡で集光して光電変換素子で受光するので、光電変換素子の設置面積が小さくても大きな光電変換出力を取り出すことができる。しかも光源からの光に含まれる可視光と赤外光とを波長選択素子で分離して、光電変換素子は分離された可視光を受光するので、光電変換素子の温度上昇を抑制することができる。さらには熱利用素子は分離された赤外光で受光するので、光源からの光に含まれる熱エネルギーを有効利用することができる。

【0014】
　この発明は例えば、前記波長選択素子を可視光を反射し赤外光を透過するコールドミラーで構成することができる。この場合前記光電変換素子は前記コールドミラーで反射された可視光を受光し、前記熱利用素子は前記コールドミラーを透過した赤外光を受光するように配置することができる。またこの発明は前記波長選択素子を可視光を透過し赤外光を反射するコールドフィルターで構成することもできる。この場合前記光電変換素子は前記コールドフィルターを透過した可視光を受光し、前記熱利用素子は前記コールドフィルターで反射された赤外光を受光するように配置することができる。

【0015】
　この発明は前記凹面鏡の鏡面形状を放物面、球面、楕円面等とすることができる。また前記波長選択素子の入射面形状を凸面（双曲面、球面等）、平面等とすることができる。また前記凹面鏡の鏡面形状を半筒状凹面とし、前記波長選択素子を半筒状凸面、平面等とすることができる。また前記波長選択素子の凸面または半筒状凸面は連続面またはフレネル面等で構成することができる。また前記凹面鏡の凹面は連続面またはフレネル面等で構成することができる。

【0016】
　この発明は前記熱利用素子を例えば熱電変換素子、スターリングエンジン、温水器、蒸気タービン発電機等とすることができる。

【発明を実施するための最良の形態】

【0017】
《実施の形態１》
　この発明の光エネルギー収集装置の実施の形態１を図１に示す。光エネルギー収集装置１０は凹面鏡１２、波長選択素子１４、光電変換素子１６、熱利用素子１８を具えている。凹面鏡１２は鏡面形状が放物面に形成されている。放物面の軸２０は入射される光２２と平行またはほぼ平行に配置される。凹面鏡１２は図１（ｂ）に示すように、軸２０の方向から見た形状が半円形に形成されている。凹面鏡１２は赤外光と可視光を含む光源からの光２２として太陽光を入射し、該太陽光２２をそのまま（赤外光と可視光を含んだまま）反射して集光する。集光された光は凹面鏡１２の焦点位置Ａに焦点を結ぶ。

【0018】
　波長選択素子１４は凹面鏡１２から凹面鏡１２の焦点位置Ａに至る光路の途中に配置されている。波長選択素子１４は入射面形状が凸状の双曲面に形成されている。双曲面の軸は凹面鏡１２の軸２０と同じ位置に配置されている。波長選択素子１４は図１（ｂ）に示

すように、軸２０の方向から見た形状が半円形に形成されている。波長選択素子１４はこの実施の形態ではコールドミラーで構成されている。凹面鏡１２で反射され集光された太陽光２２はコールドミラー１４に入射される。コールドミラー１４は入射した太陽光２２に含まれる各波長領域の光のうち可視光２２ａを反射し、赤外光２２ｂを透過する。コールドミラー１４の透過率特性の一例を図２に示す。この特性例では可視光のほか可視光よりも波長が短い領域の光も反射される。

【0019】

コールドミラー１４で反射された可視光２２ａは軸２０上の位置Ｂ（凹面鏡１２に近接した位置）に焦点を結ぶ。光電変換素子１６は軸２０上の焦点位置Ｂまたはその近傍位置（可視光２２ａを受光できる位置）に、受光面を軸２０に直角に配してコールドミラー１４に向けて配置されている。光電変換素子１６は太陽電池で構成されている。この太陽電池１６は可視光に対して高い変換効率が得られる結晶シリコン太陽電池、ＧａＡｓ系等の化合物系太陽電池等が使用される。コールドミラー１４で反射された可視光２２ａは太陽電池１６で受光される。これにより太陽電池１６は光起電力を発生する。発生された光起電力は適宜の電源用途に利用される。

【0020】

熱利用素子１８はコールドミラー１４を挟んで凹面鏡１２と反対側にある凹面鏡１２の焦点位置Aまたはその近傍位置（赤外光２２ｂを受光できる位置）に配置されている。熱利用素子１８は熱電変換素子、スターリングエンジン、温水器等の熱エネルギーで動作する装置で構成される。コールドミラー１４を透過した赤外光２２ｂは熱利用素子１８で受光される。これにより熱利用素子１８は、熱電変換素子であれば発電し、スターリングエンジンであれば回転し、温水器であれば水を加熱する。

【0021】

以上の構成の光エネルギー収集装置１０によれば、太陽光２２を凹面鏡１２で集光して太陽電池１６に照射するので、太陽電池１６の設置面積が小さくても大きな光電変換出力を取り出すことができる。同様に熱利用素子１８についても、太陽光２２を凹面鏡１２で集光して熱利用素子１８に照射するので、熱利用素子１８が小型でも大きな出力を取り出すことができる。しかも太陽電池１６に入射される光２２ａはコールドミラー１４で赤外光を除去した光なので、太陽電池１６の温度上昇を抑制して光変換出力の低下を抑制することができる。さらにはコールドミラー１４で分離された赤外光２２ｂは熱利用素子１８で利用されるので、太陽光２２のエネルギーの利用効率を高めることができる。また太陽光２２を凹面鏡１２で集光してから波長選択素子１４に照射するので、前記特許文献４記載の装置のように太陽電池の表面に波長選択反射透過膜を配置する場合に比べて波長選択素子１４の設置面積を小さくすることができる。また集光に凹面鏡１２を使用するので、特許文献３の集光レンズを使用するものに比べて低コスト化が可能である。

【0022】

なお実施の形態１では凹面鏡１２の鏡面形状を放物面とし、コールドミラー１４の入射面形状を双曲面としたが、これに代えて、若干の収差は発生するものの凹面鏡１２の鏡面形状を球面または楕円面とし、コールドミラー１４の入射面形状を球面とすることもできる。双曲面形状は製造が難しいのに対し、球面にすると製造が容易になる。

【0023】

また実施の形態１ではコールドミラー１４の入射面形状を凸面としたが平面とすることもできる。ただし凸面とした方がコールドミラー１４で反射された可視光２２ａが焦点を結ぶ位置Bは波長選択素子１４から離れた位置となり、太陽電池１６を波長選択素子１４から離して配置することができるため、太陽電池１６の配置が容易になる。

【0024】

また実施の形態１では波長選択素子１４をコールドミラーで構成したがコールドフィルターで構成することもできる。コールドフィルターは入射した太陽光に含まれる各波長領域の光のうち赤外光を反射し、可視光を透過する。コールドフィルターの透過率特性の一例を図３に示す。波長選択素子１４をコールドミラーで構成する場合は図１（ａ）におい

て太陽電池１６と熱利用素子１８の配置を入れ換える。

【0025】

《実施の形態２》

この発明の光エネルギー収集装置の実施の形態２を図４に示す。これは実施の形態１が凹面鏡１２と波長選択素子１４を軸２０の方向から見てそれぞれ半円形に形成したのに対しそれぞれ円形に形成したものである。実施の形態１と共通する部分には同一の符号を用いる。光エネルギー収集装置２４は凹面鏡２６、波長選択素子２８、光電変換素子１６、熱利用素子１８を具えている。凹面鏡２６は鏡面形状が放物面に形成されている。放物面の軸２０は入射される太陽光２２と平行またはほぼ平行に配置される。凹面鏡２６は図４（ｂ）に示すように、軸２０の方向から見た形状が円形に形成されている。凹面鏡２６は太陽光２２を入射し、該太陽光２２をそのまま反射して集光する。集光された光は凹面鏡２６の焦点位置Ａに焦点を結ぶ。

【0026】

波長選択素子２８は凹面鏡２６から凹面鏡２６の焦点位置Ａに至る光路の途中に配置されている。波長選択素子２８は入射面形状が凸状の双曲面に形成されている。双曲面の軸は凹面鏡２６の軸２０と同じ位置に配置されている。波長選択素子２８は図４（ｂ）に示すように、軸２０の方向から見た形状が円形に形成されている。波長選択素子２８はこの実施の形態ではコールドフィルターで構成されている。凹面鏡２６で反射され集光された太陽光２２はコールドフィルター２８に入射される。コールドフィルター２８は入射した太陽光２２に含まれる各波長領域の光のうち可視光２２ａを透過し、赤外光２２ｂを反射する。コールドフィルター２８の透過率特性は例えば前記図３と同様とすることができる。

【0027】

光電変換素子１６はコールドフィルター２８を挟んで凹面鏡２６と反対側にある凹面鏡２６の焦点位置Ａまたはその近傍位置（可視光２２ａを受光できる位置）に、受光面を軸２０に直角に配してコールドフィルター２８に向けて配置されている。光電変換素子１６は太陽電池で構成されている。この太陽電池１６は可視光に対して高い変換効率が得られる結晶シリコン太陽電池、ＧａＡｓ系等の化合物系太陽電池等が使用される。コールドフィルター２８を透過した可視光２２ａは太陽電池１６で受光される。これにより太陽電池１６は光起電力を発生する。発生された光起電力は適宜の電源用途に利用される。

【0028】

コールドフィルター２８で反射された赤外光２２ｂは軸２０上の位置Ｂ（凹面鏡２６の表面付近の位置）に焦点を結ぶ。熱利用素子１８は軸２０上の焦点位置Ｂまたはその近傍位置（赤外光２２ｂを受光できる位置）に配置されている。熱利用素子１８は熱電変換素子、スターリングエンジン、温水器等の熱エネルギーで動作する装置で構成される。コールドフィルター２８で反射された赤外光２２ｂは熱利用素子１８で受光される。これにより熱利用素子１８は、熱電変換素子であれば発電し、スターリングエンジンであれば回転し、温水器であれば水を加熱する。

【0029】

以上の構成の光エネルギー収集装置２４によれば、太陽光２２を凹面鏡２６で集光して太陽電池１６に照射するので、太陽電池１６の設置面積が小さくても大きな光電変換出力を取り出すことができる。同様に熱利用素子１８についても、太陽光２２を凹面鏡２６で集光して熱利用素子１８に照射するので、熱利用素子１８が小型でも大きな出力を取り出すことができる。しかも太陽電池１６に入射される光２２ａはコールドフィルター２８で赤外光を除去した光なので、太陽電池１６の温度上昇を抑制して光変換出力の低下を抑制することができる。さらにはコールドフィルター２８で分離された赤外光２２ｂは熱利用素子１８で利用されるので、太陽光２２のエネルギーの利用効率を高めることができる。また太陽光２２を凹面鏡２６で集光してから波長選択素子２８に照射するので、前記特許文献４記載の装置のように太陽電池の表面に波長選択反射透過膜を配置する場合に比べて波長選択素子２８の設置面積を小さくすることができる。また集光に凹面鏡２６を使用す

るので、特許文献３の集光レンズを使用するものに比べて低コスト化が可能である。

【0030】

なお実施の形態２では凹面鏡２６の鏡面形状を放物面とし、コールドフィルター２８の入射面形状を双曲面としたが、これに代えて、若干の収差は発生するものの凹面鏡２６の鏡面形状を球面または楕円面とし、コールドフィルター２８の入射面形状を球面とすることもできる。

【0031】

また実施の形態２ではコールドフィルター２８の入射面形状を凸面としたが平面とすることもできる。ただし凸面とした方がコールドフィルター２８で反射された赤外光２２ｂが焦点を結ぶ位置Ｂは波長選択素子２８から離れた位置となり、熱利用素子１８を波長選択素子２８から離して配置することができるため、熱利用素子１８の配置が容易になる。

【0032】

また実施の形態２では波長選択素子２８をコールドフィルターで構成したがコールドミラーで構成することもできる。コールドミラーの透過率特性は例えば前記図２と同様とすることができる。波長選択素子２８をコールドミラーで構成する場合は図4（ａ）において太陽電池１６と熱利用素子１８の配置を入れ換える。

【0033】

〈実施の形態２の実施例〉

実施の形態２においてコールドフィルター２８として波長が７００ｎｍよりも短い光（可視光）を透過し７００ｎｍ以上の光（赤外光）を反射する特性のものを使用した。赤外光２２ｂが焦点を結ぶ位置Ｂの温度は赤外光の集光による熱エネルギーで６００℃に到達した。同位置Ｂに熱利用素子１８としてスターリングエンジンの高温部を配置して該スターリングエンジン動作させ、クランク機構を使って該スターリングエンジンの出力ピストンの往復運動を回転運動に変換してモーターを駆動したところ約０．９ｍWの発電出力が得られた。このとき位置Aに配置した市販の太陽電池１６の表面温度は４５℃であり、同太陽電池１６からは１．０ｍWの発電出力が得られた。

【0034】

〈比較例〉

比較例として上記実施例で使用した太陽電池１６に太陽光を集光せずに直接照射した。このとき太陽電池１６の表面温度は６５℃であり、同太陽電池１６からは０．１ｍWの発電出力が得られた。

【0035】

上記実施例と比較例によれば次のことが言える。

（ａ）太陽光２２を凹面鏡２６で集光して太陽電池１６に照射することにより、太陽光２２を集光せずに同じ面積の太陽電池１６に照射する場合に比べて大きな光電変換出力を取り出すことができる。

（ｂ）太陽電池１６に入射される光２２ａはコールドフィルター２８で赤外光を除去した光なので、集光しているにもかかわらず太陽電池１６の温度上昇を抑制することができる。

（ｃ）コールドフィルター２８で分離された赤外光２２ｂは熱利用素子１８としてのスターリングエンジンの駆動に利用されるので、太陽光２２のエネルギーの利用効率を高めることができる。

【0036】

《実施の形態３》

この発明の光エネルギー収集装置の実施の形態３を図5に示す。これは凹面鏡および波長選択素子を半筒状にそれぞれ構成して互いに所定の間隙を隔てて同一方向に延在するように対向配置し、太陽電池および熱利用素子を該半筒の延在方向に沿ってそれぞれ配列したものである。実施の形態１，２と共通する部分には同一の符号を用いる。光エネルギー収集装置３０は凹面鏡３２、波長選択素子３４、光電変換素子３６、熱利用素子３８を具えている。凹面鏡３２、波長選択素子３４はそれぞれ半筒状に形成されている。凹面鏡３

２および波長選択素子３４は互いに所定の間隙を隔てて同一方向に延在配置されている。図５（ｂ）は光エネルギー収集装置３０を凹面鏡３２および波長選択素子３４の延在方向に直角な平面で切断した断面を示す。同断面における凹面鏡３２の鏡面形状は放物面に形成されている。また同断面における波長選択素子３４の入射面形状は凸状の双曲面に形成されている。凹面鏡３２の放物面の軸面（放物線の軸が半筒の延在方向に並んで構成される面）２０’と波長選択素子３４の双曲面の軸面２０’は互いに一致した位置にある。軸面２０’は入射される太陽光２２と平行またはほぼ平行に配置される。凹面鏡３２は太陽光２２を入射し、該太陽光２２をそのまま反射して集光する。集光された光は凹面鏡３２の焦線（放物線の焦点が半筒の延在方向に並んで構成される線）位置Ａ’に焦線を結ぶ。

【0037】

波長選択素子３４は凹面鏡３２からその焦線位置Ａ’に至る光路の途中に配置されている。波長選択素子３４はこの実施の形態ではコールドミラーで構成されている。凹面鏡３２で反射され集光された太陽光２２はコールドミラー３４に入射される。コールドミラー３４は入射した太陽光２２に含まれる各波長領域の光のうち可視光２２ａを反射し、赤外光２２ｂを透過する。コールドミラー３４の透過率特性は例えば前記図２と同様とすることができる。

【0038】

コールドミラー３４で反射された可視光２２ａは軸面２０’上の位置Ｂ’（凹面鏡３２の表面付近の位置）に焦線を結ぶ。光電変換素子３６は軸面２０’上の焦線位置Ｂ’またはその近傍位置（可視光２２ａを受光できる位置）に沿って、受光面を軸面２０’に直角に配してコールドミラー３４に向けて配置されている。光電変換素子３６は太陽電池で（太陽電池セルを焦線位置Ｂ’に沿って並べて）構成されている。この太陽電池３６は可視光に対して高い変換効率が得られる結晶シリコン太陽電池、ＧａＡｓ系等の化合物系太陽電池等が使用される。コールドミラー３４で反射された可視光２２ａは太陽電池３６で受光される。これにより太陽電池３６は光起電力を発生する。発生された光起電力は適宜の電源用途に利用される。

【0039】

熱利用素子３８はコールドミラー３４を挟んで凹面鏡３２と反対側にある凹面鏡３２の焦線位置Ａ’またはその近傍位置（赤外光２２ｂを受光できる位置）に沿って配置されている。熱利用素子３８は熱電変換素子、スターリングエンジン、温水器等の熱エネルギーで動作する装置で構成される。コールドミラー３４を透過した赤外光２２ｂは熱利用素子３８で受光される。これにより熱利用素子３８は、熱電変換素子であれば発電し、スターリングエンジンであれば回転し、温水器であれば水を加熱する。熱利用素子３８を焦線位置Ａ’に沿って敷設したパイプで構成し、該パイプ中に水等の液体を供給し、該パイプの出口側にタービンを接続することにより、焦点位置Ａ’を通る間に加熱された液体で蒸気タービン発電を行うこともできる。

【0040】

以上の構成の光エネルギー収集装置３０によれば、太陽光２２を凹面鏡３２で集光して太陽電池３６に照射するので、太陽電池３６の設置面積が小さくても大きな光電変換出力を取り出すことができる。同様に熱利用素子３８についても、太陽光２２を凹面鏡３２で集光して熱利用素子３８に照射するので、熱利用素子３８が小型でも大きな出力を取り出すことができる。しかも太陽電池３６に入射される光２２ａはコールドミラー３４で赤外光を除去した光なので、太陽電池３６の温度上昇を抑制して光変換出力の低下を抑制することができる。さらにはコールドミラー３４で分離された赤外光２２ｂは熱利用素子３８で利用されるので、太陽光２２のエネルギーの利用効率を高めることができる。また太陽光２２を凹面鏡３２で集光してから波長選択素子３４に照射するので、前記特許文献４記載の装置のように太陽電池の表面に波長選択反射透過膜を配置する場合に比べて波長選択素子３４の設置面積を小さくすることができる。また集光に凹面鏡３２を使用するので、特許文献３の集光レンズを使用するものに比べて低コスト化が可能である。

【0041】

なお実施の形態３では凹面鏡３２の鏡面形状を放物面とし、コールドミラー３４の入射面形状を双曲面としたが、これに代えて、若干の収差は発生するものの凹面鏡３２の鏡面形状を球面または楕円面とし、コールドミラー３４の入射面形状を球面とすることもできる。

【0042】

また実施の形態３ではコールドミラー３４の入射面形状を凸面としたが平面とすることもできる。ただし凸面とした方がコールドミラー３４で反射された可視光２２ａが焦線を結ぶ位置Ｂ’は波長選択素子３４から離れた位置となり、太陽電池３６を波長選択素子３４から離して配置することができるため、太陽電池３６の配置が容易になる。

【0043】

また実施の形態３では波長選択素子３４をコールドミラーで構成したがコールドフィルターで構成することもできる。コールドフィルターの透過率特性は例えば前記図3と同様とすることができる。波長選択素子３４をコールドミラーで構成する場合は図5において太陽電池３６と熱利用素子３８の配置を入れ換える。

【0044】

《実施の形態４》

この発明の光エネルギー収集装置の実施の形態４を図6に示す。これは凹面鏡をフレネルミラーで構成したものである。実施の形態１～３と共通する部分には同一の符号を用いる。光エネルギー収集装置４０はフレネル凹面鏡４２、波長選択素子４４、光電変換素子１６、熱利用素子１８を具えている。フレネル凹面鏡４２は鏡面が、放物面を同心円に輪切りにして階段状に配列した形状のフレネル面で構成されている。放物面の軸２０は入射される太陽光２２と平行またはほぼ平行に配置される。フレネル凹面鏡４２は図6（ｂ）に示すように、軸２０の方向から見た形状が円形に形成されている。フレネル凹面鏡４２は太陽光２２を入射し、該太陽光２２をそのまま反射して集光する。集光された光はフレネル凹面鏡４２の焦点位置Ａに焦点を結ぶ。

【0045】

波長選択素子４４はフレネル凹面鏡４２からフレネル凹面鏡４２の焦点位置Ａに至る光路の途中に配置されている。波長選択素子４４は入射面形状が凸状の双曲面に形成されている。双曲面の軸はフレネル凹面鏡４２の軸２０と同じ位置に配置されている。波長選択素子４４は図6（ｂ）に示すように、軸２０の方向から見た形状が円形に形成されている。波長選択素子４４はこの実施の形態ではコールドフィルターで構成されている。フレネル凹面鏡４２で反射され集光された太陽光２２はコールドフィルター４４に入射される。コールドフィルター４４は入射した太陽光２２に含まれる各波長領域の光のうち可視光２２ａを透過し、赤外光２２ｂを反射する。コールドフィルター４４の透過率特性は例えば前記図３と同様とすることができる。

【0046】

光電変換素子１６はコールドフィルター４４を挟んでフレネル凹面鏡４２と反対側にあるフレネル凹面鏡４２の焦点位置Ａまたはその近傍位置（可視光２２ａを受光できる位置）に、受光面を軸２０に直角に配してコールドフィルター４４に向けて配置されている。光電変換素子１６は太陽電池で構成されている。この太陽電池１６は可視光に対して高い変換効率が得られる結晶シリコン太陽電池、ＧａＡｓ系等の化合物系太陽電池等が使用される。コールドフィルター４４を透過した可視光２２ａは太陽電池１６で受光される。これにより太陽電池１６は光起電力を発生する。発生された光起電力は適宜の電源用途に利用される。

【0047】

コールドフィルター４４で反射された赤外光２２ｂは軸２０上の位置Ｂ（フレネル凹面鏡４２の表面付近の位置）に焦点を結ぶ。熱利用素子１８は軸２０上の焦点位置Ｂまたはその近傍位置（赤外光２２ｂを受光できる位置）に配置されている。熱利用素子１８は熱電変換素子、スターリングエンジン、温水器等の熱エネルギーで動作する装置で構成される。コールドフィルター４４で反射された赤外光２２ｂは熱利用素子１８で受光される。

これにより熱利用素子１８は、熱電変換素子であれば発電し、スターリングエンジンであれば回転し、温水器であれば水を加熱する。

【0048】

以上の構成の光エネルギー収集装置４０によれば、太陽光２２をフレネル凹面鏡４２で集光して太陽電池１６に照射するので、太陽電池１６の設置面積が小さくても大きな光電変換出力を取り出すことができる。同様に熱利用素子１８についても、太陽光２２をフレネル凹面鏡４２で集光して熱利用素子１８に照射するので、熱利用素子１８が小型でも大きな出力を取り出すことができる。しかも太陽電池１６に入射される光２２ａはコールドフィルター４４で赤外光を除去した光なので、太陽電池１６の温度上昇を抑制して光変換出力の低下を抑制することができる。さらにはコールドフィルター４４で分離された赤外光２２ｂは熱利用素子１８で利用されるので、太陽光２２のエネルギーの利用効率を高めることができる。また太陽光２２をフレネル凹面鏡４２で集光してから波長選択素子４４に照射するので、前記特許文献４記載の装置のように太陽電池の表面に波長選択反射透過膜を配置する場合に比べて波長選択素子４４の設置面積を小さくすることができる。また集光にフレネル凹面鏡４２を使用するので、特許文献３の集光レンズを使用するものに比べて低コスト化が可能である。

【0049】

また図６の光エネルギー収集装置４０によれば図４の実施の形態２の光エネルギー収集装置２４に比べて次のような効果が得られる。図７は図４の光エネルギー収集装置２４と図６の光エネルギー収集装置４０を凹面鏡２６，４２を同一直径に形成して対比して示したものである。これによれば光エネルギー収集装置４０は平板状のフレネル凹面鏡４２で太陽光２２を収集するため、光エネルギー収集装置２４に比べて波長選択素子４４を小面積（小径）に形成でき、結果として、使用できる太陽光２２の面積が広くなり、高い集光能力が得られる。またフレネル凹面鏡４２は平板状であるため、設置が容易である。またフレネル凹面鏡４２のフレネル形状は成型加工でき、また波長選択素子４４は小面積（小径）に形成できるので製造コストを低くできる。

【0050】

なお実施の形態４ではフレネル凹面鏡４２の鏡面形状を放物面とし、コールドフィルター４４の入射面形状を双曲面としたが、これに代えて、若干の収差は発生するもののフレネル凹面鏡４２の鏡面形状を球面または楕円面とし、コールドフィルター４４の入射面形状を球面とすることもできる。

【0051】

また実施の形態４ではコールドフィルター４４の入射面の凸面形状を連続面で構成したがフレネル面で構成することもできる。すなわちコールドフィルタ４４の基板をフレネル凹面鏡４２と同様に平板状に構成し、その入射面（フレネル凹面鏡４２との対向面）を双曲面、球面等によるフレネル面で構成し、該フレネル面の表面にコールドフィルターを構成する光学多層膜を成膜する。これによりコールドフィルター４４で反射された赤外光２２ｂは位置Ｂに焦点を結び、コールドフィルター４４を透過した可視光２２ａは大部分がそのまま直進して位置Ａに焦点を結ぶ。なお実施の形態１（図１）、実施の形態２（図４）の波長選択素子１４，２８についても入射面の凸面形状を連続面に代えてフレネル面で構成することができる。同様に実施の形態３（図５）について、半筒状凹面鏡３２、半筒状波長選択素子３４の基板をそれぞれ平板状に構成し、半筒状凹面鏡３２の鏡面の凹面形状を連続面に代えてフレネル面（フレネルの縞が筒の軸方向に直線状に延在するフレネル面）で構成し、半筒状波長選択素子３４の入射面の凸面形状を連続面に代えてフレネル面（フレネルの縞が筒の軸方向に直線状に延在するフレネル面）で構成することもできる。

【0052】

また実施の形態４ではコールドフィルター４４の入射面形状を凸面としたが平面（フレネル面でなく連続面）とすることもできる。ただし凸面とした方がコールドフィルター４４で反射された赤外光２２ｂが焦点を結ぶ位置Ｂは波長選択素子４４から離れた位置となり、熱利用素子１８を波長選択素子４４から離して配置することができるため、熱利用素

子１８の配置が容易になる。

【0053】

　また実施の形態４では波長選択素子４４をコールドフィルターで構成したがコールドミラーで構成することもできる。コールドミラーの透過率特性は例えば前記図２と同様とすることができる。波長選択素子４４をコールドミラーで構成する場合は図6（ａ）において太陽電池１６と熱利用素子１８の配置を入れ換える。

【0054】

　また前記各実施の形態では赤外光と可視光を含む光源からの光として太陽光を使用した場合について説明したが、太陽光以外の光を使用することもできる。例えば昼間に太陽光発電で蓄えた電力を用いて夜間人工光源を駆動するシステムにおいて、人工光源からの光をこの発明の光エネルギー収集装置の光源として使用して再発電することができる。

【図面の簡単な説明】

【0055】

【図1】この発明の光エネルギー収集装置の実施の形態１を示す図で、（ａ）は凹面鏡１２の軸２０を通る平面で切断した断面図（（ｂ）のＸ－Ｘ矢視断面図）、（ｂ）は平面図（軸２０の方向から見た図）である。

【図2】図１のコールドミラー１４の透過率特性の一例を示す線図である。

【図3】図１のコールドミラー１４をコールドフィルターに置き換えた場合のコールドフィルターの透過率特性の一例を示す線図である。

【図4】この発明の光エネルギー収集装置の実施の形態２を示す図で、（ａ）は凹面鏡２６の軸２０を通る平面で切断した断面図（（ｂ）のＹ－Ｙ矢視断面図）、（ｂ）は平面図（軸２０の方向から見た図）である。

【図5】この発明の光エネルギー収集装置の実施の形態３を示す図で、（ａ）は斜視図、（ｂ）は光エネルギー収集装置３０を凹面鏡３２および波長選択素子３４の半筒の延在方向に直角な平面で切断した断面図である。

【図6】この発明の光エネルギー収集装置の実施の形態４を示す図で、（ａ）はフレネル凹面鏡４２の軸２０を通る平面で切断した断面図（（ｂ）のＺ－Ｚ矢視断面図）、（ｂ）は平面図（軸２０の方向から見た図）である。

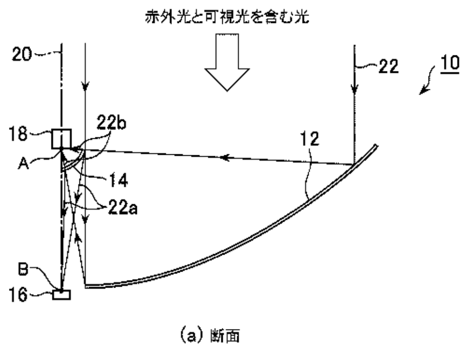
【図7】図４の光エネルギー収集装置２４と図６の光エネルギー収集装置４０を凹面鏡２６，４２を同一直径に形成して対比して示した図で、それぞれ集光鏡の軸を通る平面で切断した断面図である。

【符号の説明】

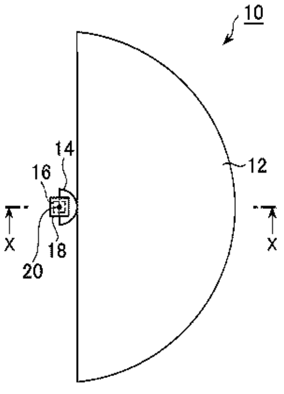
【0056】

　１０，２４，３０，４０…光エネルギー収集装置、１２，２６，３２…凹面鏡（凹面が連続面で構成されている凹面鏡）、１４，３４…コールドミラー（波長選択素子）、１６，３６…光電変換素子、１８，３８…熱利用素子、２２…太陽光（赤外光と可視光を含む光源からの光）、２８，４４…コールドフィルター（波長選択素子）、４２…凹面鏡（凹面がフレネル面で構成されている凹面鏡）

【図1】

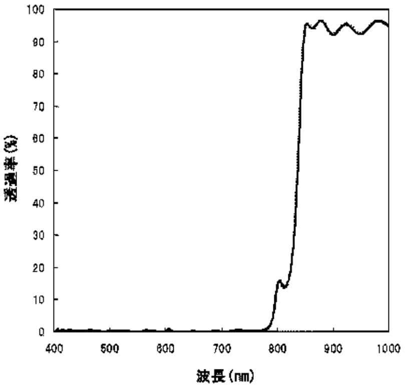


(a) 断面

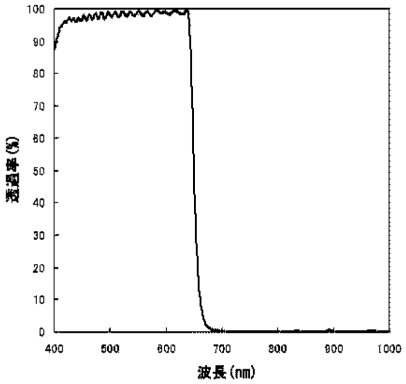


(b) 平面

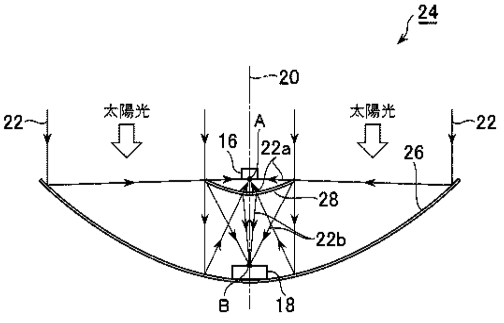
【図2】



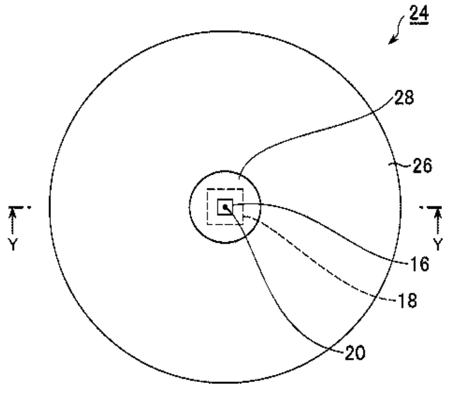
【図3】



【図4】

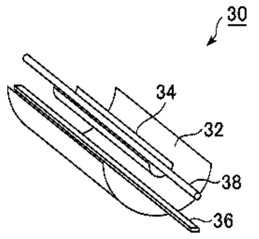


(a) 断面

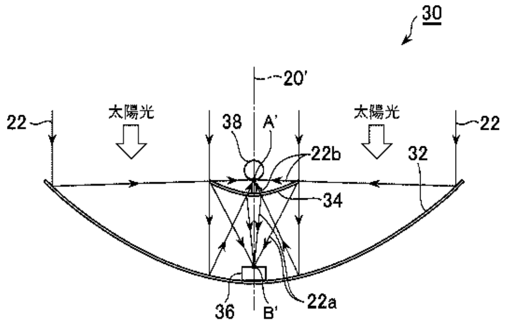


(b) 平面

【図5】

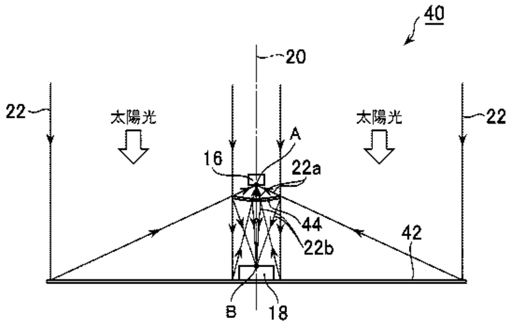


(a) 斜視

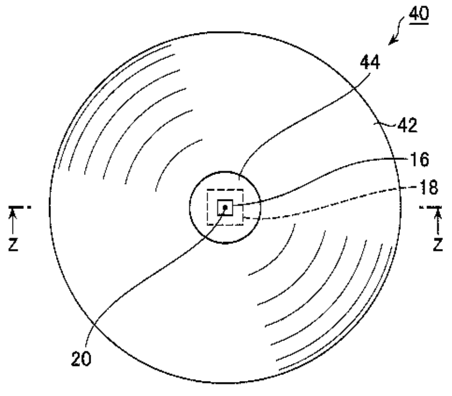


(b) 断面

【図6】

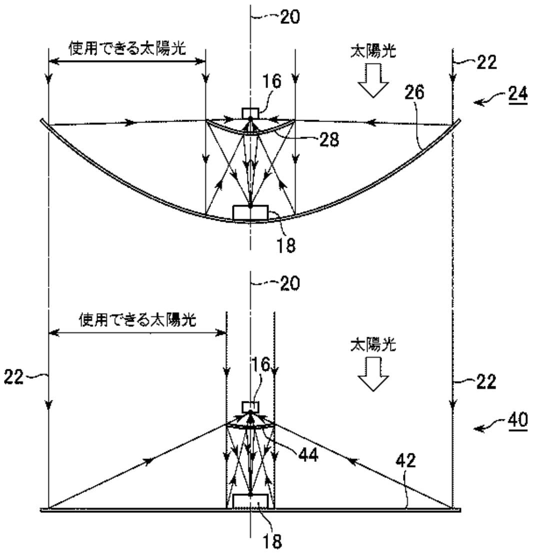


(a) 断面



(b) 平面

【図7】



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(54) Reflective light wavelength modulator

(57) A reflective light wavelength modulator includes a reflection module 10,50 with a reflective arc surface 11, 51, at least one thermal conducting column 20 installed at the reflective arc surface 11,51, at least one optoelectric conversion module 30,70, particularly an illumination module, a solar cell or an photocell, installed on a distal surface of the thermal conducting column 20, and a reflective mask 40,80 installed at an appropriate distance from the optoelectric conversion module 30,70. The reflection module 10,50 or the reflective mask 40,80is made of a wavelength modulation material, such that when the light produced by the optoelectric conversion module 30,70 or the received light source is reflected from the reflective mask 40,80, the wavelength of the light source is changed to achieve the effects of providing a wavelength modulation function of a light source with a color and a cost-effective optoelectric equipment.

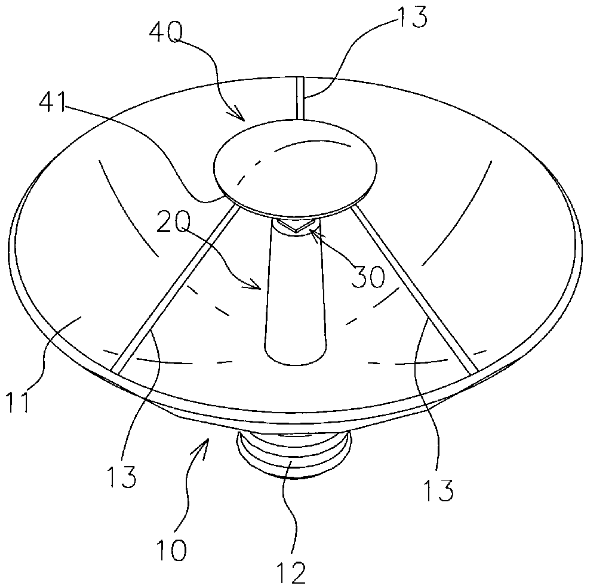

FIG. 1

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an illumination or photoelectric conversion device, and more particularly to a reflective illumination or photoelectric conversion device capable of modulating a light source'swavelength..

2. Description of the Related Art

[0002] Light emitting diode (LED) comes with the advantages of a high efficiency, a power saving feature, a long life, a cool light without infrared spectrum property, a quick response, and a consistent color over other traditional light sources, and thus the light emitting diode (LED) is used extensively in illumination equipments, and it becomes an important subject for the development of optoelectronic and illumination industries. LED has replaced the applications of traditional light sources gradually, and present single-chip light emitting diodes (LED) emit white light by coating a phosphor onto the LED. For example, a yellow phosphor is coated onto a blue LED, or a RGB tri-band phosphor is added to an ultraviolet LED for producing white light. When the phosphor is excited by an excited beam that is emitted from the LED, an emitting beam is excited. In the meantime, when the remaining excited beam emitted from the LED but not absorbed by the phosphor is mixed with the beam excited by the phosphor, a white light is formed. The conventional LED emits light in a way with an insufficient flexibility of color modulation which constitutes a limitation to the popularity and application of the LED, and thus the design of the conventional LED is not good enough. Furthermore, the lifespan and the function of the LED are related to the heat dissipation efficiency, and thus the heat dissipation is a main issue of the development of present LEDs. The conventional low power LED emits light without using any peripheral application to provide a heat dissipation function, and thus this issue must be overcome in order to have a breakthrough in the high power LED industry.

[0003] Similarly, a related optoelectric conversion is used for improving the conversion efficiency and focusing a light source (such as solar energy) or using a wavelength modulation technique to improve the utility rate of sunlight, and overcoming the drawbacks of heat dissipating material and structure.

[0004] In view of the shortcomings of the application and the deficiency of the structural design of the conventional light emitting diode, and the illumination and focusing of a light source, the inventor of the present invention based on years of experience in the related industry to conduct extensive researches and experiments, and finally developed a practical and cost-effective reflective light wavelength modulator, in hope of enhancing the heat dissipating effect, providing a cost-effective and practical service to the general public, and promoting the development of the industry.

SUMMARY OF THE INVENTION

[0005] Therefore, it is a primary objective of the present invention to provide a reflective light wavelength modulator applied in an illumination module using such as a light emitting diode (LED) as a light emitting source or a light source (such as solar energy) for an illumination to generate electric energy, and the reflective light wavelength modulator of the present invention provides a wavelength modulation function to the light source by means of the wavelength modulator operated together with simple peripherals, and the illumination module or photocell can be manufactured economically.

[0006] Another objective of the present invention is to provide a reflective light wavelength modulator that projects and reflects a light source to a wavelength modulation material to achieve the effects of modulating a light source color or improving an optoelectric conversion efficiency, while achieving an excellent heat dissipation.

[0007] To achieve the foregoing objective, the present invention provides a reflective light wavelength modulator comprising: a reflection module, made of a wavelength modulation material coated reflector, and having a reflective arc surface; at least one heat conducting column, installed at a position of the reflective arc surface of the reflection module; at least one optoelectric conversion module, particularly an illumination module, a solar cell or a photocell, installed onto a distal surface of the heat conducting column; a reflective mask, made of a wavelength modulation material, and installed with an appropriate distance from the optoelectric conversion module, such that the optoelectric conversion module can project a light onto the reflective mask or reflect a light source from the reflection module received by the photocell module to provide the effect of modulating the wavelength of the light source.

[0008] The present invention further comprises a plurality of optoelectric conversion modules, each being installed on a distal surface of each heat conducting column, wherein the heat conducting column is in a long bar shape.

[0009] The foregoing and other technical characteristics of the present invention will become apparent with the detailed description of the preferred embodiments and the illustration of the related drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a perspective view of a first preferred embodiment of the present invention;

FIG. 2 is an exploded view of a first preferred embodiment of the present invention;

FIG. 3a is a cross-sectional view of an operating status of a first preferred embodiment of the present invention;

FIG. 3b is another cross-sectional view of an operating status of a first preferred embodiment of the present invention;

FIG. 4 is a perspective view of a second preferred embodiment of the present invention;

FIG. 5 is a cross-sectional view of an operating status of a second preferred embodiment of the present invention; and

FIG. 6 is a schematic view of a heat dissipating base of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] With reference to FIGS. 1, 2 and 3a for a reflective light wavelength modulator in accordance with a first preferred embodiment of the present invention, the reflective light wavelength modulator comprises a reflection module 10, a thermal conducting column 20, a optoelectric conversion module 30 and a reflective mask 40, wherein the reflection module 10 is made of a wavelength modulation material coated reflector, the coated material comosed of such as an organic polymer carrier added with an organic wavelength modulation material, a quantum dot luminescence color rendering modulation material and nanoparticle light intensity enhancer composite material, and the reflection module 10 of this preferred embodiment is a reflecting mirror, and the reflection module 10 includes an electric connector 12 installed under the reflective arc surface 11, and the reflection module 10 has a heat dissipation function, and the electric connector 12 is provided for connecting a power supply or inverter and includes a circuit board 14 as shown in FIG. 3a.

[0012] The thermal conducting column (or heat conducting column) 20 is substantially in a bar shape and installed at a central position of the reflective arc surface 11.

[0013] The conversion module 30 is an photocell (such as a solar cell) or a light source (such as light emitted diode) to generate light, and the conversion module 30 is installed on a distal surface of the thermal conducting column 20. In other words, the conversion module 30 is installed to the thermal conducting column 20 and disposed on a distal surface at another end of the reflection module 10, wherein the conversion module 30 is a light emitting diode (LED) package or laser diode (LD) package illumination element or photocell (such as a solar cell).

[0014] The reflective mask 40 is an opaque or semi-transparent reflecting mirror (wherein a light source is reflected or a portion of the light source is passed through the mask) and made of a wavelength modulation material such as an organic polymer carrier added with an organic wavelength modulation material, a quantum dot luminescence color rendering modulation material and a nanoparticle light intensity enhancer composite material, and the reflective mask 40 and the conversion module 30 are installed with an appropriate distance apart. In other words, the conversion module 30 is installed between the reflective mask 40 and the reflection module 10, such that the conversion module 30 can project a light source onto or receive a light source by the reflective mask 40 respectively. In a preferred embodiment, the reflective mask 40 is fixed at an appropriate position as shown in FIGS. 1 and 2, and a plurality of fixing elements 13 (or other fixing elements with different fixing methods) are coupled between the reflective mask 40 and the reflection module 10, and the fixing element 13 is a sheet support frame provided for fixing the reflective mask 40 (wherein the application of fixing elements 13 on the left side is an example showing one of the methods, but persons skilled in the art may use other methods to achieve the same effect). In addition, the reflective mask 40 has a projecting arc surface 41 disposed at a position opposite to the conversion module 30 (as shown in FIG. 3a).

[0015] With reference to FIG. 3a for an application of the reflective light wavelength modulator in accordance with this preferred embodiment, if the conversion optoelectric module 30 is a light emitting diode (LED) package or laser diode (LD) package light emitting element, the light of the conversion module 30 is projected onto the reflective mask 40. Since the reflective mask 40 is a semi-transparent reflecting mirror, a portion of light A is passed through the reflective mask 40 and transmitted to the outside, and a portion of light B is reflected from the projecting arc surface 41 of the reflective mask 40, and the reflected light B is projected onto the reflective arc surface 11 of the reflection module 10 and a light C is reflected from the reflective arc surface 11, and the sum of the light A and the light C is equal to the total light projection intensity. Since the reflective mask 40 and the reflection module 10 both reflectors are coated with or made of a wavelength modulation material, a light projected onto the reflective mask 40 and reflected or passed through the reflection module 10 for a light reflection goes through a light source wavelength modulation, such that the light source color can be modulated. On the other hand, the heat generated by the optoelectric conversion module 30 can be conducted and dissipated from the thermal conducting column 20 to the reflection module 10, wherein the reflection module 10 is a metal based reflecting mirror with a heat dissipation function for dissipating the heat from the reflection module 10. Of course, a heat dissipating base 15 can be further installed at the bottom of the reflection module 10 as shown in FIG. 6 for providing an excellent heat dissipating effect.

[0016] In FIG. 3b, if the conversion module 30 is an photoelectric conversion element (such as a solar cell), the sun light beam is projected onto the reflective mask 40. Since the reflective mask 40 is a semi-transparent reflecting mirror made of a wavelength modulation material, therefore a portion of light A is passed through the reflective mask 40 and then projected and focused at the conversion module 30 (such as the solar cell), and a portion of light C is projected onto the reflection module 10 and then reflected from the reflective arc surface 11 for a light reflection. The reflected light beam B is projected onto the reflective mask 40, reflected by the projecting arc surface 41, and focused at the conversion module 30. Since both the reflective mask 40 and the reflection module 10 are made of or coated with a wavelength modulation material, both of the light passed through the reflective mask 40 and reflected from the reflection module 10 go through a light source wavelength modulation, such that the conversion module 30 can have both a better sunlight energy conversion and focusing effect to increase the photoelectric conversion efficiency.

[0017] With reference to FIGS. 4 and 5 for a reflective light wavelength modulator in accordance with a second preferred embodiment of the present invention, the reflective light wavelength modulator comprises a reflection module 50, a plurality of thermal conducting columns 60, a plurality of optoelectric conversion modules 70 and a reflective mask 80, wherein the reflection module 50 is made of a wavelength modulation material coated reflector with such as an organic polymer carrier added with an organic wavelength modulation material, a quantum dot luminescence color rendering modulation material and a nanoparticle light intensity enhancer composite material, etc, and the reflection module 50 is substantially in a long-disc shape and includes a reflective arc surface 51 and two lateral end plates 52, and the reflection module 50 is a reflecting mirror having a heat dissipation function, and the plurality of thermal conducting columns 60 are installed on a reflective arc surface 51 of the reflection module 50, and the plurality of optoelectric conversion modules 70 are installed on a distal surface and corresponding to the plurality of the thermal conducting column 60 respectively. In other words, the optoelectric conversion module 70 is installed to the thermal conducting column 60 and opposite to a distal surface at another end of the reflection module 50, and the optoelectric conversion module 70 is a light emitting diode (LED) package or laser diode (LD) package light emitting element or photocell (solar cell). The reflective mask 80 is a semi-transparent reflecting mirror made of a wavelength modulation material such as an organic polymer carrier added with an organic wavelength modulation material, a quantum dot luminescence color rendering modulation material and a nanoparticle light intensity enhancer composite material. The reflective mask 80 and the conversion module 70 are installed with an appropriate distance apart. In other words, the conversion module 70 is installed between the reflective mask 80 and the reflection module 50, such that the light beam emitted from or received by the conversion module 70 is projected by the reflective mask 80 or reflected by the reflection module 50 and the reflective mask 80. In this preferred embodiment, the reflective mask 80 is fixed at an appropriate position as shown in FIG. 4, and both lateral sides of the reflective mask 80 are fixed onto the reflection module 50 by a fixing element 53 (such as a sheet support frame) or any other fixing element with a different fixing method), and the reflective mask 80 has a projecting arc surface 81 disposed opposite to the conversion module 70.

[0018] With reference to FIG. 5 for an application of the reflective light wavelength modulator of this preferred embodiment, if the conversion module 70 is a light emitting diode (LED) package or laser diode (LD) package light emitting element, the light source of the illumination module or the photocell is projected onto the reflective mask 80. Since the reflective mask 80 is a semi-transparent reflecting mirror, a portion of light A1 is passed through the reflective mask 80 and projected to the outside, and a portion of light B1 is reflected from the projecting arc surface 81 of the reflective mask 80, and the reflected light B1 is further projected onto the reflective arc surface 51 of the reflection module 50, and a light C1 is reflected from the reflective arc surface 51, and the sum of the light A1 and the light C1 is equal to the total light projection intensity. Since both the reflective mask 80 and the reflection module 50 are made of or coated with a wavelength modulation material, the light projected onto the reflective mask 80 and then reflected from or passed through the reflection module 50 goes through the light source wavelength modulation, such that the light source color can be modulated. On the other hand, the heat generated by the conversion module 70 can be conducted and dissipated from the thermal conducting column 60 to the reflection module 50, and the reflection module 50 is a metal based reflecting mirror having a heat dissipation function and capable of dissipating the heat from the conversion module 70.

[0019] Similarly, if the optoelectric conversion module 70 is an photoelectric conversion element such as a solar cell (same as the one as shown in the first preferred embodiment), the optoelectric conversion module 30 also has a better sunlight focusing effect to improve the optoelectric conversion efficiency.

[0020] In view of the description above, the present invention improves over the prior art and complies with patent application requirements, and thus is duly filed for patent application. While the invention has been described by device of specific embodiments, numerous modifications and variations could be made thereto by those generally skilled in the art without departing from the scope and spirit of the invention set forth in the claims.

Claims

1. A reflective light wavelength modulator, comprising:

   a reflection module 10, 50, made of a wavelength modulation material coated reflector, and having a reflective arc surface 11,51;
   at least one heat conducting column 20, being in a bar shape, and

installed at a position of the reflective arc surface11,51 of the reflection module 10,50;
at least one optoelectric conversion module 30, 70, installed on a distal surface of the conducting column 20;
a reflective mask 40, 80, made of a wavelength modulation material,
and installed at a position corresponding to the conversion module 30, 70, for projecting a light beam to the reflective mask 40,80, or reflecting the light beam to an appropriate distance.

2. The reflective light wavelength modulator of claim 1, wherein the reflection module 10, 50 includes a metal based reflecting mirror having a heat dissipation function.

3. The reflective light wavelength modulator of claim 1, wherein the optoelectric conversion module 30, 70 is an illumination element and the illumination element is light emitting diode (LED) package or laser diode (LD) package.

4. The reflective light wavelength modulator of claim 1, wherein the optoelectric conversion module 30, 70 is a photoelectric conversion element, and the photoelectric conversion element is a solar cell or an photocell.

5. The reflective light wavelength modulator of claim 1, wherein the reflective mask 40,80 is fixed onto the reflection module 10,50 by a fixing element 13.

6. The reflective light wavelength modulator of claim 1, wherein the reflective mask 40, 80 includes a projecting arc surface 41, 81 corresponding to the optoelectric conversion module 30, 70.

7. The reflective light wavelength modulator of claim 6, wherein the light source emitted from the optoelectric conversion module 30, 70 is projected onto the reflective mask 40, 80 and a portion of the light source is passed through the reflective mask 40, 80 and projected to the outside, and another portion of the light source is reflected from the reflective mask 40, 80 to the reflection module 10, 50 and then reflected from the reflective arc surface 11, 51 to the outside.

8. The reflective light wavelength modulator of claim 6, wherein the portion of the light source received by the reflection module 10, 50 is projected to the reflective mask 40, 80 and part of light beam which received by the reflective mask 40, 80 is passed through the reflective mask 40, 80 and the rest part of light beam received by the reflective mask 40, 80 is reflected from the reflective mask and then projects to the optoelectric conversion module 30, 70.

9. The reflective light wavelength modulator of claim 1, wherein the reflection module 10, 50 includes a plurality of heat conducting columns 20, and each heat conducting column 20 includes a optoelectric conversion module 30, 70.

10. The reflective light wavelength modulator of claim 1, wherein the reflection module 10, 50 includes a heat dissipating base 15 disposed at the bottom of the reflection module 10, 50.

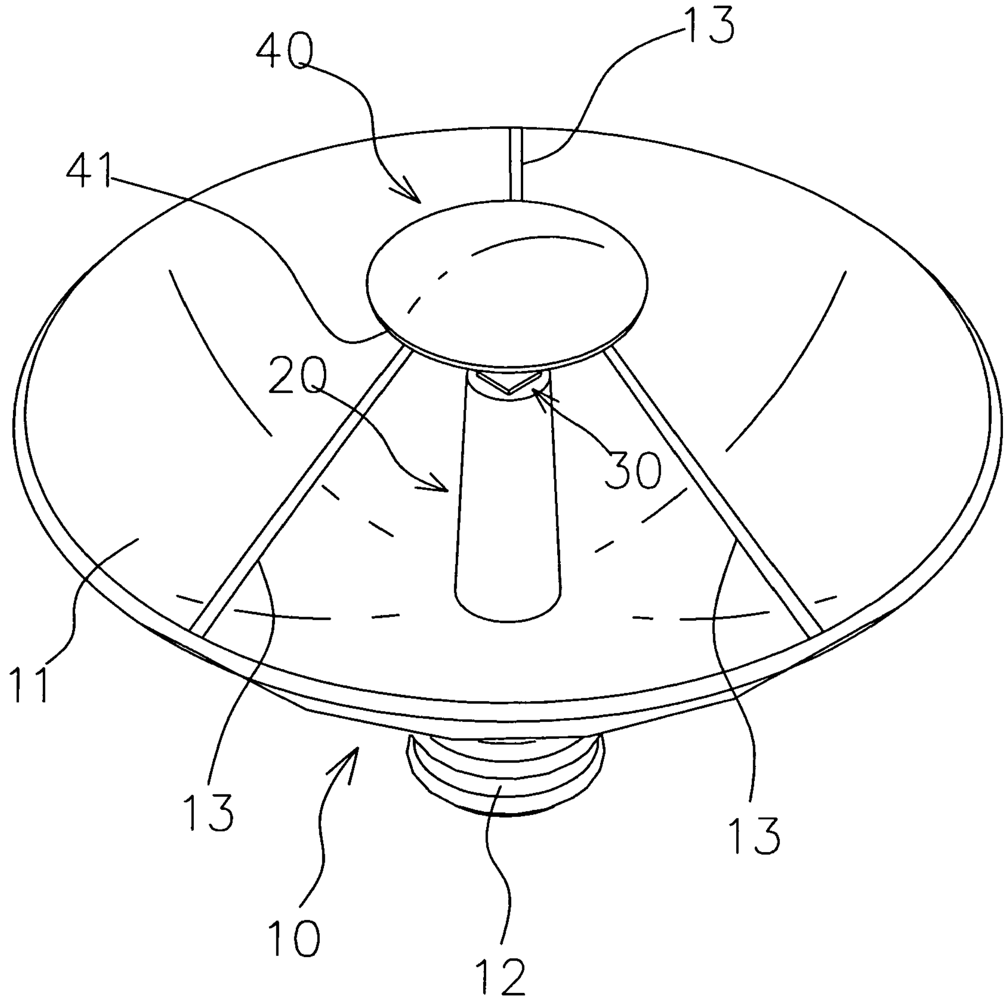

FIG. 1

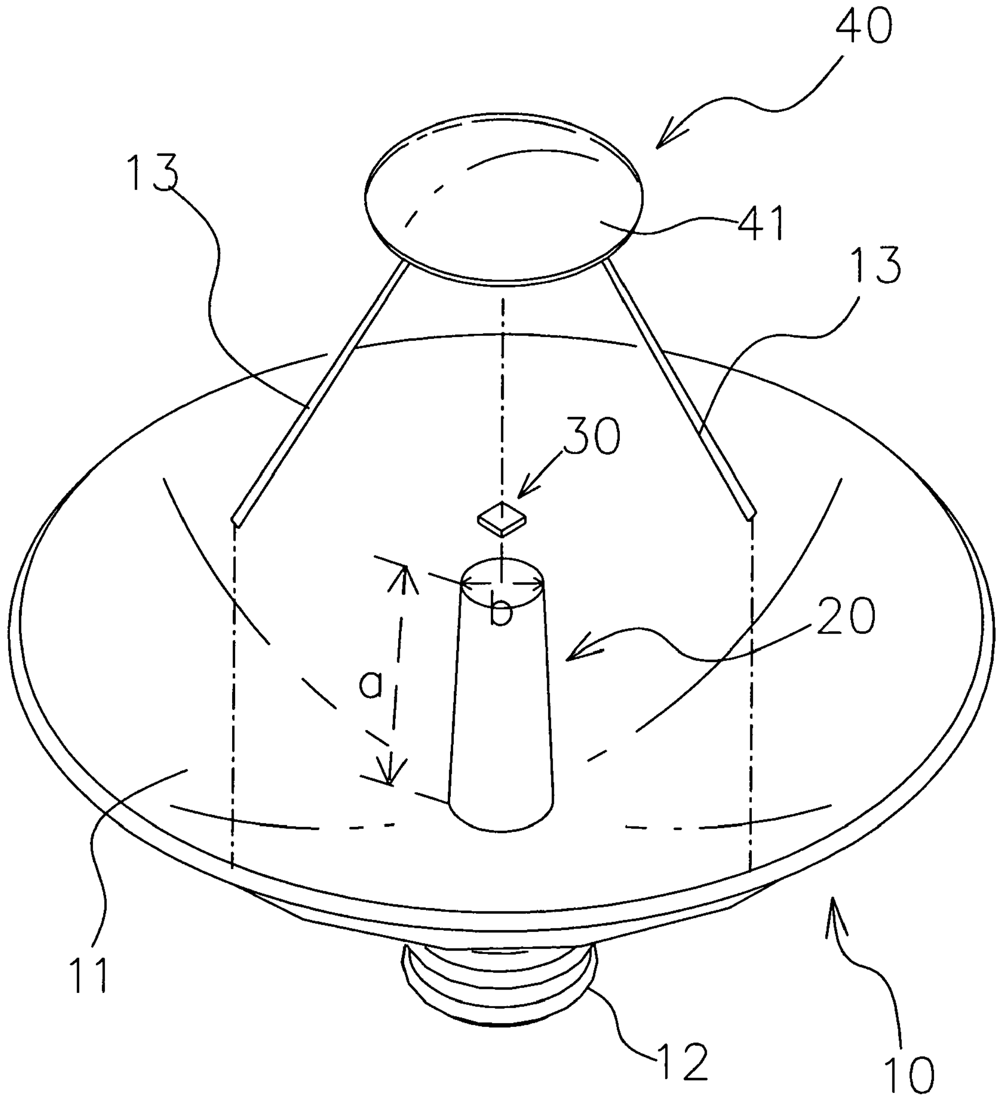

FIG. 2

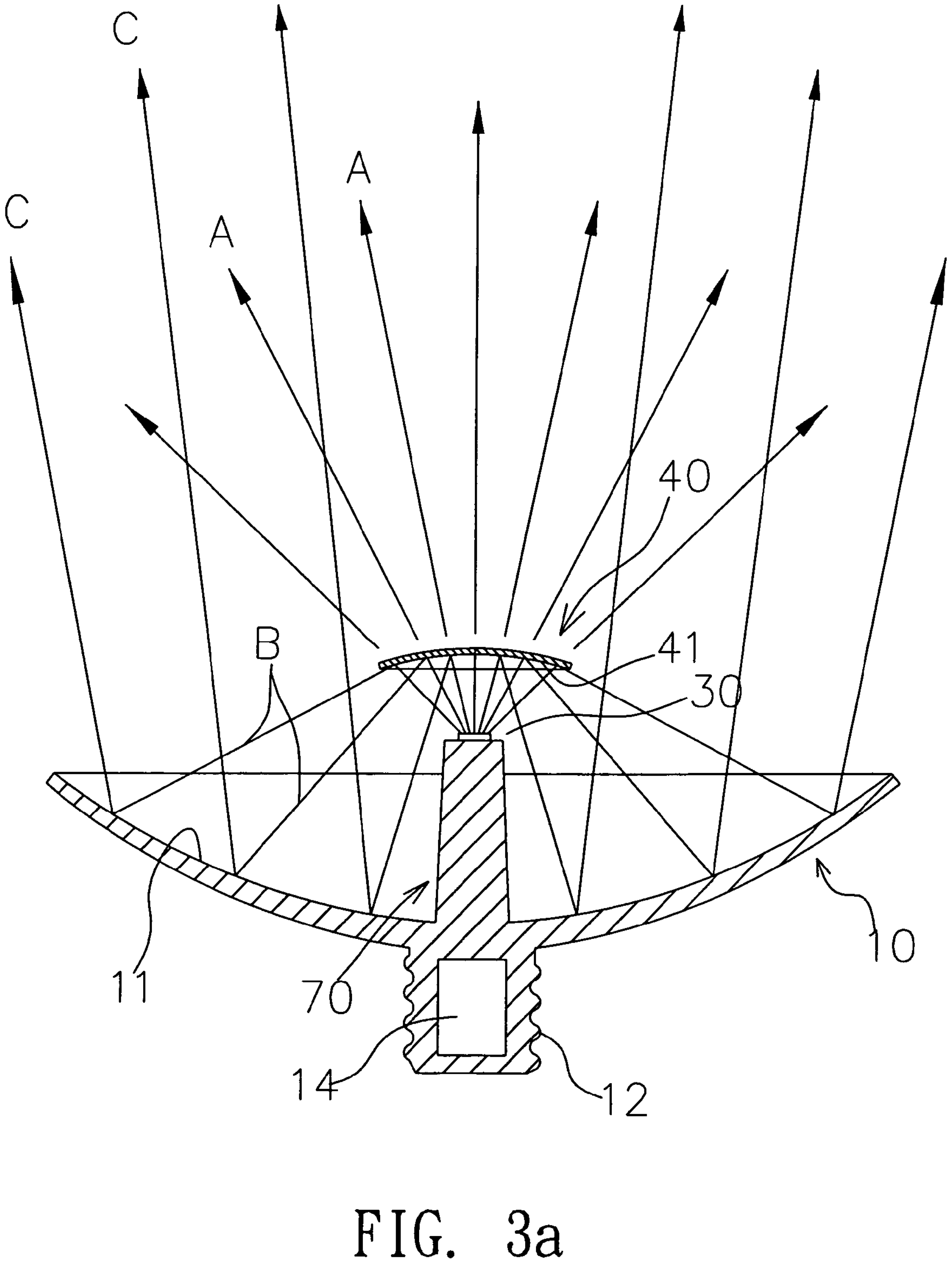

FIG. 3a

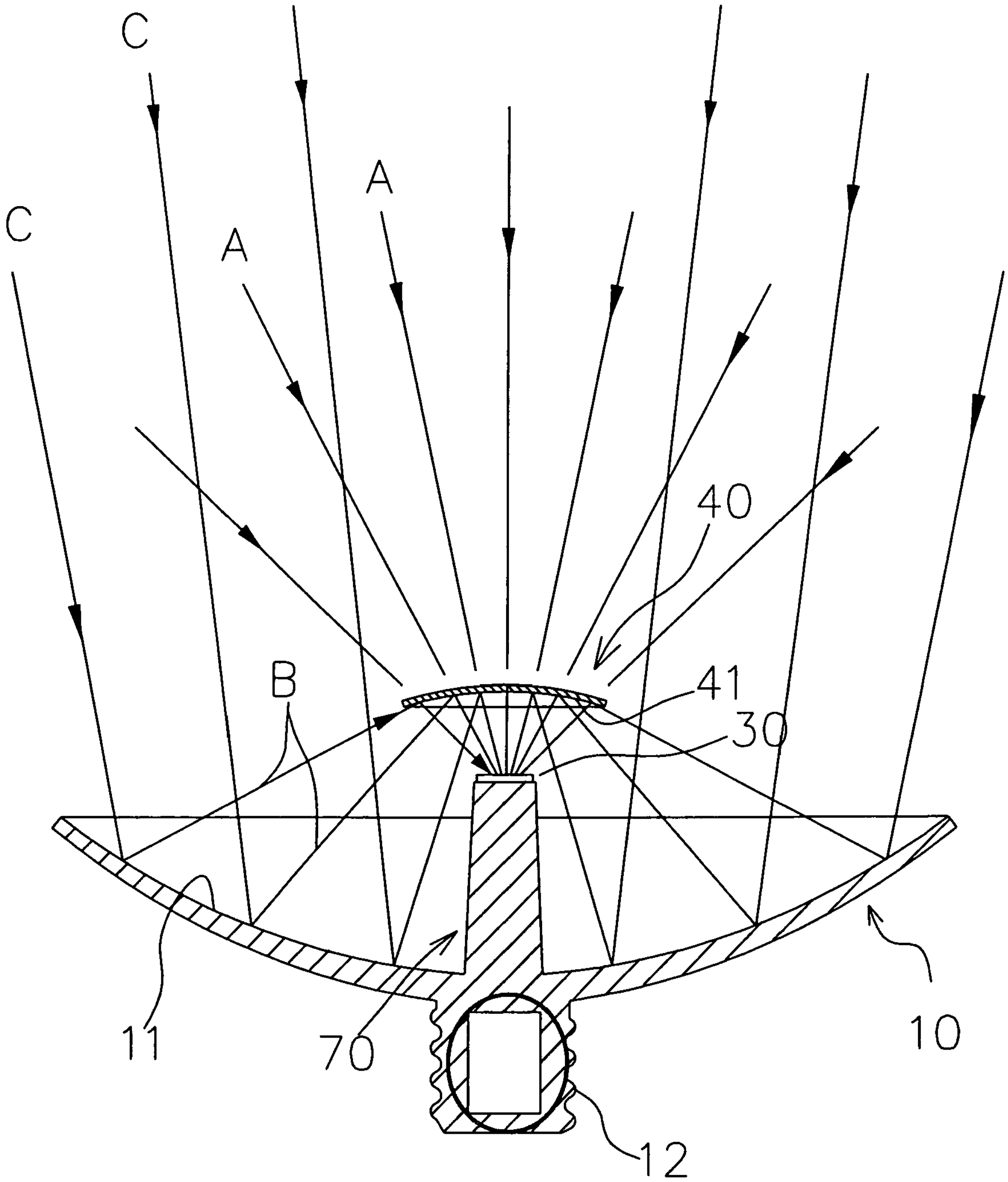

FIG. 3b

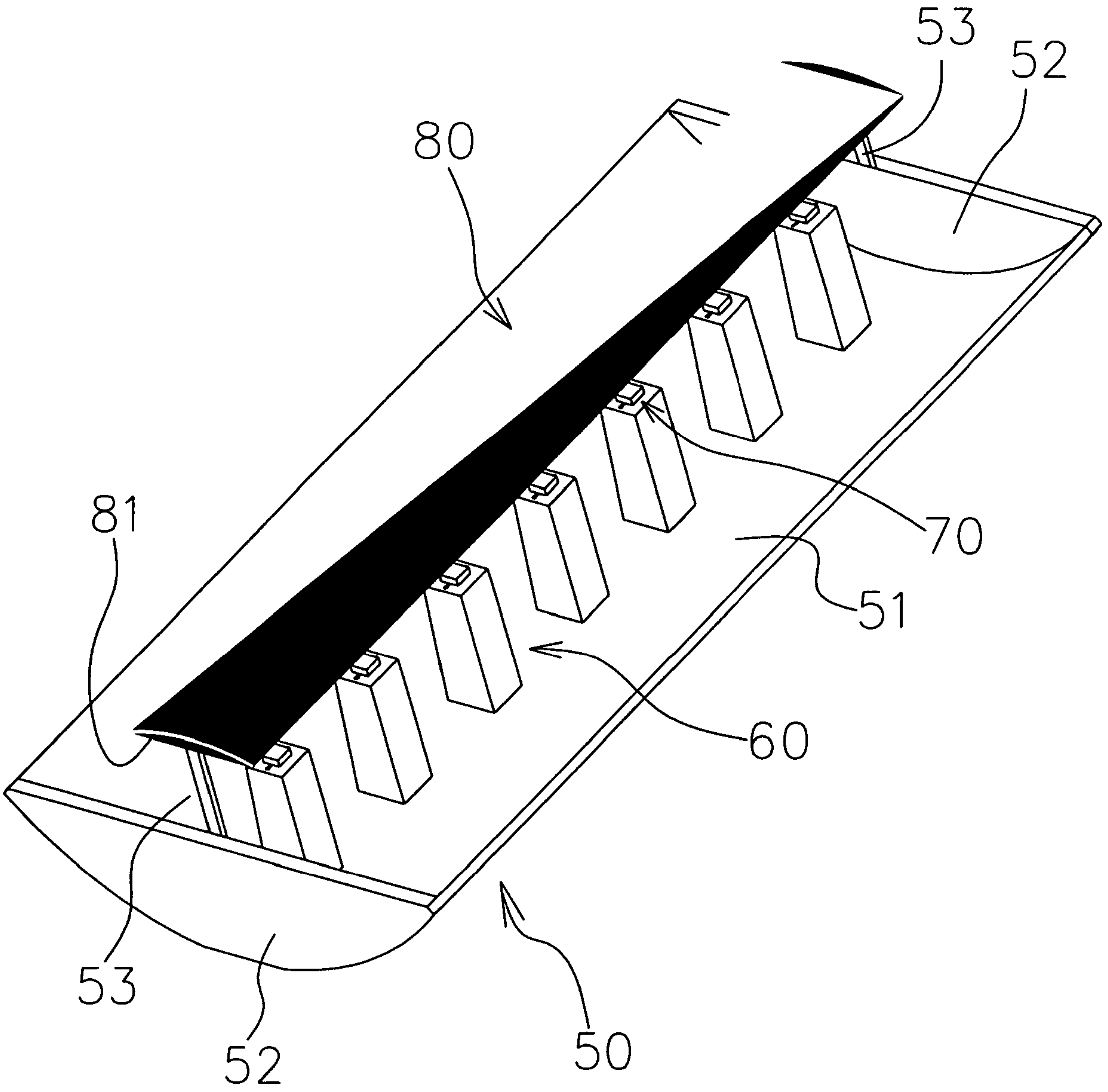

FIG. 4

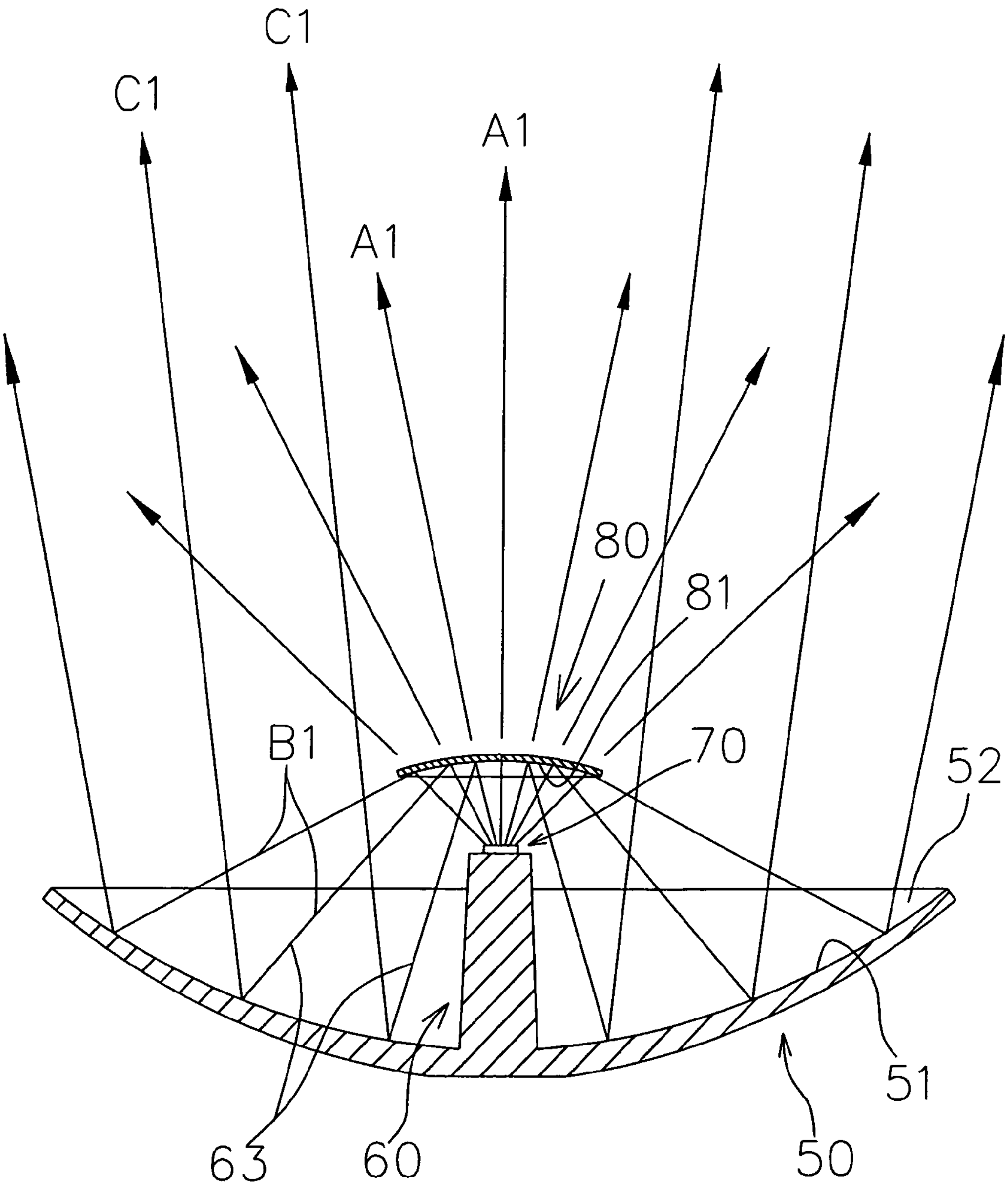

FIG. 5

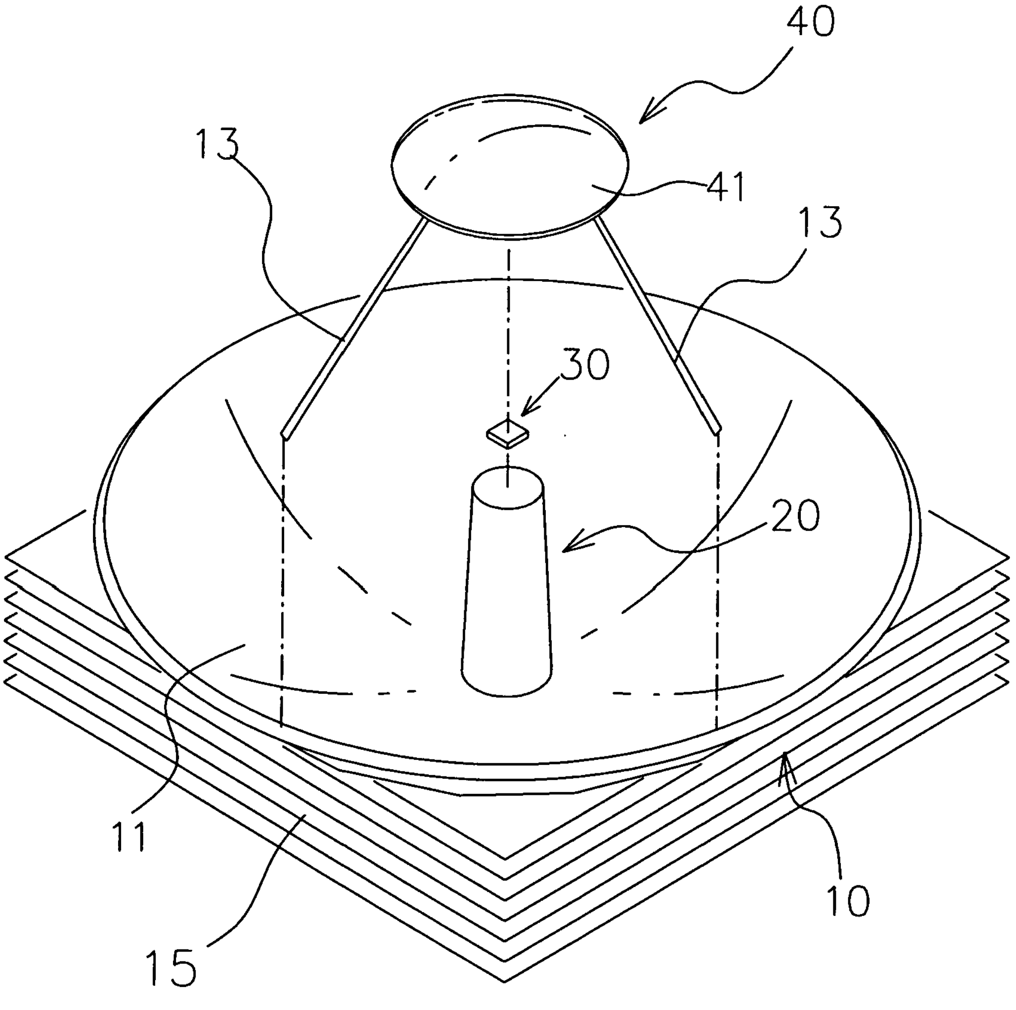

FIG. 6

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(81) 指定国 (除另有指明，要求每一种可提供的国家保护): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW。

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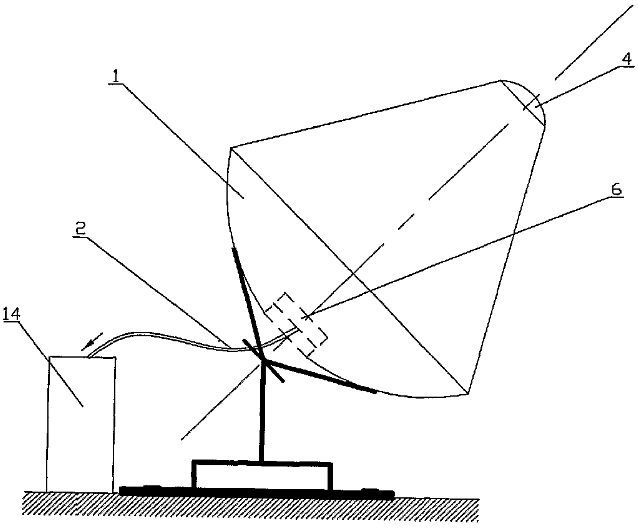
[见续页]

(54) Title: HIGH EFFICIENT APPARATUS USING SOLAR ENERGY

(54) 发明名称: 一种高性能太阳能装置



(57) Abstract: Apparatus using solar energy including a concentrator (1) and a focal reflector (4) mounted on a support is disclosed. The concentrator (1) focuses and reflects the sunlight to the focal reflector (4) positioned above the concentrator (1) accordance with a certain degrees. A focal lens (6) is positioned below the focal reflector (1). Both the concentrator (1) and the focal reflector (4) have a same optical axis. And the apparatus (2) such as solar battery modules, optical fibers or super conductive heat pipes, which can convert solar energy, are positioned under the focal lens (6) and along said optical axis. Said apparatus using solar energy can be used to produce electric energy, heat energy or light energy, to meet different requirement.

(57) 摘要:

一种太阳能装置，包括固定安装在支架上的聚光器（1）和会聚反射镜（4），聚光器（1）按照一定角度将太阳光会聚反射到设置在其上部的会聚反射镜（4）上，在会聚反射镜（4）下方设置有会聚透镜（6），会聚透镜（6）与上述会聚反射镜（4）也位于同一光轴上，在会聚透镜（6）的下方，并沿所述光轴方向设置有太阳能电池组件、光导纤维或超导热管等光能转换设备（2）。使用该装置可以产生电能、热能或光能，以满足不同使用需求。

本国际公布：

— 包括国际检索报告。

所引用双字母代码及其它缩写符号，请参考刊登在每期PCT公报期刊起始的“代码及缩写符号简要说明”。

一种高性能太阳能装置

技术领域

本发明涉及一种太阳能利用设备，具体涉及一种高性能太阳能装置。

背景技术

太阳能电池组件的光电转换效率和转换材料的效率与光生载流子的多少密切相关，采用大量的太阳能电池组件导致成本极高；太阳光中约５０％的光不能产生载流子，仅产生热。因此，要满足高注入载流子的条件是提高光照强度。采用单一聚光器，需要很高的聚光精度，带来制造成本大幅度增加；光照强度提高必然产生大量的热，而高热将使太阳能电池转换效率下降，甚至损坏太阳能电池；太阳能电池组件因封装和裸露于露天环境使表面不洁产生热岛效应，导致电池片的损坏相当高，且生产技术难度也较大；大功率太阳能发电装置一般都必须固定安装，不能车载或便携，限制了使用环境；目前，太阳能热水器基本上是中温型，也即在 90℃以下，冬天或者在高寒地区不适用；目前使用的太阳能灶基本上是露天使用，即不方便也不卫生，并且不便于操作；现在应用的太阳光照明装置，由于采光原因达不到正常照明所要求的照度。

发明内容

本发明的目的是克服现有太阳能应用设备的不足，设计制造一种结构简单、成本低廉的满足太阳能产生电能、热能或光能的高性能太阳能装置。

上述发明的目的是通过以下技术方案实现的：一种高性能太阳能装置，包括固定安装在支架上的聚光器和会聚反射镜，所述聚光器和会聚

反射镜具有同一光轴，聚光器按照一定角度将太阳光会聚反射到设置在其上部的会聚反射镜上，所述一定角度是指聚光器会聚的光斑应等于或小于会聚反射镜的镜口面积；在会聚反射镜下方设置有会聚透镜，会聚透镜与上述会聚反射镜也位于同一光轴上，会聚反射镜与会聚透镜之间的距离应使会聚反射镜的反光光斑完全照射到会聚透镜上，即光斑面积应等于会聚透镜垂直于光轴的中心截面积；在会聚透镜的下方，并沿所述光轴方向设置有光能转换设备。

所述光能转换设备为太阳能电池组件、光导纤维或超导热管，使用该设备产生电能、热能或光能，以满足不同的使用要求。

本发明的有益效果是：由于本装置经过多次会聚、反射达到高聚光度，太阳能利用充分，且单个聚光器的精度不需要很高，聚光器、会聚反射镜等可采用任何材料加装光反射层制作，可以大幅度降低制造成本；太阳能电源可作成分体式，便于车载、携行、检修、更换，使用十分方便。

附图说明

下面结合附图及实施例对本发明作进一步说明。

图 1 为本发明发电、发热装置结构示意图；

图 2 为外置式太阳能电池组件集成箱装置示意图；

图 3 为本发明聚光照明装置结构示意图；

图 4 为本发明热发电装置结构示意图。

图中： 1.聚光器 2.超导热管 3.水箱 4.会聚反射镜 5.会聚反射镜支架 6.会聚透镜 7.滤光镜 8.太阳能电池组件 9.支架 10.基座 11.光纤 12.光轴 13.照明灯 14.蒸汽发电机组 15.太阳能电池组件箱 16.发散透镜 17.太阳能电池片。

具体实施方式

本发明一种高性能太阳能装置包括有聚光器 1 和会聚反射镜 4 等，聚光器及会聚反射镜形状可以为抛物镜或其它多种几何形状。如图 1 所示，抛物镜面形状的聚光器 1 固定安装在支架 9 上，支架 9 固定在基座 10 上，聚光器 1 将太阳光会聚、反射至其上方的光线会聚反射镜 4 上，所述会聚反射镜 4 设置在会聚反射镜支架 5 的顶端；聚光器 1 和会聚反射镜 4 具有同一光轴 12；聚光器 1 按照一定角度将太阳光会聚反射到会聚反射镜 4 上；在会聚反射镜 4 下方设置有会聚透镜 6，会聚反射镜 4 将会聚的太阳光反射到会聚透镜 6 上，会聚透镜 6 与上述会聚反射镜 4 也位于光轴 12 上；由会聚透镜 6 会聚后的高聚光束照在透镜下方的也位于垂直放置在光轴 12 的太阳能电池组件 8 上，通过调整聚光器 1、会聚反射镜 4、会聚透镜 6 与太阳能电池组件 8 之间的相互距离，达到最佳聚光效果，并使本系统结构紧凑。聚光器 1 与会聚反射镜 4 之间的距离应使会聚反射镜 4 不对聚光器 1 产生遮挡，聚光器 1 会聚的光斑应等于或小于会聚反射镜 4 的镜口面积；会聚反射镜 4 与会聚透镜 6 之间的距离应为会聚反射镜 4 的反光光斑完全照射到会聚透镜 6 上，即光斑面积应等于或小于会聚透镜 6 垂直于光轴 12 的中心截面积；会聚透镜 6 与太阳能电池组件 8 之间的距离应为经会聚透镜 6 会聚的高聚光束，均匀照射在太阳能电池组件 8 上，即经会聚透镜 6 会聚的高聚光束光斑面积应等于太阳能电池组件 8 的面积。

按照使用要求，太阳能电池组件 8 可采用单片、也可用未经过封装的数片太阳能电池片层叠在一起，由于会聚的光束很强，因此透射的光线很强，电池片的厚度可以将上部电池片透射的光传至后片同时发电，可最大限度避免光线反射散失，使太阳光得到充分利用。层叠在一起的

太阳能电池片可简单封装，降低生产难度、减少封装材料，降低了生产成本，并可避免热岛效应，提高电池寿命。为了提高光电转换效率，同时降低太阳能电池组件表面的温度，可在会聚透镜 6 和太阳能电池组件 8 之间设置有滤光镜 7，滤光镜 7 可滤除不能产生载流子而只产生热的光。

如图 1 所示，在会聚透镜 6、滤光镜 7 和太阳能电池组件 8 之间设置有一根以上超导热管 2，所述超导热管 2 的一端连接在会聚透镜 6 和太阳能电池组件 8 之间，超导热管 2 的另一端与水箱 3 相连，可将高会聚太阳光产生的热量传走，达到散热的目的，并可产生高温热水，该水箱 3 可作成分体式，适用于冬季或高寒地区取暖，获取生活用热水。对于大型太阳能发电场，可将多个这样的单体太阳能光电发电装置产生的热汇集在一个或数个蒸汽发电装置上，形成太阳能热蒸汽发电机，使太阳能得到更充分的利用，并可大大降低太阳能发电的总成本。

太阳能发电装置中，太阳能电池组件 8 可以是单片太阳能电池板，也可以是不经过封装的、层叠在一起的数片太阳能电池片，且太阳能电池片 17 采用卡式插接方式连接；其厚度可保证从上部电池片透射的光能传至下一电池片。

图 2 所示为外置式太阳能电池组件集成箱的实施例，太阳能电池组件箱 15 设置在远离会聚透镜 6 的位置上，太阳能电池组件箱 15 内装设有发散透镜 16 和太阳能电池片 17，多个太阳能电池片 17 通过卡式插接方式叠装，这时从会聚透镜 6 引入的太阳光通过光纤 11 引出，经发散透镜 16 集中投射到太阳能电池片 17 上，也可以将所述光纤 11 引出的太阳光经发散透镜 16 分别投射到叠层的太阳能电池片 17 的各个分层。本装置实现了太阳能电池片 17 的集成化、模块化、小型化，可使太阳能电池片避免风吹、雨淋、冰雹、夏季高温环境所造成的转换效率降低，也可

避免外界硬物的直接击打、强震和冲击，每块电池片不用封装，避免热岛效应，提高光的使用效率和电池的寿命。采用上述结构可将太阳能电源作成分体式，便于车载、携行、检修、更换。所述会聚透镜 6 和光纤 11 之间设置有滤光镜 7，同时在该外置式太阳能电池组件集成箱 15 上设置有风扇或超导热管散热，以满足太阳能电池组件最佳转换效率所需的温度。

图 3 显示本发明聚光照明装置的实施例。将本装置会聚透镜 6 会聚的光束通过光纤 11 引入需要照明的场所内的照明灯 13 上，可获得很强的照明光线，就单一照明使用要求而言，可将太阳光的利用效率达到最高。实际使用中，还可以用导热快的材料制成太阳能光灶，将光纤 11 的另一端直接与太阳能光灶相连。

图 4 所示为本发明热发电装置的实施例。在会聚透镜 6 下面设置有一根以上超导热管 2，将超导热管 2 通入蒸汽发电机组 14 的蒸汽锅炉，可使太阳能直接用于蒸汽发电；这一热源也可通过超导热管 2 接入室内，使超导热管 2 的另一端与太阳能热灶相连，供若干分体太阳能热灶使用，或直接通入水箱，提供生活热水。

本发明所述的高性能太阳能装置设置有太阳跟踪系统，可以保持抛物镜面或几何形状的反光板始终朝向太阳，达到聚光效果最佳。本装置可调节聚光度达数百倍以上，因此在同等条件下，可大幅度减少太阳能电池组件的用量，同时可极大提高现有太阳能电池转换效率一倍以上。由于本装置经过多次会聚、反射达到高聚光度，单个聚光器的精度不需要很高，因此大幅度降低了制造成本。

另外，本装置的聚光器 1、会聚反射镜 4 等装置可采用任何材料制作，并在其上加装光反射层，形式可以是硬式或折叠式，只要能够满足使用

要求即可。

本装置设置有充电装置、蓄能装置、逆变器、稳压装置，能制成各种功率的太阳能电源，以满足不同负载的需要。通过大型阵列还可形成大型发电场，并网发电。

权利要求书

1. 一种高性能太阳能装置，包括固定安装在支架上的聚光器和会聚反射镜，其特征是：所述聚光器和会聚反射镜具有同一光轴，会聚反射镜设置在会聚反射镜支架的顶端，聚光器按照一定角度将太阳光会聚反射到设置在其上部的会聚反射镜上，所述一定角度是指聚光器会聚的光斑应等于或小于会聚反光镜的镜口面积；在会聚反射镜下方设置有会聚透镜，会聚透镜与上述会聚反射镜也位于同一光轴上，会聚反光镜与会聚透镜之间的距离应使会聚反射镜的反光光斑完全照射到会聚透镜上，即光斑面积应等于或小于会聚透镜垂直于光轴的中心截面积；在会聚透镜的下方，并沿所述光轴方向设置有光能转换设备。

2. 如权利要求 1 所述的一种高性能太阳能装置，其特征是：所述光能转换设备为太阳能电池组件、光纤或超导热管。

3. 如权利要求 2 所述的一种高性能太阳能装置，其特征是：所述太阳能电池组件可以是单片太阳能电池板，也可以是不经过封装的、层叠在一起的数片太阳能电池片，且电池片采用卡式插接方式连接；其厚度可保证从上部电池片透射的光能传至下一电池片。

4. 如权利要求 3 所述的一种高性能太阳能装置，其特征是：在所述会聚透镜和太阳能电池组件之间设置有滤光镜。

5. 如权利要求 2 或 3 所述的一种高性能太阳能装置，其特征是：所述太阳能电池组件为设置在远离会聚透镜的位置上的外置式太阳能电池组件集成箱，即从会聚透镜引入的太阳光通过光纤引出，经发散透镜集中投射到一组太阳能电池片上，也可以将所述光纤引出的太阳光经发散

透镜分别投射到叠层的太阳能电池片的各个分层；所述会聚透镜和光纤之间设置有滤光镜；在该外置式太阳能电池组件集成箱上设置有风扇或超导热管。

6. 如权利要求 1 或 2 所述的一种高性能太阳能装置，其特征是：在所述会聚透镜和太阳能电池组件之间设置有一根以上超导热管，所述超导热管的一端连接在会聚透镜和太阳能电池组件之间；超导热管的另一端与水箱或蒸汽锅炉相连。

7. 如权利要求 1 或 2 所述的一种高性能太阳能装置，其特征是：在所述会聚透镜下面设置有一根以上超导热管，超导热管的另一端与太阳能热灶、水箱或蒸汽锅炉相连。

8. 如权利要求 1 或 2 所述的一种高性能太阳能装置，其特征是：在所述会聚透镜下设置有光纤，所述光纤的一端连接在会聚透镜下，另一端引入室内照明或与太阳能光灶相连。

9. 如权利要求 1 所述的一种高性能太阳能装置，其特征是：所述聚光器及会聚反射镜形状可以为抛物镜或其它多种几何形状。

10. 如权利要求 1 所述的一种高性能太阳能装置，其特征是：所述支架上设置有太阳跟踪系统、充电装置、蓄能装置、逆变器和稳压装置。

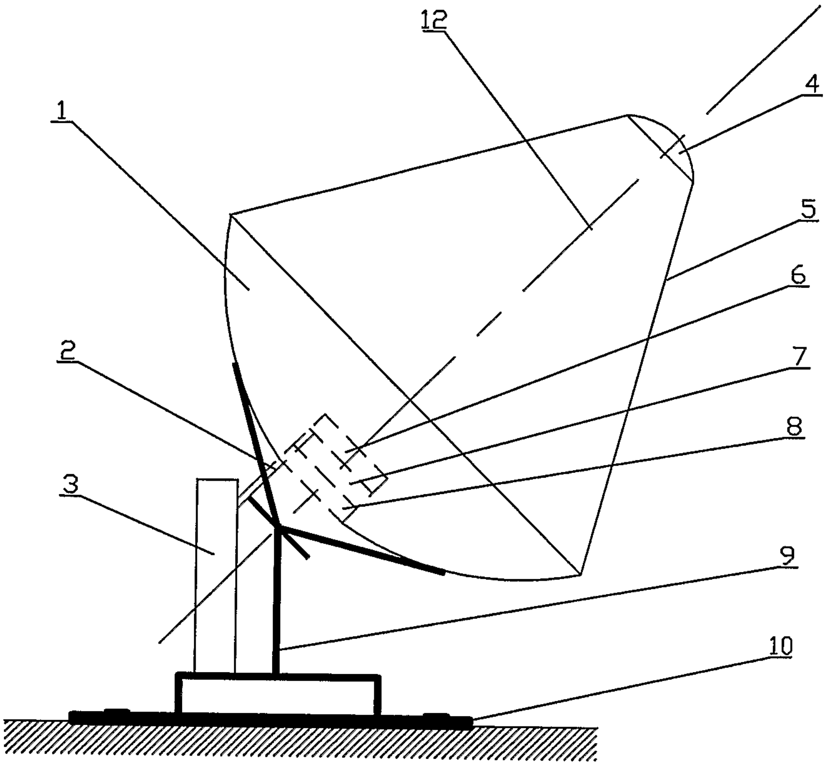


图 1

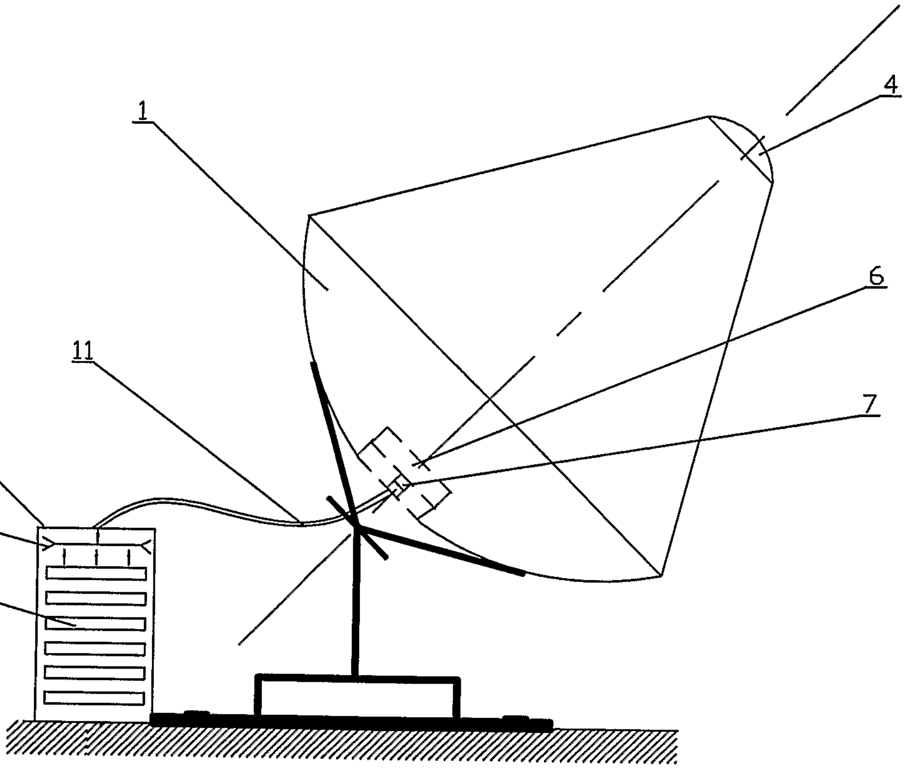


图 2

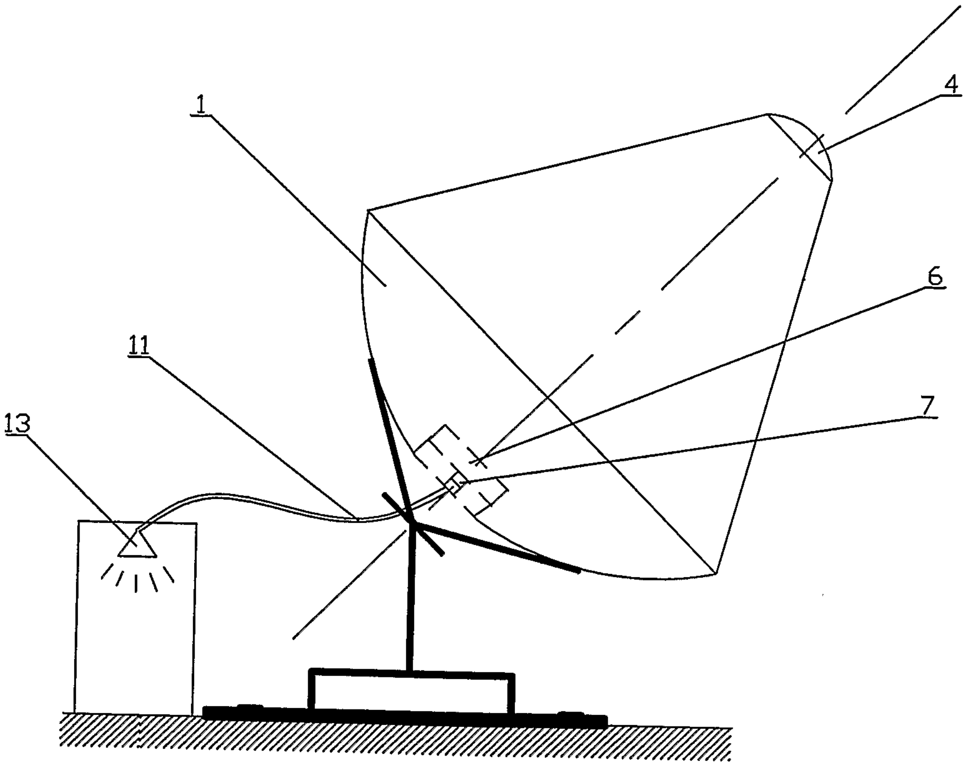


图 3

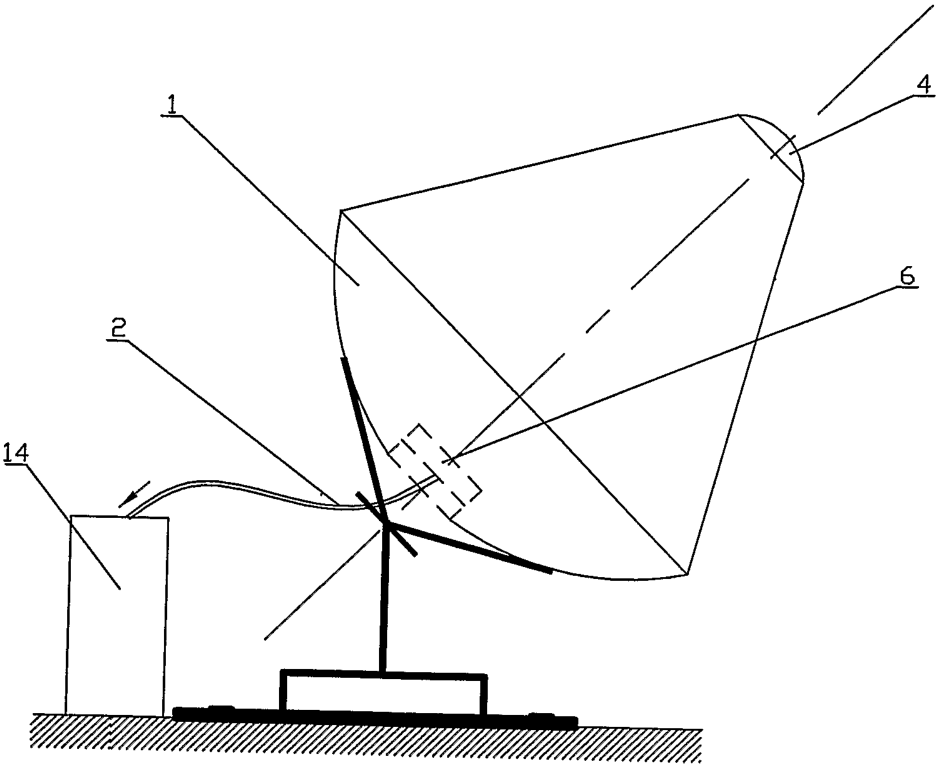


图 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2006/003658

A. CLASSIFICATION OF SUBJECT MATTER

see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F24J2/00; H01L31/042; F03G6/00; G02B6/00; H01L31/058

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC,WPI,PA, Chinese Patent Database, Chinese journal net: solar energy reflect+ concentrat+ lens+ frame support

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US4627418A (Geruldine Gibson, Santa Monica) 9 Dec.1986 (09.12.1986) Column 4,line 59 to Column 5,line 60,figure 1	1-3,5-10
Y		4
Y	US4249516A (North American Utility Construction Corp.,) 10 Feb.1981 (10.02.1981) Column 29,line 28-33,figure 27	4

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 15 Mar.2007 (15.03.2007)	Date of mailing of the international search report 05 · APR 2007 (05 · 04 · 2007)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer ZHONG Yi Telephone No. 86-10-62086338

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2006/003658

CLASSIFICATION OF SUBJECT MATTER

F24J2/00 (2007.01)I

H01L31/042 (2007.01)i

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2006/003658

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN1357684A (LI RUXIU) 10 Jul.2002 (01.07.2002) The whole document	1-3,5-10
Y		4
X	CN2624120Y (MU RUILI) 07.Jul.2004 (07.07.2004) The whole document	1-3,5-10
Y		4
X	US4068474A (DIMITROFF BORIS) 17 Jan.1978 The whole document	1-3,5-10
Y		4
X	WO80/00489A1 (ADVANCED SOLAR POWER COMPANY) 20 Mar.1980 (20.03.1980) Page 7,line 35 to page 11,line 12,figure 1	1-3,5-10
Y		4

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2006/003658

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
US4627418A	09.12.1986	US4472367A	09.18.1984
US4249516A	10.02.1981	FR2423730A	21.12.1979
		US4210121A	01.07.1980
CN1357684A	10.07.2002	NONE	
CN2624120Y	07.07.2004	NONE	
US4068474A	17.01.1978	NONE	
WO80/00489A1	20.03.1980	BE869754A	18.12.1978
		DE2749286A	10.05.1979
		FR2407439AB	25.05.1979
		NL7807477A	15.01.1980
		EP0016175A	01.10.1980
		GB1590091A	28.05.1981
		US4686581A	01.09.1981
		CA1113812A	08.12.1981
		DK7802907A	04.02.1980
		IL53194A	30.05.1980
		IT1109415B	16.12.1985

国际检索报告	国际申请号 PCT/CN2006/003658

A. 主题的分类

见附加页

按照国际专利分类表(IPC)或者同时按照国家分类和 IPC 两种分类

B. 检索领域

检索的最低限度文献(标明分类系统和分类号)

IPC： F24J2/00；H01L31/042；F03G6/00；G02B6/00； H01L31/058

包含在检索领域中的除最低限度文献以外的检索文献

在国际检索时查阅的电子数据库(数据库的名称，和使用的检索词（如使用）)

中国专利数据库，中文期刊网，WPI，EPODOC，PAJ：太阳能 聚光 反射 透镜 滤光 架 光纤 solar energy reflector concentrat+ lens+ frame support+

C. 相关文件

类 型*	引用文件，必要时，指明相关段落	相关的权利要求
X	US4627418A （Geruldine Gibson，Santa Monica） 09.12 月 1986 （09.12.1986） 说明书第 4 栏第 59 行-第 5 栏第 60 行，附图 1	1-3，5-10
Y		4
Y	US4249516A （North American Utility Construction Corp.,） 10.2 月 1981 （10.02.1981） 说明书第 29 栏第 28-33 行，附图 27	4
X	CN1357684A （李儒秀） 10.7 月 2002 （10.07.2002） 说明书全文	1-3，5-10

☒ 其余文件在 C 栏的续页中列出。 ☒ 见同族专利附件。

* 引用文件的具体类型：

“A” 认为不特别相关的表示了现有技术一般状态的文件

“E” 在国际申请日的当天或之后公布的在先申请或专利

“L” 可能对优先权要求构成怀疑的文件，或为确定另一篇引用文件的公布日而引用的或者因其他特殊理由而引用的文件

“O” 涉及口头公开、使用、展览或其他方式公开的文件

“P” 公布日先于国际申请日但迟于所要求的优先权日的文件

“T” 在申请日或优先权日之后公布，与申请不相抵触，但为了理解发明之理论或原理的在后文件

“X” 特别相关的文件，单独考虑该文件，认定要求保护的发明不是新颖的或不具有创造性

“Y” 特别相关的文件，当该文件与另一篇或者多篇该类文件结合并且这种结合对于本领域技术人员为显而易见时，要求保护的发明不具有创造性

“&” 同族专利的文件

国际检索实际完成的日期 15.3 月 2007 (15.03.2007)	国际检索报告邮寄日期 05 · 4月 2007 (05 · 04 · 2007)
中华人民共和国国家知识产权局(ISA/CN) 中国北京市海淀区蓟门桥西土城路 6 号 100088 传真号： (86-10)62019451	受权官员 钟翊 电话号码：(86-10)62086338

国际检索报告	国际申请号 PCT/CN2006/003658

主题的分类

F24J2/00 (2007.01)i

H01L31/042 (2007.01)i

C(续). 相关文件

类　型	引用文件，必要时，指明相关段落	相关的权利要求
Y		4
X	CN2624120Y （穆瑞力） 7.7 月 2004 （07.07.2004） 说明书全文	1-3，5-10
Y		4
X	US4068474A (DIMITROFF BOTIS) 17.1 月 1978 （17.01.1978） 说明书全文	1-3，5-8
Y		4
X	WO80/00489A1 （ADVANCED SOLAR POWER COMPANY） 20.3 月 1980 （20.03.1980） 说明书第 7 页第 35 行-第 11 页第 12 行，附图 1	1-3，5-10
Y		4

国际检索报告

关于同族专利的信息

国际申请号
PCT/CN2006/003658

检索报告中引用的专利文件	公布日期	同族专利	公布日期
US4627418A	09.12.1986	US4472367A	09.18.1984
US4249516A	10.02.1981	FR2423730A	21.12.1979
		US4210121A	01.07.1980
CN1357684A	10.07.2002	无	
CN2624120Y	07.07.2004	无	
US4068474A	17.01.1978	无	
WO80/00489A1	20.03.1980	BE869754A	18.12.1978
		DE2749286A	10.05.1979
		FR2407439AB	25.05.1979
		NL7807477A	15.01.1980
		EP0016175A	01.10.1980
		GB1590091A	28.05.1981
		US4686581A	01.09.1981
		CA1113812A	08.12.1981
		DK7802907A	04.02.1980
		IL53194A	30.05.1980
		IT1109415B	16.12.1985

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
8 May 2003 (08.05.2003)

PCT

(10) **International Publication Number**
WO 03/038348 A1

(51) **International Patent Classification⁷:** **F24J 2/06**, 2/18, C12M 1/00, H01L 31/052, F21S 11/00, 8/00

(21) **International Application Number:** PCT/US02/29645

(22) **International Filing Date:** 18 September 2002 (18.09.2002)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
09/953,848 18 September 2001 (18.09.2001) US

(71) **Applicant:** **UT-BATTELLE, LLC** [US/US]; P.O. Box 2008, Oak Ridge, TN 37831 (US).

(72) **Inventors:** **MUHS, Jeffrey, D.**; 4023 Highway 70E, Lenoir City, TN 37772 (US). **EARL, Dennis, D.**; 5913 West Pine Lane, Knoxville, TN 37909 (US).

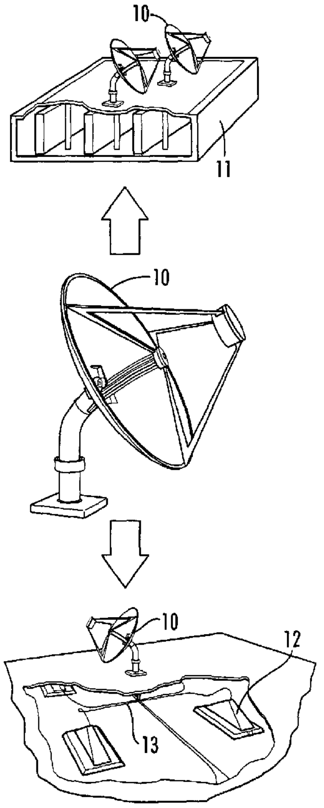
(74) **Agents:** **HARDAWAY, John, B., III** et al.; Nexsen Pruet Jacobs & Pollard, LLC, P.O. Box 10107, Greenville, SC 29603 (US).

(81) **Designated States** *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),

[Continued on next page]

(54) Title: ADAPTIVE, FULL-SPECTRUM SOLAR ENERGY SYSTEM



(57) **Abstract:** An adaptive, full-specturm solar energy system having at least one hybrid solar concentrator (10), at least one hybrid luminaire (12), at least one hybrid photobioreactor (11), and a light distribution system (13) operably connected to each hybrid solar concentrator (10), each hybrid luminaire (12), and each hybrid photobioreactor (11). A lighting control system operates each component.

Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for all designations*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

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TITLE

ADAPTIVE, FULL-SPECTRUM SOLAR ENERGY SYSTEM

Statement Regarding Federal Sponsorship

This invention was made with Government support under contract no. DE-AC05-00OR22725 to UT-Battelle, LLC, awarded by the United States Department of Energy. The Government has certain rights in the invention.

Field of the Invention

This invention relates to the field of solar energy systems and more specifically to an adaptive, full-spectrum solar energy system having hybrid solar concentrator collector(s) for capturing incident solar radiation and using different portions of the solar spectrum for different real-time end-use purposes in buildings such as lighting and electricity generation. Direct lighting is distributed to either hybrid luminaire fixtures or photobioreactors. Electricity generated by photovoltaics is used for building power.

Background of the Invention

Throughout the 1900s, use of the sun as a source of energy has evolved considerably. Early in the century, the sun was the primary source of interior light for buildings during the day. Eventually, however, the cost, convenience, and performance of electric lamps improved and the sun was displaced as our primary method of lighting building interiors. This, in turn, revolutionized the way we design buildings, particularly commercial buildings, making them minimally dependent on natural daylight. As a result, lighting now represents the single largest consumer of electricity in commercial buildings.

During and after the oil embargo of the 1970s, renewed interest in using solar energy emerged with advancements in daylighting systems, hot water heaters, photovoltaics, etc. Today, daylighting approaches are designed to overcome earlier shortcomings related to glare, spatial and temporal variability, difficulty of spatial control and excessive illuminance. In doing so, however, they waste a significant portion of the visible light that is available by shading, attenuating, and or diffusing the dominant portion of daylight, i.e., direct sunlight which represents over 80% of the light reaching the earth on a typical day. Further, they do not use the remaining half of energy resident in the solar spectrum (mainly infrared radiation between 0.7 and 1.8 μm), add to building heat gain, require significant architectural modifications, and are not easily reconfigured. Previous attempts to use sunlight directly for interior lighting via fresnel lens collectors, reflective light-pipes, and fiber-optic bundles have been plagued by significant losses in the collection and distribution system, ineffective use of nonvisible solar radiation, and a lack of integration with collocated electric lighting systems required to supplement solar lighting on cloudy days and at night.

Similar deficiencies exist in photovoltaics, solar thermal electric systems, and solar hot water heaters. Fig. 2 shows the conversion efficiency of traditional silicon-based solar cells as depicted in the silicon spectral response curve **23.** Conversion efficiency is low in the ultraviolet and short wavelength visible region **21**, but the incident radiation flux is high in the same region **21** as depicted in the solar irradiance curve at sea level **22.** Solar energy residing beyond ~1.1 μm is essentially wasted. To overcome this and address other economic barriers, one approach has been to develop utility-scale photovoltaic (PV) and solar thermal concentrators, the rationale being that the cell area and, consequently, the cell cost can be reduced by approximately the same amount as the desired concentration ratio. Unfortunately, this cost-savings is typically offset by the added cost and complexity of the required solar concentrator and tracking system.

In recent years, researchers have begun developing photobioreactors that use sunlight-induced photosynthesis to sequester carbon to produce biofuels such as hydrogen using cyanobacteria. Large-scale photobioreactors are already indispensable in the successful commercial production of phototrophic unicellular algae valued in such markets as aquaculture, pharmaceuticals, animal-feed additives and health foods. Unfortunately, very little of the incident sunlight is tapped to maximize cyanobacteria growth rates, and only 10% of the energy residing in the visible portion of the spectrum is typically used productively to produce biomass. Terrestrial solar radiation can reach ~2000 μEm^2s^{-1}, which easily satisfies the photosynthetic photon flux (PPF) requirements of algae. Indeed, at elevated PPF levels (greater than ~200 μEm^2s^{-1}), the kinetic imbalance between the rate of photon excitation and thermally-activated electron transport results in saturation of the photosynthetic rate. In the case of thermophilic and mesophilic cyanobacteria that are ideally-suited for carbon sequestration because of their thermal adaptation to higher temperatures, even a lower PPF level (~6 - 100 μEm^2s^{-1}) is required to achieve maximum carbon fixation. Thus, most of the lighting energy available from solar irradiance goes unused.

The principal hurdle to the scale up of photobioreactors to achieve a viable commercial-scale production of algae is lighting limitation, both in terms of light delivery and distribution and energy expenditure. For instance, current methods for mass cultivation of marine microalgae include translucent fiberglass cylinders, polyethylene bags, carboys and tanks under artificial lighting or natural illumination in greenhouses. In these cases, however, at an algal density of 0.45 g/L, for example, light penetrates the suspension only to a depth of 5 cm, leaving a significant percentage of the cells in complete darkness at any given time. As such, microalgal production in these systems seldom exceeds 100 kg DW (dry weight) per year per facility, and maintaining these systems is labor- and space-intensive and quite unreliable. Moreover, when lighting is provided by artificial lamps (such as fluorescent, high-pressure sodium or incandescent) in close proximity to the bioreactor vessel, the comparatively poor luminous efficacy and dissipation of heat from the lamps present a constant problem.

Natural bioreactors using traditional raceway cultivators commonly waste 90 to 95% of the incident photosynthetic photon flux at high algal densities along with the remaining solar energy resident in the UV and IR portion of the spectrum. This equates to an overall solar energy utilization factor of 2.5 to 5%, making conventional photobioreactors very difficult to justify from a cost and performance perspective.

The approach first demonstrated in Japan to improve the sunlight utilization efficiency of natural photobioreactors is to collect, transport, and distribute sunlight over a larger surface area, thereby improving the sunlight utilization efficiency by reducing losses caused by saturation. The concept included the use of the earlier-mentioned fresnel lens sunlight collector and a fiber optic bundle system to transport and distribute the light. Losses in the visible-light collection, transport and distribution system were typically more than 75%, and the 2x-to-3x improvements in sunlight utilization was far outweighed by the added cost ($5,000/m^2 of sunlight collected). This approach serves as partial precursor to this invention.

Brief Summary of the Invention

This invention improves the total end-use power displacement efficiency of solar energy by integrating solar technologies into multi-use hybrid systems that better utilize the entire solar energy spectrum. As illustrated in Fig. 3, a primary mirror **30** concentrates the entire solar spectrum of incoming sunlight **31** onto a spectrally selective secondary mirror **32** where the visible light **34** in the solar spectrum is separated from the UV and near infrared light in the solar spectrum. The two energy streams are used for different purposes. The visible light **34** is used for lighting and photobioreactors. The UV and near infrared light is used for electricity generation and/or process heat through a solar thermal and/or photovoltaic system **33**.

This adaptive, full-spectrum (AFS) solar energy system is a unique alternative to solar energy use in buildings and photosynthetic-based bioreactors. It uses solar energy from a dynamic, systems-level perspective, integrates multiple interdependent technologies, and makes better use of the entire solar energy spectrum on a real-time basis.

The AFS solar energy system, as shown in Fig. 1, uses a hybrid solar concentrator **10** that efficiently collects, separates, and distributes the visible portion of sunlight while simultaneously generating electricity from the infrared portion of the spectrum using new gallium antimonide (GaSb) infrared thermophotovoltaics (IR-TPVs). The optical and mechanical properties of improved large-core polymer optical fiber light distribution system **13** more efficiently deliver large quantities of visible sunlight into buildings and photobioreactors **11**. Once delivered, the visible sunlight is used much more effectively than previously to illuminate building interiors using new hybrid luminaires **12**. Improved cyanobacteria growth rates, packing densities, and solar utilization efficiencies in hybrid solar photobioreactors **11** that use fibers to more efficiently distribute and use light that would have otherwise been wasted via photosynthetic saturation is also provided.

This invention redirects and more efficiently uses portions of the solar energy spectrum originating from a common two-axis, tracking solar concentrator in real-time using electro-optic and or opto-mechanical devices. Analytical/experimental models and intelligent control strategies enhance the use of adaptive, full-spectrum solar energy systems in its two primary applications, that is, commercial buildings and hybrid solar photobioreactors used to mitigate CO_2 at power plants.

This invention uses: a) advanced materials including GaSb thermophotovoltaics, and spectrally-selective UV cold mirror thin film coatings; b) biomass resource development through innovative approaches to improve sunlight utilization in photobioreactors used in carbon sequestration and the production of fuels, chemicals, and agriculture products; c) intelligent sensor/control systems for use in adaptive solar energy systems in commercial buildings; d) computational science tools to aid in the design of adaptive, full-spectrum solar energy systems, model application-specific dynamic system behavior, and predict/optimize performance; and e) distributed power conversion systems for use in buildings and new hybrid solar photobioreactors.

Brief Description of the Drawings

Figure 1 shows the major components of the adaptive, full-spectrum (AFS) solar energy system.

Figure 2 is a graph showing the approximate spectral radiance R_λ and emissivity E_λ of the sun vs. wavelength λ at mean earth-sun separation and the associated silicon spectral response.

Figure 3 shows a schematic representation of hybrid solar concentrator.

Figure 4 is a bar graph showing the luminous efficacy of common light sources.

Figure 5 shows the components of the hybrid solar concentrator.

Figure 6 is a graph of the spectral response of the sputtered UV cold mirror.

Figure 7 is a front view of the IR-TPV.

Figure 8 is a section cut A-A of the IR-TPV showing the cooling fan.

Figure 9 is the end-to-end attenuation in large-core optical fibers at various incident angles.

Figure 10 is the hybrid luminaire rendering.

Figure 11 is the concentric fiber mount assembly.

Figure 12 is a graph of the results of initial optical analysis showing incident angles of light entering large-core optical fibers.

Figure 13 the sidelighting design configuration for hybrid solar photobioreactor.

Figure 14 shows a first embodiment of the hybrid solar concentrator.

Figure 15 shows a modified first embodiment of the hybrid solar concentrator.

Figure 16 shows a typical light dispersing element and optical fiber for the hybrid luminaires.

Detailed Description

The adaptive, full-spectrum (AFS) solar energy system takes advantage of the fact that new GaSb IR-TPV very efficiently convert concentrated energy residing in the near-IR solar spectrum between 0.7 and 1.8 μm at a conversion efficiency of ~23%. Similarly, the visible portion of sunlight is inherently more efficient when used directly for lighting. Fig. 4 is a bar graph showing the luminous efficacy, in lumens per watt, of the following common light sources: **410** Filtered Sunlight, **420** Direct Sunlight, **430** Low Pressure Sodium Lamps, **440** Scattered Daylight, **450** Metal Halide Lamps, **460** High Pressure Sodium Lamps, **470** New Fluorescent Lamps, **480** Old Fluorescent Lamps, **490** Compact Fluorescent Lamps, **500** Mercury Vapor Lamps, **510** Incandescent Lamps, and **520** Candles. The luminous efficacy of direct sunlight **420** is 90 to 100 lumens/Watt (lm/W) depending on the sun's orientation relative to the earth, atmospheric conditions, etc. The luminous efficacy of filtered sunlight **410** is 180 – 200 lm/W, which far exceeds existing electric lamps (15 – 90 lm/W). Unlike most comparisons with nonrenewable alternatives, the luminous efficacy of filtered sunlight is more than double its only competition (electric lamps). Therein lies the primary motivation for using filtered sunlight for lighting purposes in buildings and photobioreactors while using the remaining IR energy for electricity generation.

Fig. 5 illustrates a preferred embodiment of the hybrid solar concentrator **10** that takes advantage of the above strategy for both applications. A 1.6 meter diameter primary mirror **51** is fabricated using formed glass with a second surface reflective coating that concentrates 2 m^2 of sunlight onto a 25 cm diameter secondary optical element **52** consisting of a faceted, high temperature glass substrate sectioned into twelve or more surfaces each of which is shaped to reflect visible light onto large-core optical fibers using a sputtered UV cold mirror coating having a spectral response shown in Fig. 6. The secondary optical element **52** also includes a nonimaging optic concentrator that uniformly distributes IR radiation onto a IR-TPV with an accompanying self-power cooling fan, as shown in Fig. 8. A concentric fiber mount assembly **53** contains 12 or more large-core optical fibers **54,** each fiber 5 to twelve mm in diameter. An angled, hollow rotating assembly **55** reduces the range of motion required for altitude tracking by the conventional azimuth rotational tracking mechanism **56.**

The spectral response of a UV cold mirror is shown in Fig. 6. Percent reflectance (%) is graphed for various wavelengths (nm) under the following conditions: Illuminant = White; Medium = Air; Substrate = Glass; Exit = Glass; Detector = Ideal; Angle = 0.0 degrees; Reference = 560.0 nm; and Polarization = Average.

Fig. 7 and Fig. 8 show a typical non-imaging optic concentrator with a light-directing cone **72** that directs light onto an array of forty-eight infrared photovoltaic cells **71.** The photovoltaic cells **71** are mounted on a heat sink **83** that is cooled by a fan **84** powered by the photovoltaic cells **71.**

Other embodiments of the hybrid solar concentrator include a first concentrator embodiment, as shown in Fig. 14, which utilizes a good-quality 1.1 m diameter glass primary mirror and segmented planar secondary optical element to precisely focus light into eight large core optical fibers. A modified first embodiment, which orients the optical fibers at a slight angle for improved efficiency, is shown in Fig. 15. The modified first concentrator embodiment again utilizes a good-quality 1.1 m diameter glass primary mirror but uses an elliptical secondary optical element. The elliptical secondary element extends the focus of the primary mirror and couples light into a packed array of nine optical fibers. The elliptical secondary element is modified for use with optical fibers tilted at 10°. The redirected focus is located 95.0 mm from the base of the secondary mirror, in the optical fiber plane. The fiber optic holder is modified slightly to accommodate the 10° tilt in the optical fiber along with a small spacing between optical fibers. A third concentrator embodiment (not shown) represents a lower cost solution and uses a low quality coated 1.5 m diameter hydroformed satellite dish as the primary mirror with an elliptical secondary element that re-focuses the light onto a packed array of nine optical fibers.

The first concentrator embodiment, as seen in Fig. 14, uses a good quality parabolic primary mirror **163** with a planar segmented secondary mirror **160** to precisely split and focus incident solar radiation into eight large-core optical fibers **161**. The system is designed to couple a maximum of 10,000 lumens into each optical fiber with a high total system efficiency in the visible portion of the spectrum. Collimated light from the sun is collected and focused using a good quality parabolic primary mirror **163**. The focused light is split and redirected toward eight large-core optical fibers **161** mounted to a center post. The mounting hardware **162** does obscure some of the light focused by the primary mirror and will result in less than optimal efficiency for this design. This reduction in efficiency was necessary to meet the mechanical requirements that all fibers fit into a 4” post after exiting the backside of the primary mirror.

The first embodiment uses a 46.5” diameter parabolic mirror with a focal length of 16.5”, as manufactured by ROC glassworks, to serve as the primary mirror. The glass primary mirror, with front-surface coating, was fabricated using a “glass bending” technique that provided a good quality optical surface at a reasonable price. A 12” hole was bored in the center of the primary mirror to permit future mounting of a secondary mirror and fiber-optic holding apparatus. The primary mirror was coated, by FLABEG Inc., with an enhanced aluminum coating. The coating provides high reflectivity across the visible spectrum and is a durable coating suitable for the environmental conditions expected. On a cloudless day, 1.0 m^2 of sunlight delivers an average of 1000 Watts of optical power. Of that, 490 watts lies in the visible portion of the spectrum. The area of the primary mirror (assuming no center hole) of the first embodiment is approximately 1.096 m^2, giving a maximum theoretical collection energy of 537 Watts. Simulations predict that the first embodiment mirror will collect only 458 Watts. The efficiency of the primary mirror, having considering surface aberrations, scattering losses, coating losses, and center bore hole loss, is approximately 85.2%.

The purpose of the secondary optical element is two-fold. First, the secondary element must function to redirect focused light toward multiple large core optical fibers and, second, it should separate out non-visible light for use in photovoltaic conversion. To redirect the light focused by the previously described primary, a segmented secondary element was used. The mirror in the element utilizes a cold mirror coating to efficiently separate the infrared and visible portions of the spectrum. The "HeatBuster" cold mirror coating, developed by Deposition Sciences Inc., is a typical cold mirror coating that reflects UV and visible light while transmitting IR. Using a MicroDyn sputtering technique allows the coating to operate up to a maximum temperature of 500°C. This high temperature capability is necessary since it is anticipated that the secondary element may absorb significant levels of heat.

For the first embodiment of Fig. 14, an initial input energy of 537 Watts, which corresponds to the maximum possible power of visible solar light falling within a 46.5" diameter space, the total amount of light focused on the optical fiber plane is 381 Watts. This corresponds to a total concentrator efficiency of 70.9% and includes the coating losses in the primary and secondary, center hole losses in the primary, obscuration of the beam path by the fiber optic holder apparatus, and surface deviations/scattering losses in the primary. Fresnel losses at the optical fiber interface are not included.

For the modified first embodiment of Fig. 15, an initial input energy of 537 Watts, which corresponds to the maximum possible power of visible solar light falling within a 46.5" diameter space, the total amount of light focused on the optical fiber plane is 407 Watts. This corresponds to a total concentrator efficiency of 75.9% and includes the coating losses in the primary and secondary, center hole losses in the primary, obscuration of the beam path by the fiber optic holder apparatus, and surface deviations/scattering losses in the primary. Fresnel losses at the optical fiber interface are not included.

For building applications, the most significant loss factor in the light collection and distribution system is the end-to-end attenuation in large-core optical fibers (see Fig. 9). This invention more efficiently and cost-effectively transports sunlight through new polymer-based large-core optical fibers rather than glass fiber optic bundles. A new "hybrid" luminaire, illustrated in Fig. 10, spatially distributes both fiberoptic-delivered sunlight and electric light in a general lighting application and controlling the relative intensity of each based on sunlight availability using photosensors and dimmable electronic ballasts. Thus, natural light is collected at a central location and distributed to multiple luminaires.

A major step toward the realization of using fiber optic transported solar light for internal lighting purposes involves the development of a hybrid luminaire to seamlessly balance lamp and fiber optic transported solar illuminants. Fluctuations in the intensity of collected solar light, due to changing cloud coverage or solar collector movement, requires rapid compensation by electric lamps to maintain a constant room illumination. If the spatial intensity distribution of a hybrid luminaire's electric lamp does not closely match the spatial intensity distribution of the luminaire's fiber optic end-emitted solar illuminant, then the shift between artificial and solar lighting will be noticeable to the occupant and is highly undesirable.

A four-tube Lithonia GT8 troffer, as rendered in Fig. 10, equipped with a #19 pattern 4.0 mm acrylic lens diffuser, was modified to include two 15 cm diameter light dispersing elements **101** which utilize micro-optic structures. Fig. 10 shows only one light dispersing element **101.** The two 4.0 mm thick light dispersing elements **101** are mounted within the fixture's acrylic lens diffuser and allow a range of highly divergent quasi-elliptical spatial intensity distributions to be generated from two circular fiber optic end-emitting sources fed through the top surface of the fixture's troffer. Variations in the spatial intensity distribution of the dispersed solar light can be made without the need to readjust the alignment or spacing between the optical fiber **181** and the light dispersing element **101,** as shown in Fig. 16. The large core optical fibers **181** are mounted in the upper portion of the troffer. A static configuration is maintained.

The optical efficiency of the light dispersing elements has been estimated at greater than 90% while the optical efficiency of the original luminaire is reduced by 3%, from 76% to 73%. To improve the matching between the electric and solar spatial intensity distributions, the number of elements can be increased to four or even eight. However, increasing the number of light dispersing elements **101** reduces the optical efficiency of the fixture and results in higher costs.

A second embodiment of the hybrid luminaire comprised a cylindrical diffusing rod having a 2.54 cm diameter, 1.0 m long, optically clear cylinder with a polished lower hemisphere and a diffuse upper hemisphere. Light launched from a butt-coupled optical fiber, scatters from the diffuse upper surface of the cylinder and escapes through the polished lower surface of the cylinder. To improve efficiency, upward-scattered light is redirected back toward the lower hemisphere of the diffusing rod with a silver-coating on the upper hemisphere.

Three diffusing rods, each placed mid-way and slightly above adjacent fluorescent lamps in a 4-tube PARAMAX® Parabolic Troffer with 24-cell louvre baffle, were expected to produce a spatial intensity distribution which closely matched that of the four fluorescent tubes. However, initial modeling of the diffusing rod indicated that the intensity of the scattered light was too highly concentrated toward one end of the rod, creating uneven illumination. In addition, a large portion of the light entering the diffusing rod at small angles was not being scattered at all and, instead, was merely being reflected from the planar end of the diffusing rod back into the butt-coupled optical fiber. To overcome these deficiencies, a silver-coated concave mirror surface at the end of the rod was added to the diffusing rod model. This concave end-mirror strongly diverged low-angle incident light, hence improving the optical efficiency of the diffusing rod while also improving the overall uniformity of the scattered light. To further improve the uniformity of the scattered light, a 40 cm strip along the center of the diffusing rod's top hemisphere was modeled with a larger scattering fraction than the outer ends to increase the amount of scattered light emitted from the center of the diffusing rod.

Simulations of the spatial intensity distribution resulting from the fluorescent lamps and/or the diffusing rods revealed only minor differences between the two distributions, and only minor deviation from the fixture's original spatial intensity distribution. However, due to obstruction and scattering losses associated with the inclusion of the three diffusing rods, the optical efficiency of the fixture was decreased from 64% to 53%. The diffusing rod itself was estimated to be only 50% efficient at converting a fiber optic end-emitted source into a cylindrical source. This efficiency was strongly dependent upon the intensity profile of the fiber optic end-emitted light and the combination of scattering values used along the top surface of the diffusing rod.

The cylindrical diffusing rod was a 2.54 cm diameter, 1 m long, cast acrylic rod, with high optical clarity and optically smooth outer surface. The rod was diamond-machined on one end to create a concave surface with a radius of curvature of 4.0 cm, and polished on the other end to create a planar optical surface suitable for butt-coupling to a large-core optical fiber. The top hemisphere of the rod was sandblasted to produce a uniform scattering surface and both the top hemisphere and concave end-mirror were coated with aluminum. Due to construction limitations, the top surface did not exhibit a variable surface scatter as originally modeled.

Preliminary testing of the cylindrical diffusing rod revealed a discrepancy between the desired modeled surface scatter and the actual surface scatter created by the sandblasting technique. Because optical scattering is often difficult to accurately premodel in software, the result was not entirely unexpected. The actual surface scatter created by the sandblasting technique was much larger than modeled and created a diffusing rod with an uneven illumination. However, now given the correlation between the modeled scattering values and the actual scattering values, it is possible to re-simulate and re-design the cylindrical diffusing rod to emit a more uniform intensity distribution. Additional factors related to optical efficiency and construction costs are currently being evaluated.

In the hybrid solar photobioreactors, large-core optical fibers are used to transport light into growth chambers and once inside, function as a distributed light source (much like fluorescent lamps) to illuminate cyanobacteria. New fiber configurations specifically designed to optimize the sidelighting efficiency of large-core optical fibers are used, improving upon the cost and performance of fiber optic bundle sidelighting designs developed in the 1980s. The improved illumination design configurations of the photobioreactor: a) take advantage of improved sidelighting; b) increase the surface area illuminated; c) drastically reduce photosynthetic saturation; d) demonstrate the ability to achieve much higher volumetric carbon fixation rates; e) filter unwanted UV and IR radiation from the bioreactor; f) minimize heat delivery; and e) increase the overall sunlight utilization efficiency and cost-effectiveness when compared to earlier photobioreactors.

To make the above system adaptive, that is, able to respond to time-varying factors affecting its overall efficiency, this “intelligent” solar energy system adapts in real-time and continually optimizes solar energy utilization by using a lighting control system. For example, as lights are turned on and off or dimmed inside of buildings because of changing occupant needs or more visible light is available over and beyond what is needed for illuminating a certain region of a building or photobioreactor, the adaptive system redirects more visible light to other areas requiring illumination or possibly to an optional photovoltaic cell **110,** mounted on the fiber mount assembly, that is ideally-suited for energy conversion in the visible portion of the spectrum. See Fig. 11. Eight optical fibers **112** surround the optional photovoltaic cell **110** such that the visible light can be used by the optical fibers **112** or the optional photovoltaic cell **110**. Unused light **111** is available for redirection to alternate location or optional PV cell.

Light collection and delivery losses in the AFS system, as seen in Table 1, will be approximately 50% for a single-story application and an additional 15% for second-story applications. These loss factors take into account losses attributed to the primary mirror, secondary UV cold mirror, large-core optical fibers (including bends), luminaires and preliminary estimates for debris build-up and aging of the various optical components.

Table 1

AFS System Performance

Loss Parameter	Transmission
Primary Mirror	92%
Secondary Mirror	94%
Collection Losses	97%
Fresnel Losses	94%
Fiber Attenuation (@ 6 meters)	78%
Fresnel Losses	94%
Luminaire Losses	85%
TOTAL	50%

The single largest contributor of loss is the large-core optical fibers. Fig. 9 graphs the transmittance of large-core optical fibers as a function of fiber length, in meters, for various angles of incident flux. The baseline transmittance of 1.0 is for a fiber length of 0.5 meters. Note that attenuation, or loss of transmittance, is strongly dependent in incident angle. Optical analyses of the invention indicate light will enter the fibers at an average incident angle of well under ten degrees, as shown in Fig. 12. This represents one of several advantages of the AFS system when compared to earlier fresnel-based designs. Further, the fibers are solid-filled rather than a fiber-optic bundle. As such, packing fraction losses are eliminated. Also, the luminaire efficacy of fiber-based systems is much better than traditional lamp/luminaire combinations (85% -vs-70%) because the directional nature of delivered sunlight emerging from the fibers makes it much easier to control than light from traditional lamps.

The electrical energy displacement efficiency of the system, as seen in Table 2, summarizes the performance during peak use periods per 1000 Watts of incoming solar flux.

Table 2

Electrical Energy Displacement for 1000 Watts

Estimated Visible Portion = 490 Watts		**Estimated Near-IR Portion = 400 Watts**	
X 200 lm/w	Luminous efficacy of filtered sunlight	X 0.85 (-15%)	Collection Losses
= 98,000 lm	Available visible light	X 0.23	IR energy conversion efficiency
X 0.5	Passive distribution losses	X 0.9 (-10%)	Power conversion efficiency (dc/ac)
= 50,000 lm	Distributed light	= 70 Watts	Electrical energy generated
÷ 63 lm/W	Efficacy of electric lamp/ballast/luminaire		
X 1.15 or (+15%)	Cooling load credit		
= 900 Watts	Electrical energy displaced		
Total Grid-Provided Electrical Energy Displaced = 900 + 70 = 970 Watts			

Note that the total electrical energy displacement efficiency is very close to 100% (970 Watts displaced for 1000 Watts flux). In other words, 1000 W of collected sunlight displaces nearly an equal amount of electricity. At first glance, this might seem unreasonable. However, included in the performance summary are the following considerations: 1) the sunlight is filtered, the visible portion (~490 W) used for displacing much less efficient electric light and the near-IR radiation (~400 W) used to generate electricity using ideally-sited IR-TPVs; 2) the luminous efficacy of the displaced electric light (63 lm/W) includes the luminous efficacy of the lamp/ballast (~90 lm/W) and the luminaire efficiency (70%); and 3) the elimination of excess heat generated by electric lights in sunbelt regions, which reduces subsequent HVAC loads by ~ 15%.

Optical losses in the sunlight collection/distribution system of this invention were recalculated for the hybrid solar photobioreactor. The results of this evaluation show that light collection and delivery losses in the AFS solar lighting system will be approximately 40% as compared to 50% for the top story of a commercial building. This is due to the fact that once inside the bioreactor, light losses along its length are desirable. Losses cause fibers to emit light (glow like a linear fluorescent lamp). The estimated photon flux rate that is effectively used to achieve maximum photosynthetic efficiency is therefore 1200 μEm^2s^{-1}.

For mesophilic cyanobacteria whose preferred photosynthetic flux rate is 60 μEm^2s^{-1}, approximately 15 large-core fibers 5 mm in diameter, 6 m in length, and spaced 20 cm apart will deliver adequate lighting to achieve the desired spatial redistribution of 1 m^2 of direct sunlight into ~ 20 m^2 of vertically-stacked enclosed cyanobacteria growth area, i.e. $(0.60)(2000\ \mu Em^2s^{-1})\ /\ 20\ m^2 = 60\ \mu Es^{-1}$. Fig. 13 illustrates an example of how this sidelighting configuration is used to illuminate cyanobacteria surfaces spaced 15 cm apart. Optical fibers **150** with sidelighting capability are used to illuminate the flat-plate cyanobacteria growth membranes **151.**

Compared to earlier light collection systems developed by Himawara Corp. for solar lighting applications in buildings and photobioreactors, the AFS hybrid concentrator design provides several advantages:

1. fewer, easily assembled, system components integrated into a smaller, less costly, and more compact design configuration;
2. improved IR heat removal and management;
3. improved optical fiber placement and articulation (bundled and pivoted about a radial axis);
4. a longer optical path for light and lower entrance angles for visible light entering large-core optical fibers. This results in much lower overall transmission losses in the accompanying light delivery system (see Fig. 9);
5. centrally-concentrated IR radiation, allowing for convenient implementation of IR-TPVs.

Table 3 compares the projected cost and performance of the AFS system with that of a state-of-the-art commercial system. Accordingly, the anticipated cost per delivered lumen of the AFS system far exceeds its only commercial counterpart.

Table 3		
Parameter	**AFS System**	**Commercial System**
System Cost	\$2000/m^2	\$5000/m^2
Delivered lumens (*buildings*)	50,000/m^2	25,000/m^2
Delivered lumens (*photobioreactors*)	60,000/m^2	25,000/m^2
\$/delivered lumen (*buildings*)	\$0.04/lm	\$0.20/lm
\$/delivered lumen (*photobioreactor*)	\$0.03/lm	\$0.20/lm

Skylights are generally accepted as the most cost-effective form of conventional topside daylighting. On average, incident sunlight does not enter skylights normal to the horizontal plane. Depending on the type and configuration of skylight, light transmission varies dramatically and is attenuated significantly. This is due to several factors but is predominately determined by the efficiency of the light well and glare control media. The typical transmittance of state-of-the-art tubular, domed skylights varies widely, depending on lighting requirements, but for commercial applications is typically well under 50%.

The coefficient of utilization (CU) of a single 1-m^2 tubular skylight will inherently be much lower than a system that distributes light from the same square meter to six or more luminaires. Assuming that the room cavity ratio and other room parameters are identical, the CU of the more distributed hybrid system is significantly better. If the single 1-m^2 skylight were replaced by ~6 much smaller skylights, the two systems' CUs would compare equally, yet the cost of the skylights would increase prohibitively.

Skylights are typically not designed based on the maximum amount of light that can be supplied but rather designed to approximate that which is produced by the electric lighting system when the total exterior illuminance is 3000 footcandles. This reduces over-illumination and glare. Because of this, all light produced by skylights beyond this value is typically wasted. As such, preliminary estimates suggest that on average, depending on location, approximately 30% of the total visible light emerging from skylights on a sunny day is excess light not used to displace electric lighting. Conventional skylights are also plagued by problems associated with heat gain and do not harvest non-visible light. Finally, conventional skylights are not easily reconfigured during floor-space renovations common in today's commercial marketplace. Once all factors are considered, the simple payback (typically >8 years) and energy end-use efficiency of even the best topside daylighting systems is considerably worse than projected adaptive, full-spectrum solar energy systems.

Commercial solid-state semiconductor PV modules typically have a total conversion efficiency of < 15%. Solar thermal systems typically have a conversion efficiency somewhat higher (< 25%), depending on system design and complexity. Further, losses attributed to electric power transmission/distribution (~8%) and dc/ac power conversion (10 - 15%) further reduce the overall efficacy of conventional solar technologies. Because of these and other reasons, conventional solar technologies have not displaced significant quantities of nonrenewable energy and are expected to be used in the United States for residential and commercial buildings, peak power shaving, and intermediate daytime load reduction. The PV modules currently sell for between $3 - $5/Wp. The projected peak performance of adaptive, full-spectrum (AFS) solar energy systems ($3,200 per 1,940 Wp or $1.65/Wp) have the immediate potential to more than double the affordability of solar energy when compared to these solar technologies.

Calculations based on earlier studies by Hirata et al. and Ohtaguchi et al. indicated that a little more than 1,000,000 m^2 bioreactor surface is required to reduce the CO_2 emission of a typical 500 MW coal-fired generation unit by 25%. This translates into 257 acres of water surface area for a high-density raceway type reactor. Using the design of Bayless et al., incorporating the novel solar collection technology described herein, the required area decreases to 11.7 acres. In a more practical scenario that considers roof-top collector/receiver packing densities and other factors, the required space would likely increase to 15 acres. An enclosed reactor of this size may be formidable to site and construct, but is certainly manageable compared to siting and operating a 257-acre pond near a power plant, which would create numerous groundwater contamination concerns. Further, an enclosed reactor has a number of options for delivery of the CO_2, including as raw flue gas. Bubbling flue gas through a 257 acre pond would be illegal, as the ground level contamination would pose extreme health threats to the area. Therefore, a raceway reactor would require CO_2 separation before utilization, eliminating virtually any energy advantage of a bioreactor in CO_2 control.

Compared to previous attempts to develop similar solar-enhanced photobioreactors incorporating fresnel lenses and fiber-optic bundles, the anticipated cost per delivered lumen (2.8 cents –vs- 20 cents) also represents a seven-fold improvement in the cost of sunlight utilization not including the added benefit of electrical power generation. Thus, the primary advantages are enhanced sunlight utilization and less power consumption.

Non-photosynthetic carbon sequestration is a significant net energy loss. Separation of CO_2 from the flue gas either requires refrigeration or mechanical action. The sequestration (compression or pumping) of the separated CO_2 also requires significant energy. All totaled, CO_2 sequestration by non-photosynthetic means will require 25-40% of the power generated by a host utility compared to 2-5% for the hybrid solar photobioreactor. That means more fossil fuel will have to be burned to produce the same net power output before sequestration. This also has direct implications on the environment. Because more fuel must be burned to power the sequestration systems, more associated pollutants will be released, including ozone forming NO_x, mercury, PM.2.5 and other particulates. Only a system utilizing solar energy to produce biomass, as described in this invention, will require minimal power generation to minimize CO_2 emissions and does not produce significant harmful emissions.

Separation and use of different portions of the solar spectrum for different purposes improves the overall cost and performance of solar energy used at power plants. In addition to this advantage, biomass has inherent value beyond that of carbon sequestration. It can be used as a feedstock, agricultural supplement, food supplement, or in pharmacological uses. Third, coal must remain a viable fuel to maintain fuel diversity. Without coal, the long term (20+ years) price of electrical power will escalate at a dangerous rate, especially with regards to national economic growth. This system provides a critical component in the portfolio of carbon management techniques that will allow coal to remain viable.

The following references contain material relevant to this invention and are hereby incorporated by reference in their entirety:

1. National Laboratory Directors for the U.S. Department of Energy, "Technology Opportunities: to Reduce U.S. Greenhouse Gas Emissions, and

"Technology Opportunities: to Reduce U.S. Greenhouse Gas Emissions: Appendix B; Technology Pathways," October 1997.

2. Barnes, F. A., et al., Electro-Optics Handbook: Technical Series EOH-11, RCA Corporation, 1974, p. 70.
3. Hanagata, N., Takeuchi, T., Fukuju, Y., Barnes, D., Karube, I., "Tolerance of Microalgae to High CO2 and High Temperature," Phytochemistry, Vol. 31(10), 1992, pp. 3345-3348.
4. Hirata, S., Hayashitani, M., Taya, M., and Tone, S. "Carbon Dioxide Fixation in Batch Culture of Chlorella sp. Using a Photobioreactor with a Sunlight Collection Device," Journal of Fermentation and Bioengineering, Vol.81, 1996, pp.470-472.
5. Ohtaguchi, K., Kajiwara, S., Mustaqim, D., Takahashi, N., "Cyanobacterial Bioconversion of Carbon Dioxide for Fuel Productions," Energy Conversion and Management, Vol.38 (Supplemental Issue), 1997, pp. 523-528.

Claims

I claim:

1. An adaptive full spectrum solar energy system comprising:

at least one hybrid solar concentrator, said concentrator further comprising:

a fixed base,

a rotating assembly,

a rotational tracking mechanism operably connecting said fixed base to said rotating assembly, said rotating assembly further comprising:

a primary mirror for producing reflected full spectrum solar radiation,

a secondary optical element supported in position for receiving said reflected full spectrum solar radiation,

a concentric fiber mount assembly operably mounted to said rotating assembly,

at least one optical fiber extending from said concentric fiber mount assembly to said light distribution system,

at least one hybrid luminaire;

at least one hybrid photobioreactor;

a light distribution system operably connected to each of said hybrid solar concentrator, said hybrid luminaire, and said hybrid photobioreactor; and

a means for controlling at least one of said hybrid solar concentrator, said hybrid luminaire, said hybrid photobioreactor, and said light distribution system.

2. The solar energy system of Claim 1 wherein said hybrid luminaire further comprises:

at least one electric lamp,

at least one large-core optical fiber operably connected to said light distribution system, and

at least one light dispersing element fixably mounted in a lens diffuser.

3. The solar energy system of Claim 2 wherein said hybrid luminaire further comprises at least one cylindrical diffusing rod fixably aligned with said electric lamp.

4. The solar energy system of Claim 1 wherein said secondary optical element further comprises:

at least one secondary mirror for receiving said reflected full spectrum solar radiation and further reflecting only infrared filtered solar radiation, at least one nonimaging optic concentrator positioned for accepting infrared solar radiation transmitted through said secondary mirror, and

at least one thermophotovoltaic cell positioned for accepting infrared solar radiation from said nonimaging optic concentrator.

5. The solar energy system of Claim 1 wherein said optical fiber is large-core polymer construction.

6. The solar energy system of Claim 4 wherein said secondary mirror further comprises a high temperature glass substrate with a sputtered ultraviolet cold coating on a first reflective surface.

7. The solar energy system of Claim 4 wherein said secondary mirror further comprises segmented planar sections that precisely focus light into eight optical fibers.

8. The solar energy system of Claim 4 wherein said secondary optical element further comprises an elliptical secondary element that extends the focus of said primary mirror and couples light into a packed array of nine optical fibers.

9. The solar energy system of Claim 8 wherein said primary mirror is a low quality coated 1.5 m diameter hydroformed satellite dish.

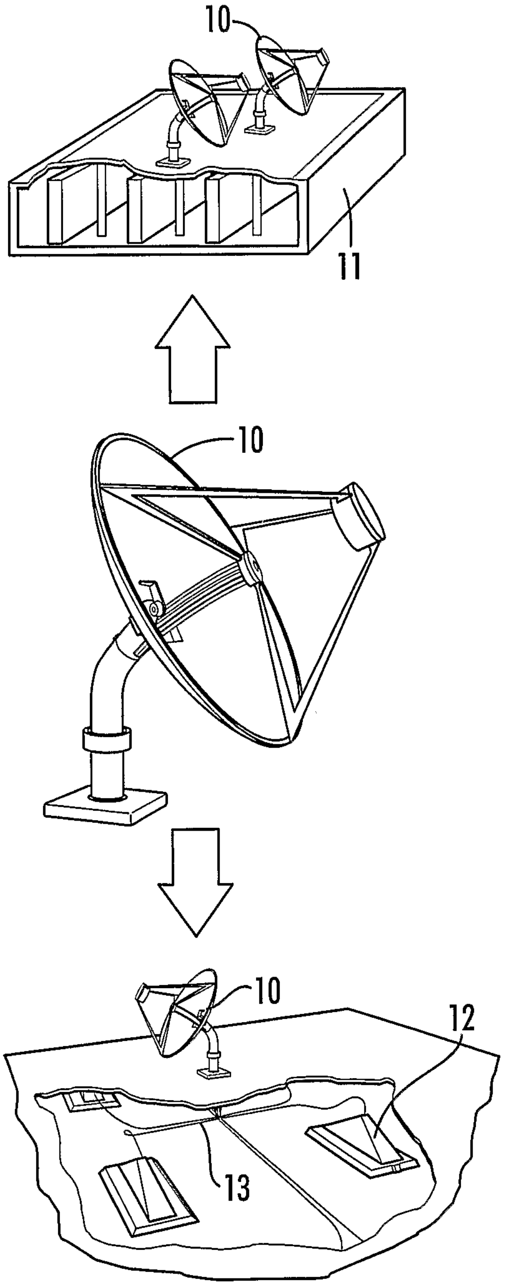
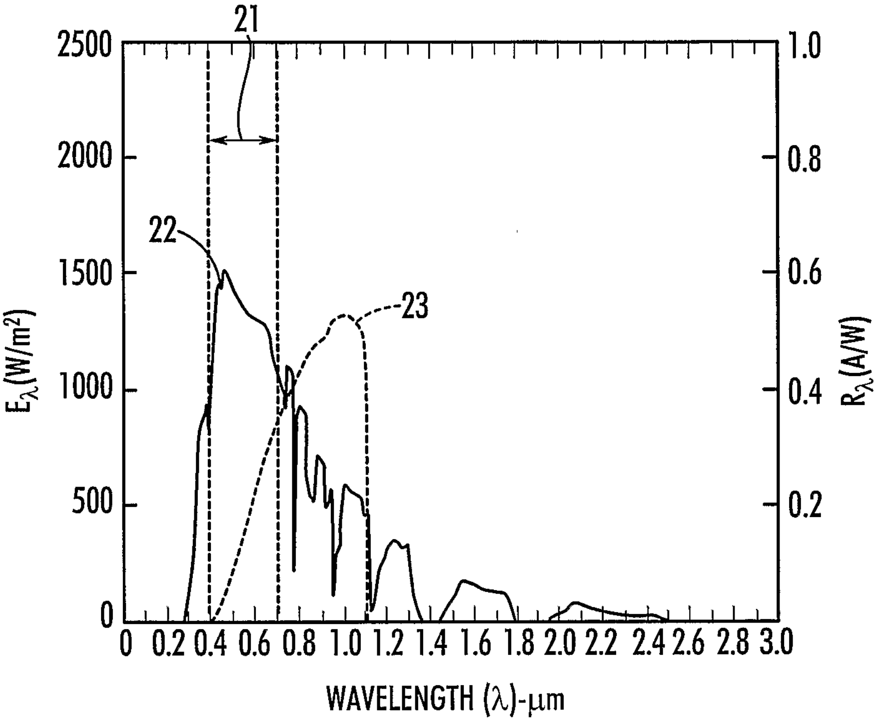


FIG.1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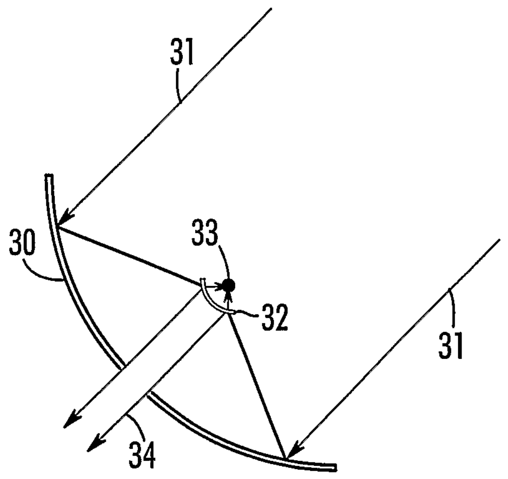
22
23
2500
2000
1500
1000
500
0
1.0
0.8
0.6
0.4
0.2
E_λ(W/m^2)
R_λ(A/W)
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0
WAVELENGTH (λ)-μm

FIG.2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33
32
31
34

FIG.3

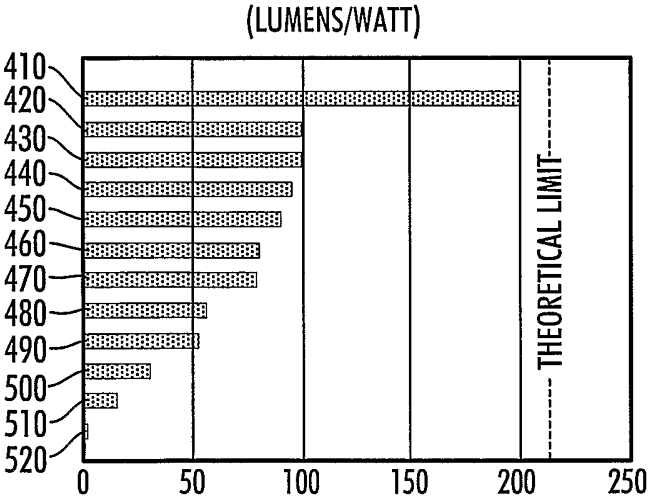

(LUMENS/WATT)
410
420
430
440
450
460
470
480
490
500
510
520
THEORETICAL LIMIT
0
50
100
150
200
250

Fig.4

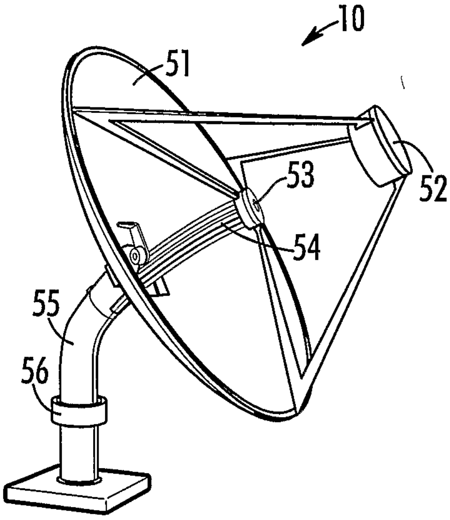

10
51
52
53
54
55
56

Fig.5

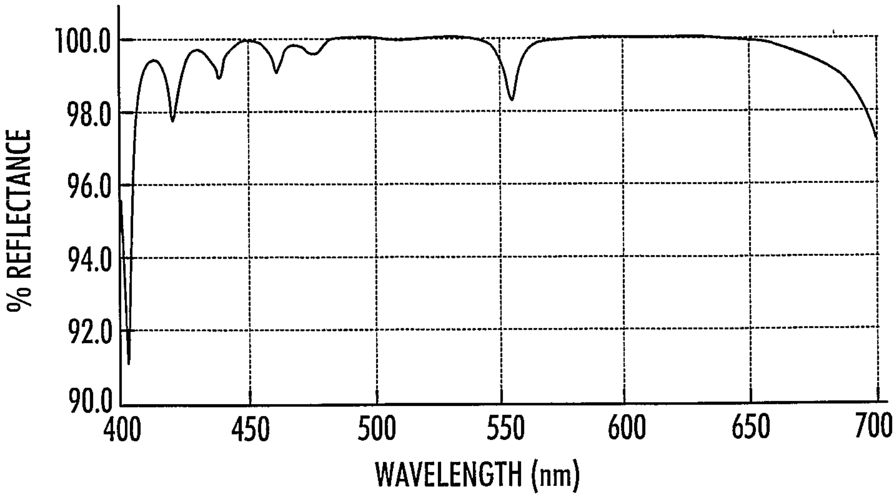


Fig.6

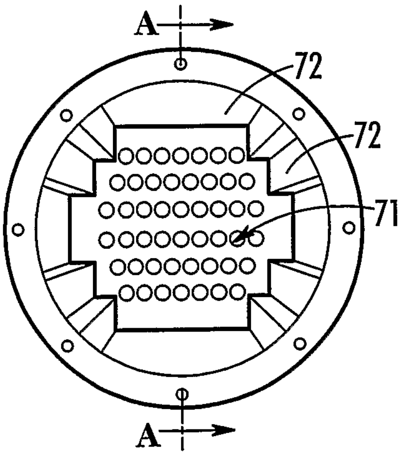


Fig.7

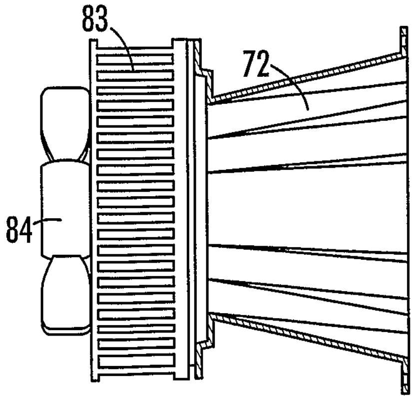
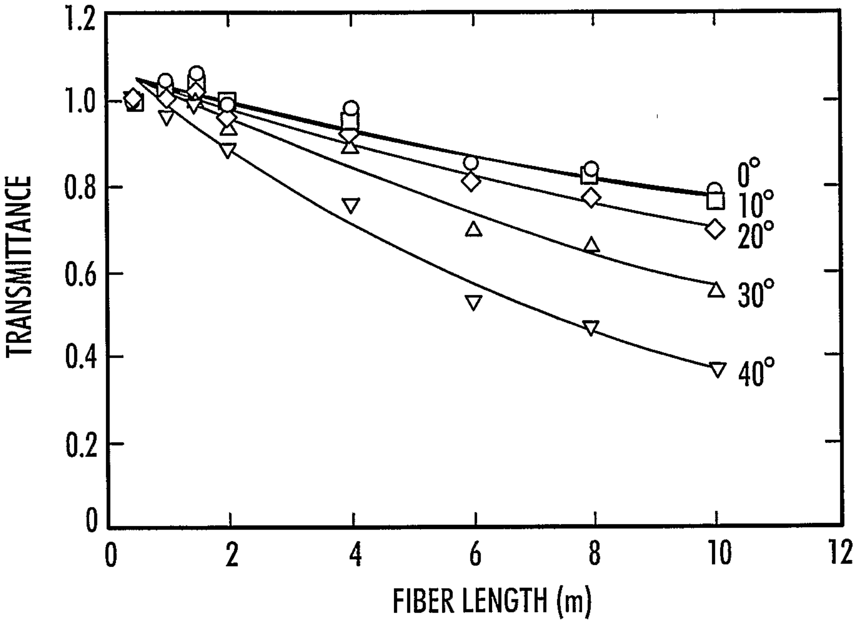


Fig.8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1.0
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
FIBER LENGTH (m)
0°
10°
20°
30°
40°

FIG. 9

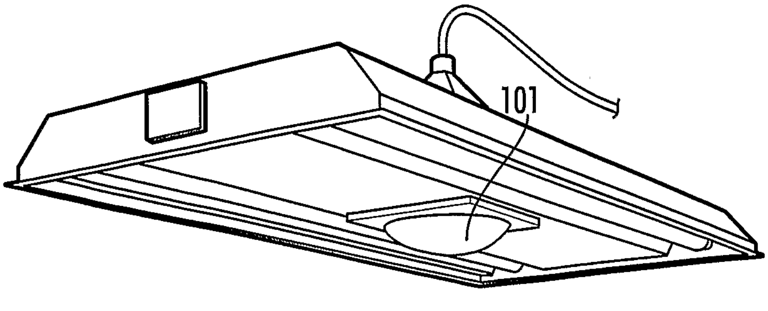
101

FIG. 10

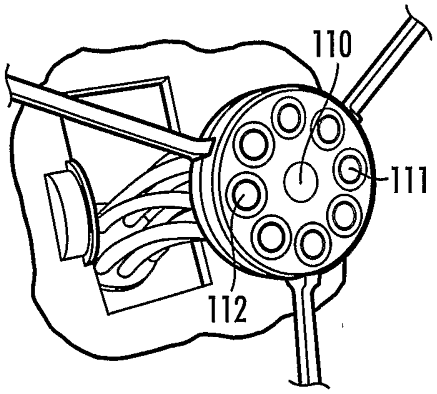
110
111
112

FIG.11

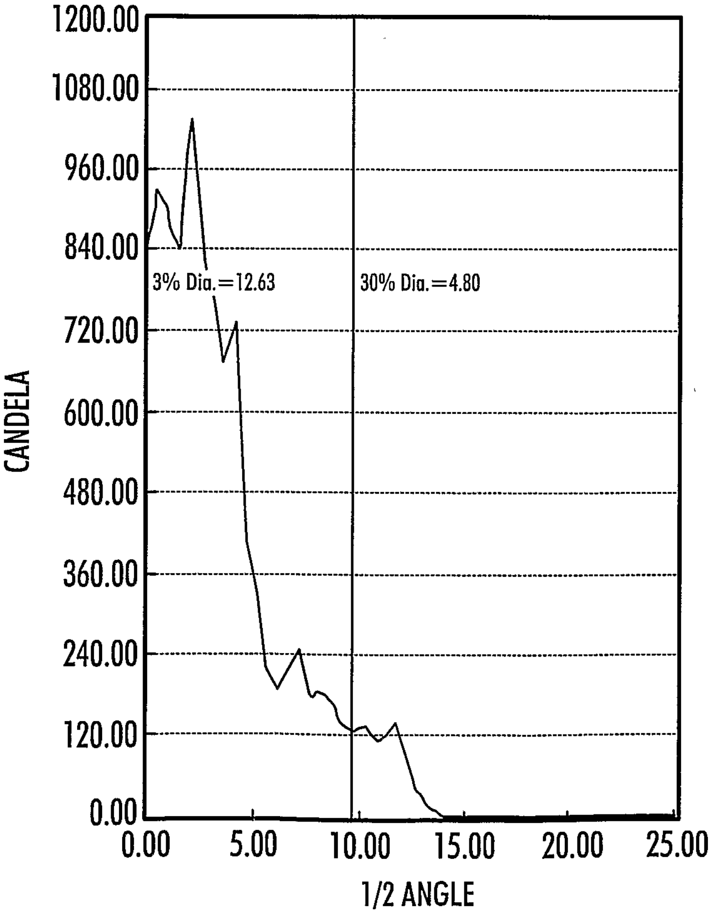
1200.00
1080.00
960.00
840.00
720.00
600.00
480.00
360.00
240.00
120.00
0.00
CANDELA
3% Dia.=12.63
30% Dia.=4.80
0.00
5.00
10.00
15.00
20.00
25.00
1/2 ANGLE

FIG.12

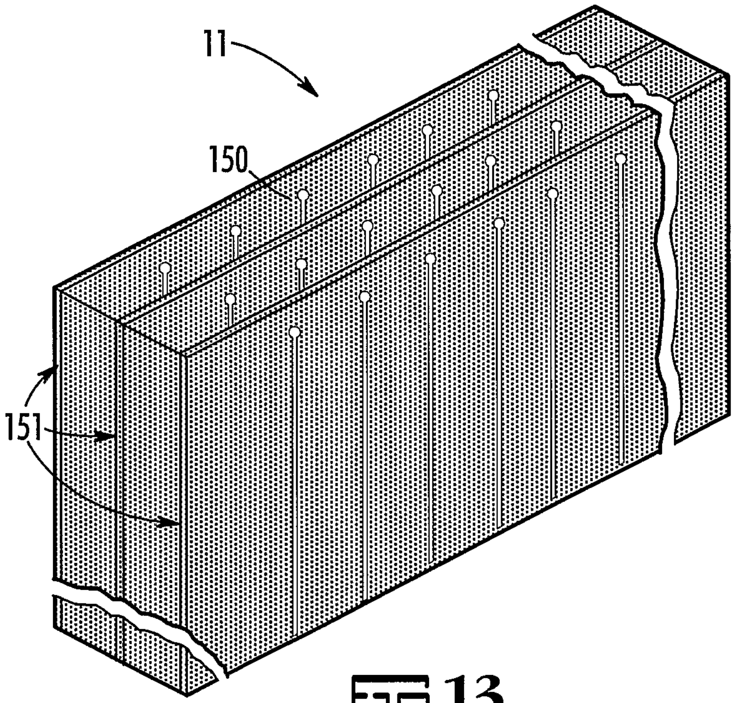

FIG.13

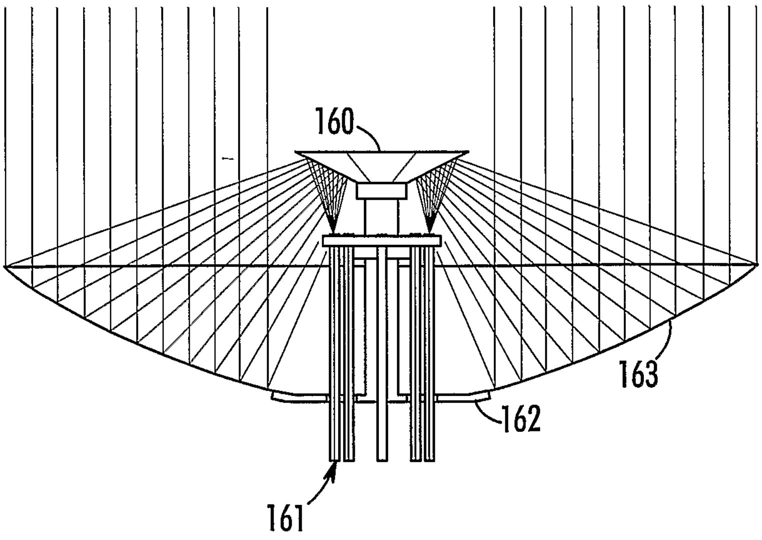

FIG.14

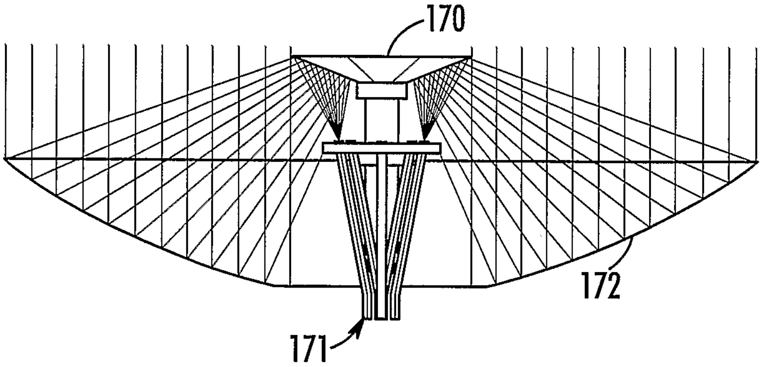

FIG.15

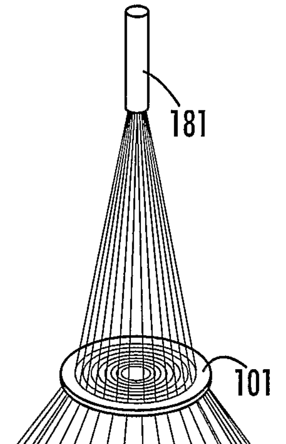

FIG.16

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/29645

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F24J2/06 F24J2/18 C12M1/00 H01L31/052 F21S11/00
F21S8/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F24J C12M H01L F21S F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 2 029 883 A (ENTE NAZ ENERGIA ELETTRICA) 26 March 1980 (1980-03-26) page 1, line 43 - line 51 page 2, line 37 - line 39 page 3, line 24 - line 26 page 3, line 39 - line 43 page 3, line 58 - line 65 page 4, line 29 - line 48; figures 1-7 ---	1,2
Y	PATENT ABSTRACTS OF JAPAN vol. 016, no. 304 (C-0959), 6 July 1992 (1992-07-06) -& JP 04 084883 A (SUMITOMO HEAVY IND LTD), 18 March 1992 (1992-03-18) abstract --- -/--	1,2

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search 10 January 2003	Date of mailing of the international search report 17/01/2003
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Beltzung, F

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/29645

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 575 860 A (CHERNEY MATTHEW) 19 November 1996 (1996-11-19) column 4, line 52 -column 9, line 48; figures 1-21	1,2
Y	US 5 658 448 A (LASICH JOHN BEAVIS) 19 August 1997 (1997-08-19) column 5, line 9 - line 56 column 6, line 16 - line 22 column 16, line 48 - line 58; figure 4	1
Y	US 4 525 031 A (MORI KEI) 25 June 1985 (1985-06-25) column 2, line 24 - line 68; figure 1	1
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 376 (C-1084), 15 July 1993 (1993-07-15) -& JP 05 064577 A (EBARA RES CO LTD;OTHERS: 02), 19 March 1993 (1993-03-19) abstract	1
A	EP 0 922 914 A (CEO CENTRO DI ECCELLENZA OPTRO) 16 June 1999 (1999-06-16) column 1, line 57 -column 5, line 27; figures 1-10	1
A	US 6 128 135 A (KINNEY LAURENCE F ET AL) 3 October 2000 (2000-10-03) column 3, line 9 -column 4, line 53; figures 1-8	1
A	US 4 539 625 A (BORNSTEIN JONATHAN G ET AL) 3 September 1985 (1985-09-03) column 3, line 23 -column 7, line 59; figures 1-4	1-3
A	US 5 371 660 A (LEVENS KURT A) 6 December 1994 (1994-12-06) column 3, line 6 - line 61 column 6, line 51 -column 7, line 26; figures 1-12	1,4
A	DE 197 05 046 A (FRAUNHOFER GES FORSCHUNG) 26 February 1998 (1998-02-26) column 2, line 41 -column 4, line 8; figures 1-3	1,5
A	US 4 626 065 A (MORI KEI) 2 December 1986 (1986-12-02) column 2, line 46 -column 4, line 60; figures 1-7B	1-3

-/--

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 328 389 A (STERN THEODORE G ET AL) 4 May 1982 (1982-05-04) column 2, line 41 -column 3, line 19; figure 1 ---	1
A	EP 0 019 016 A (MICHAEL SIMON DIPL ING) 26 November 1980 (1980-11-26) page 6, line 3 -page 10, line 4; figures 1-6 ---	1
A	DE 32 11 339 A (MASCHF AUGSBURG NUERNBERG AG) 29 September 1983 (1983-09-29) page 8, line 11 -page 10, line 31; figures 1-3 ---	1
A	US 4 297 000 A (FRIES JAMES E) 27 October 1981 (1981-10-27) column 2, line 1 -column 3, line 48; figures 1-5 ---	1
A	US 4 700 013 A (SOULE DAVID E) 13 October 1987 (1987-10-13) column 1, line 63 -column 3, line 34; figures 1-3 ---	1
A	DE 40 36 938 A (DRESCHER RUEDIGER) 21 May 1992 (1992-05-21) claims 8,9 ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 335 (C-384), 13 November 1986 (1986-11-13) -& JP 61 139382 A (HITACHI ZOSEN CORP), 26 June 1986 (1986-06-26) abstract ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 007, no. 028 (C-149), 4 February 1983 (1983-02-04) -& JP 57 181689 A (TAKASHI MORI), 9 November 1982 (1982-11-09) abstract ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 12, 26 December 1996 (1996-12-26) -& JP 08 200839 A (BROTHER:KK;SUGAWARA KIYOSHI), 6 August 1996 (1996-08-06) abstract --- -/--	1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/29645

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 04, 30 April 1997 (1997-04-30) -& JP 08 329712 A (MITSUBISHI HEAVY IND LTD), 13 December 1996 (1996-12-13) abstract -----	1

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2029883 A	26-03-1980	IT 1098721 B	07-09-1985
		DE 2934995 A1	13-03-1980
		FR 2434996 A1	28-03-1980
		JP 55098703 A	28-07-1980
JP 04084883 A	18-03-1992	JP 2753568 B2	20-05-1998
US 5575860 A	19-11-1996	US 5501743 A	26-03-1996
US 5658448 A	19-08-1997	AT 182635 T	15-08-1999
		AU 691792 B2	28-05-1998
		AU 5553994 A	22-06-1994
		WO 9412690 A1	09-06-1994
		DE 69325817 D1	02-09-1999
		DE 69325817 T2	17-02-2000
		EP 0670915 A1	13-09-1995
		EP 0927857 A2	07-07-1999
		ES 2137349 T3	16-12-1999
		GR 3031665 T3	29-02-2000
		JP 8503738 T	23-04-1996
		US 5973825 A	26-10-1999
US 4525031 A	25-06-1985	JP 54160080 A	18-12-1979
		JP 1105987 C	30-07-1982
		JP 55001008 A	07-01-1980
		JP 56051469 B	05-12-1981
JP 05064577 A	19-03-1993	JP 2068801 C	10-07-1996
		JP 7089903 B	04-10-1995
EP 0922914 A	16-06-1999	IT FI970272 A1	14-06-1999
		EP 0922914 A2	16-06-1999
US 6128135 A	03-10-2000	NONE	
US 4539625 A	03-09-1985	CA 1236808 A1	17-05-1988
US 5371660 A	06-12-1994	US 5560700 A	01-10-1996
DE 19705046 A	26-02-1998	DE 19705046 A1	26-02-1998
US 4626065 A	02-12-1986	JP 1399647 C	07-09-1987
		JP 58134986 A	11-08-1983
		JP 62006785 B	13-02-1987
		AU 552751 B2	19-06-1986
		AU 1117583 A	11-08-1983
		CA 1238808 A1	05-07-1988
		DE 3371600 D1	25-06-1987
		EP 0085926 A2	17-08-1983
		HK 27388 A	22-04-1988
		NZ 203137 A	11-04-1986
		SG 111387 G	20-05-1988
US 4328389 A	04-05-1982	NONE	
EP 0019016 A	26-11-1980	DE 2855553 A1	31-07-1980
		EP 0019016 A2	26-11-1980
		FR 2472146 A1	26-06-1981

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 02/29645

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3211339 A	29-09-1983	DE 3211339 A1	29-09-1983
US 4297000 A	27-10-1981	NONE	
US 4700013 A	13-10-1987	NONE	
DE 4036938 A	21-05-1992	DE 4036938 A1	21-05-1992
JP 61139382 A	26-06-1986	NONE	
JP 57181689 A	09-11-1982	JP 1193463 C JP 58024117 B	12-03-1984 19-05-1983
JP 08200839 A	06-08-1996	NONE	
JP 08329712 A	13-12-1996	NONE	