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(54) **Title:** CONCENTRATION PHOTOVOLTAIC SYSTEM AND CONCENTRATION METHOD THEREOF

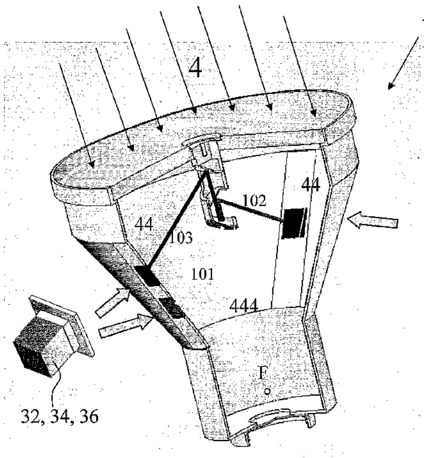

Fig. 2

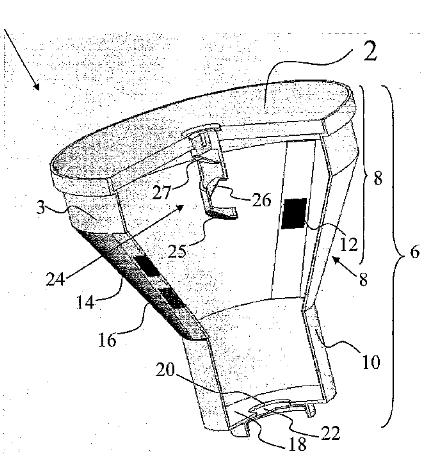

Fig. 1

(57) **Abstract:** A concentration photovoltaic system (1) comprises lens- type concentrator means (2) for intercepting and concentrating beams of incident solar rays (4), reflection means (22) for reflecting beams of concentrated solar rays (44) and is characterized in that it comprises selection means (24) for selecting the frequencies of beams of solar rays (444) reflected by said reflection means (22) and able to direct selected rays (101, 102, 103) towards a plurality of photovoltaic cells (12, 14, 16). The invention also comprises a method for concentrating beams of incident solar rays (4) which uses the concentration photovoltaic system described.

WO 2008/126113 A1

"Concentration photovoltaic system and concentration method thereof"

DESCRIPTION

Technical field

The invention relates to a concentration photovoltaic system based on concentrator means for intercepting and concentrating beams of incident solar rays; the invention relates, moreover, to a method for concentrating solar energy on photovoltaic cells, based on concentrator means for intercepting and concentrating beams of incident solar rays.

Prior art

As is well-known, photovoltaic systems comprise a certain number of photovoltaic cells which allow the reception and conversion of solar rays into energy, for example electrical energy, for the end use.

The most common photovoltaic systems are so-called "flat" photovoltaic systems in which the quantity of electrical energy produced is proportional to the surface area of the photovoltaic cells used; for this reason, these cells cover practically the whole of the surface of the panels exposed to the sun's rays, these surfaces necessarily having large dimensions in order to produce a quantity of energy which can be used in an efficient manner.

A serious drawback of these systems consists in the cost of the photovoltaic cells which represents most of the overall cost of a panel. The possibility of reducing the costs is therefore dependent almost exclusively on the reduction in the cost of the photovoltaic cells.

Research in this sector, which is not a new sector, could result in limited improvements and only at the expense of huge investments mainly in the technology of the cells.

An evolution in the photovoltaic systems consists in so-called "concentration" photovoltaic systems which use a concentrator device which intercepts the sun's rays and concentrates them on a photovoltaic cell having dimensions which are inversely proportional to the concentration factor of the concentrator device.

Concentration photovoltaic systems ensure a performance which is far superior to that of conventional flat photovoltaic systems, reduce the proportional cost of the cells and constitute a young technology with room for improvement and more extensive research.

On the other hand, however, the concentrator devices which are known hitherto and manufactured must have large dimensions and must moreover be able to follow the sun along its trajectory, by means of so-called tracking systems so as to be able to absorb the maximum power from the sun's rays during the course of the whole day. Moreover, the costs per KWh (during peak use) are at the moment higher than those of conventional flat photovoltaic systems.

Furthermore, installation is possible only on horizontal surfaces, in the open, while rarely is it possible on roofs in view of the large dimensions and weights of the present-day structures.

One solution to this problem consists in the idea of a concentration photovoltaic system which is formed by a set of small concentrators which move in synchronism, but not integrally, within a frame which also has compact dimensions. One possibility therefore is modules which are formed by several concentrators inside a frame having dimensions and weights comparable to those of flat photovoltaic panels and for this reason able to be installed on any type of horizontal or vertical surface including roofs and facades of buildings.

As a result of this solution it has been possible to widen greatly the market of the concentration photovoltaic system which is currently limited to open areas and mainly to the countryside and agricultural terrain for the reasons given above.

A problem which is encountered, however, is that the concentration also results in raising of the temperature of the cells up to dangerous levels, so that suitable heat dissipators are nearly always envisaged.

Raising of the temperature is due to the fact that the quantity of photons (solar light) which causes the movement of electrons (electric power) is not high (low efficiency) and therefore many studies have been focussed on solutions for improving the photon-electron "conversion".

One solution to this problem envisages the use of multi-joint cells, i.e. a type of multilayer photovoltaic cell which effectively increases in a significant manner the overall efficiency of the cell, allowing a lowering of the temperature. However, these cells are produced using costly and rare materials, such as germanium, and the technology is somewhat sophisticated, so that this solution is not easy to realise.

The patent application WO 2006/108806 in the name of Giuliano Martinelli et al., published on 19 October 2006, is described a system which envisages dividing up the solar energy into two or more bands (dichroic, trichroic and more generally polychroic systems) by means of two or more coaxial reflector dishes, the first of which reflects the solar radiation with a certain spectral composition, allowing the remaining parts of the radiation to pass towards the other dishes.

In the case of two dishes, each of them reflects the portion of corresponding energy towards its own focal point which does not coincide with that of the other dish. The incoming solar energy is then divided into two beams which have a different spectral composition and an energy content equal to a fraction of the total incident energy even though obviously the sum of the energies associated with each beam corresponds to that prior to division.

This division has two effects:

- it reduces the energy load on each cell for the same concentration factor;

- it results in a higher efficiency in the photon/electron conversion process.

The overall result is that the amount of solar energy which is converted into electrical energy is higher and that the heat generated in each cell is reduced significantly.

The system described in the cited patent application, although it constitutes an improvement in terms of heat dissipation, has further defects:

- the parabolic reflectors have an overall geometry which differs greatly from the mathematical area of the paraboloid and this gives rise to problems of a constructional nature which make mass-production difficult;

- the entire surface of the parabolic dishes must incorporate within it the passband filter functions for the desired frequency band together with the non-passband reflection function;

- owing to the significantly large dimensions, it is not possible to use easily low-cost technology such as plastics injection technology;

- the cells are arranged on the focal points of the parabolic dishes with an arm which projects beyond the said dishes and which, by nature, is very delicate;

- cleaning of the dishes which periodically must be performed in order to ensure the optimum efficiency of the system is difficult to perform with automatic systems which may be envisaged in large installations.

These defects make the system proposed difficult to apply on a large scale.

The object of the present invention is to provide a concentration photovoltaic system which is improved in terms of costs and manufacturing simplicity in order to overcome the drawbacks of the prior art.

<u>Summary of the invention</u>

The object indicated above is achieved by a concentration photovoltaic system comprising:

- concentrator means for intercepting and concentrating beams of incident solar rays;

- reflection means for reflecting beams of solar rays concentrated by said concentrator means;

characterized in that it comprises:

- selection means for selecting the frequencies of beams of solar rays reflected by said reflection means, able to direct selected rays towards a plurality of photovoltaic cells;

- said concentrator means being independent of the frequency of said beams of incident solar rays.

Moreover the present invention relates to a method for concentrating beams of incident solar rays on photovoltaic cells, which uses the concentration photovoltaic system, comprising the steps of:

- intercepting and concentrating beams of incident solar rays by means of concentrator means;

- reflecting beams of concentrated solar rays by means of reflection means, characterized in that it comprises the step of:

- selecting said beams of reflected rays by means of selection means so as to direct selected rays towards a plurality of photovoltaic cells.

With the invention it is possible to achieve a significant improvement in the manufacturing costs and efficiency levels.

Lenses and cells are produced using conventional and low-cost technology.

The efficiency of the system is greater than the efficiency of the systems of the prior art.

The characteristic features and the further advantages of the invention will emerge from the description, provided hereinbelow, of an example of embodiment thereof provided purely by way of a non-limiting example with reference to the accompanying drawings.

Brief description of the drawings

- Figure 1 shows a partially cut-away perspective view of a photovoltaic system according to the invention in the rest condition, namely in the condition where there is no solar radiation;

- Figure 2 shows the system according to Figure 1 in the operating condition;

- Figure 3 shows a top plan view of the system according to Figures 1 and 2;

- Figure 4 shows a sectioned view of a detail of the system according to Figures 1, 2 and 3.

Detailed description

With reference to these Figures, in Figure 1 a concentration photovoltaic system 1 comprises a casing 6 preferably composed of a first portion 8, with a hollow frustoconical shape, open at both the bases and with the large base arranged at the top; this first portion 8 rests, in the region of its small base, on a second portion 10, which is preferably cylindrical, hollow, open in the region of its top base and provided with a hole in the bottom base 18; the portion 10 of the container 6 acts as support for the concentration photovoltaic system.

The first and second portions 8 and 10 may also have a frusto-pyramidal and parallelepiped shape, respectively, or shapes which are similar to these.

The first portion 8 has, in the region of its top base, a kind of flange 3 which supports a concentrator device 2, in particular a surface 2 for receiving and concentrating beams of incident solar rays 4 (shown in Fig. 2).

According to the invention, the surface 2 is a lens, in particular a Fresnel lens, and may have different perimetral shapes, in particular a square or circular shape, corresponding to the shape of the first portion 8 of the container 6. The special feature of the Fresnel lens is that it performs the same function as a conventional semi-spherical lens of equivalent dioptric power, with the advantage that it has a small thickness and weight; this lens is obtained by splitting up a conventional semi-spherical lens into a series of concentric annular sections called Fresnel rings, as shown in cross-section in Figure 4, converting the continuous curve of a conventional semi-spherical lens into a series of surfaces 2a-2e which have the same curvature, but are not continuous.

The lens concentrates the incident and parallel solar ray beams 4 into converging ray beams 44, as shown in Figure 2, which illustrates the same system as in Figure 1, but showing specifically the paths of the solar rays which strike and pass through the concentration photovoltaic system 1.

The bottom base 18 of the second portion 10 has a hole 20 where the converging ray beams 44 converge.

According to the invention, the concentrator device 2 functions independently of the frequency of the incident solar rays 4. The beam of converging rays 44, therefore, is only a redirected and not an attenuated or filtered beam.

A parabolic mirror 22 with an upwardly directed concavity is mounted in the hole 20, the focal point F thereof, shown in Fig. 2, coinciding with the focal point of the Fresnel lens, namely the point towards which the beam of rays 44 converges.

The parabolic mirror 22 reflects the beam of converging rays 44, in the form of a beam of parallel rays 444, onto a filtering device 24 situated inside the structure 6 and fixed along its axis within the first portion 8. The device 24 performs a division, according to predefined frequency intervals, of the beam of parallel rays 444.

The beam, which is divided up according to predefined frequencies, is directed towards a certain number of photovoltaic cells arranged, according to the invention, on the side surface of the first portion 8.

The number of photovoltaic cells and the position thereof on the side surface of the first portion 8 depends on the manufacturing specifications and operation of the complete concentration photovoltaic system 1. Special mirrors may be envisaged in place of the cells, said mirrors allowing reflection, where necessary, of the divided beam.

It is possible, therefore, to decide upon the lay-out, on the side surface, of the first portion 8 of the photovoltaic cells which may be, for example, opposite each other or arranged vertically alongside each other.

According to the preferred embodiment of the invention, these photovoltaic cells are three in number and are indicated in Fig. 1 by the numbers 12, 14 and 16.

The cells are designed especially to receive solar rays in a suitable frequency range and to optimize the energy produced on the basis of these frequencies.

The filtering device 24 comprises a series of passband filters. The passband filters are known per se; each of them filters the rays 444 included in a certain band of frequencies, reflecting them at an angle equal to the angle of incidence towards the corresponding cell and allows the rays at the remaining frequencies to pass through.

In the preferred embodiment, a first passband filter 25 blocks the frequencies associated with green, reflecting them towards the photovoltaic cell 16 and allows the rays at the other frequencies to pass through. A second passband filter 26 receives the rays at the frequencies not filtered by the filter 25 and filters, in turn, the rays at the frequencies associated with red, reflecting them towards the photovoltaic cell 12 and allowing the rays at the other frequencies to pass through.

The mirror 27 reflects the rays included in the range of frequencies which are not filtered (blue) towards the photovoltaic cell 14.

The number of passband filters and the characteristics of the photovoltaic cells onto which the rays are reflected are adjusted a priori on the basis of the division of the rays 44 into predetermined frequency ranges, which can be selected as required, with a view to optimising the energy produced, maximising the efficiency of the system. In the technical jargon it is usually said that the photovoltaic cells are "tuned" to the frequencies of the reflected solar rays which they must receive.

Depending on the concavity of the parabolic mirror 22, the position of the focal point of the parabolic dish, and consequently the amplitude of the beam of reflected rays 444, is determined, always with a view to maximising the efficiency of the system.

Only optionally, heat dissipators 32, 34, 36 are envisaged and can be associated with the photovoltaic cells 12, 14, 16 in order to reduce the operating temperature thereof. These dissipators are known per se, being liquid or air operated, and are situated outside the casing 6 so as not to affect in any way the ray beam passing inside the system.

Usually, this is not necessary since the energy density is divided up over several destination cells in a manner directly proportional to the number of cells, with a consequent reduction in the temperature.

Several concentration photovoltaic systems according to the invention may be easily coupled together and made to move in synchronism, but not integrally within a frame which also has small dimensions. Modules formed by several concentrators within a frame having dimensions and weights comparable to those of flat photovoltaic panels can be installed on any type of horizontal or vertical surface, including roofs and facades of buildings.

In this way a further improvement in the efficiency is ensured on a large scale. From the description provided hitherto it is possible to understand operation of the concentration photovoltaic system according to the present invention which operates using an innovative method for concentrating solar energy.

The concentrator device 2 is positioned so as to intercept solar rays as a beam of incident parallel solar rays 4. Owing to its intrinsic physical characteristics, this device causes the beam of solar rays to converge, independently of their frequency, in the form of a beam of concentrated solar rays 44 which, in turn, strike the parabolic mirror 22, downstream of the focal point F of the concentrator device 2. The focal point F of the Fresnel lens coincides with the focal point of the parabolic mirror 22.

The parabolic mirror reflects the concentrated solar rays 44 in the form of a beam of rays 444 which are again parallel, but have a diameter smaller than the beam of incident rays 4.

This beam 444, the diameter of which depends on the predefined requisites of the system, strikes the selection device 24, in particular the first passband filter 25 which filters the rays of the beam according to a frequency range, directing them towards the photovoltaic cell 16.

The rays at different frequencies are not cut and strike the second passband filter 26 which operates in the same manner as the first filter, but in a different frequency range.

The rays at frequencies not filtered by the two filters described are reflected by means of the mirror 27 onto a last cell 14.

The energy is then extracted from the cells 12, 14 and 16 for the end use.

CLAIMS

1. Concentration photovoltaic system (1) comprising:

- concentrator means (2) for intercepting and concentrating beams of incident solar rays (4);

- reflection means (22) for reflecting beams of solar rays (44) concentrated by said concentration means (2);

characterized in that it comprises:

- selection means (24) for selecting the frequencies of beams of solar rays (444) reflected by said reflection means (22) and able to direct selected rays (101, 102, 103) towards a plurality of photovoltaic cells (12, 14, 16).

2. Photovoltaic system according to Claim 1, in which said concentrator means (2) are independent of the frequency of said beams of incident solar rays (4).

3. Photovoltaic system according to Claim 2, in which said selection means (24) comprise a plurality of passband filters (25, 26) able to select said beams of reflected solar rays (444) on the basis of the frequency.

4. Photovoltaic system according to Claim 2 or 3, in which said selection means (24) comprise a mirror (27) which is able to reflect said beams of reflected solar rays (444) not filtered previously by said plurality of passband filters (25, 26).

5. Photovoltaic system according to the preceding claims, in which said beams of reflected rays (444) are beams of parallel straight rays.

6. Photovoltaic system according to Claim 1, in which beams of incident solar rays (4) are beams of

parallel straight rays.

7. Photovoltaic system according to Claim 1, in which said concentrator means (2) are of the lens type.

8. Micro-photovoltaic system according to Claim 7, in which said concentrator means comprise a Fresnel lens.

9. Photovoltaic system according to one of the preceding claims, in which said beams of concentrated rays (44) are beams of straight rays converging at the focal point (F) of said concentrator means (2).

10. Photovoltaic system according to Claim 9, in which said focal point (F) is the focal point of said Fresnel lens.

11. Photovoltaic system according to Claim 1, in which said reflection means (22) comprise a mirror (22).

12. Photovoltaic system according to Claim 11, in which said mirror (22) has a parabolic shape.

13. Photovoltaic system according to Claims 10 and 12, in which said focal point (F) of the Fresnel lens coincides with the focal point (F) of said parabolic mirror (22).

14. Method for concentrating beams of solar rays (4) striking photovoltaic cells (12, 14, 16), which uses the concentration photovoltaic system (1) according to Claims 1 to 13, comprising the steps of:

- intercepting and concentrating beams of incident solar rays (4) by means of concentrator means (2);

- reflecting beams of concentrated solar rays (22) by means of reflection means (22);

characterized in that it comprises the step of:

- selecting said beams of reflected rays (444) by means of selection means (24) in order to reflect selectively said selected rays (101, 102, 103) towards said plurality of photovoltaic cells (12, 14, 16).

15. Method according to Claim 14, in which said selection means (24) divide said concentrated solar rays (444) on the basis of the frequencies of said concentrated solar rays (444).

16. Method according to Claim 14 or 15, in which said selection means (24) reflect said concentrated solar rays (444), divided on the basis of the frequencies, towards respective photovoltaic cells (12, 14, 16).

17. Method according to one of Claims 14 to 16, in which said cells (12, 14, 16) convert the solar rays received into energy for the end use.

18. Method according to one of Claims 14 to 17, based on the system according to Claims 1 to 13.

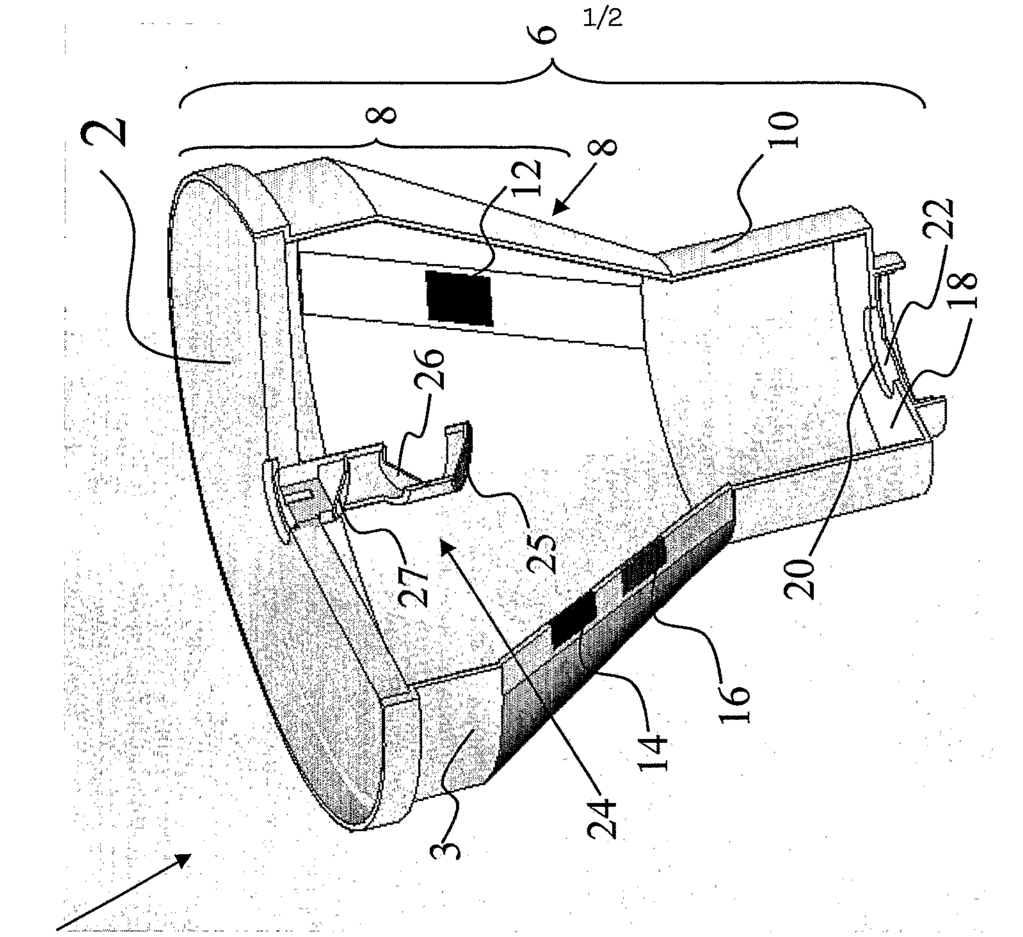
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Fig. 1

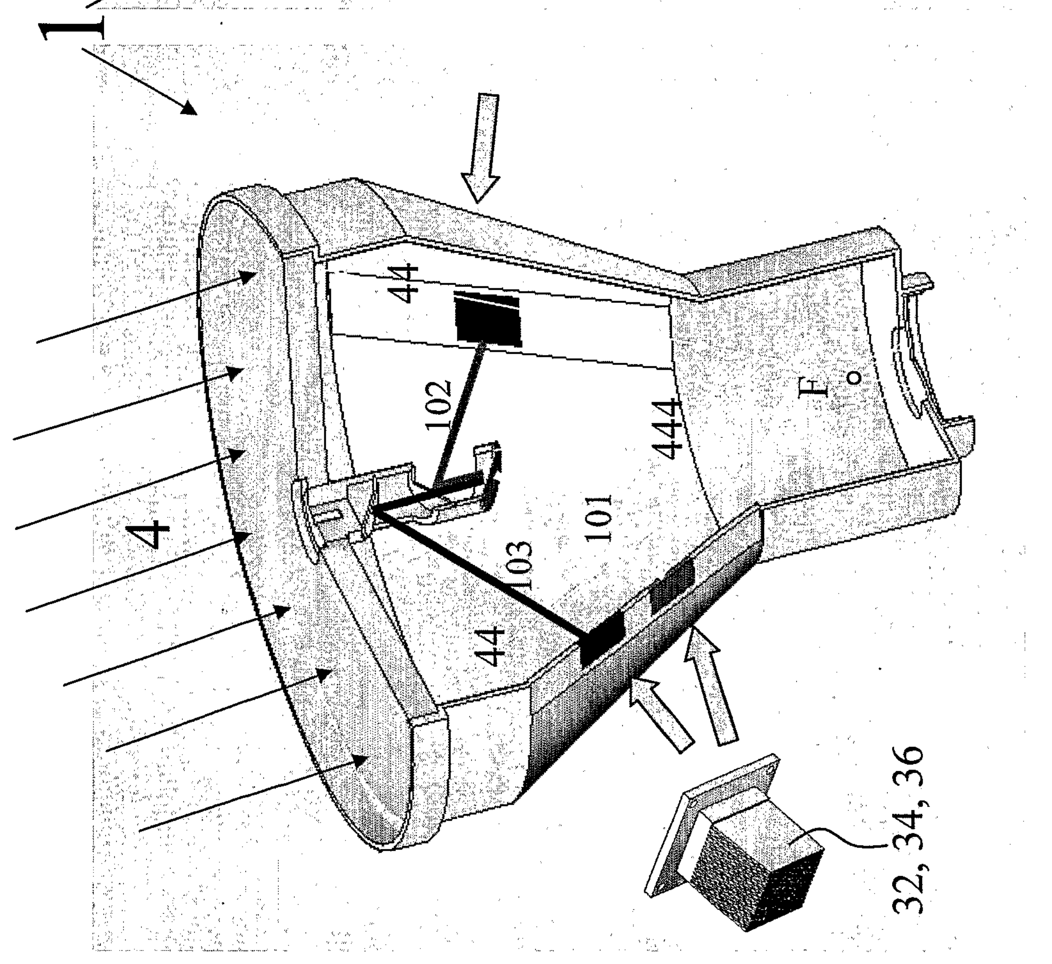
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Fig. 2

Fig. 3

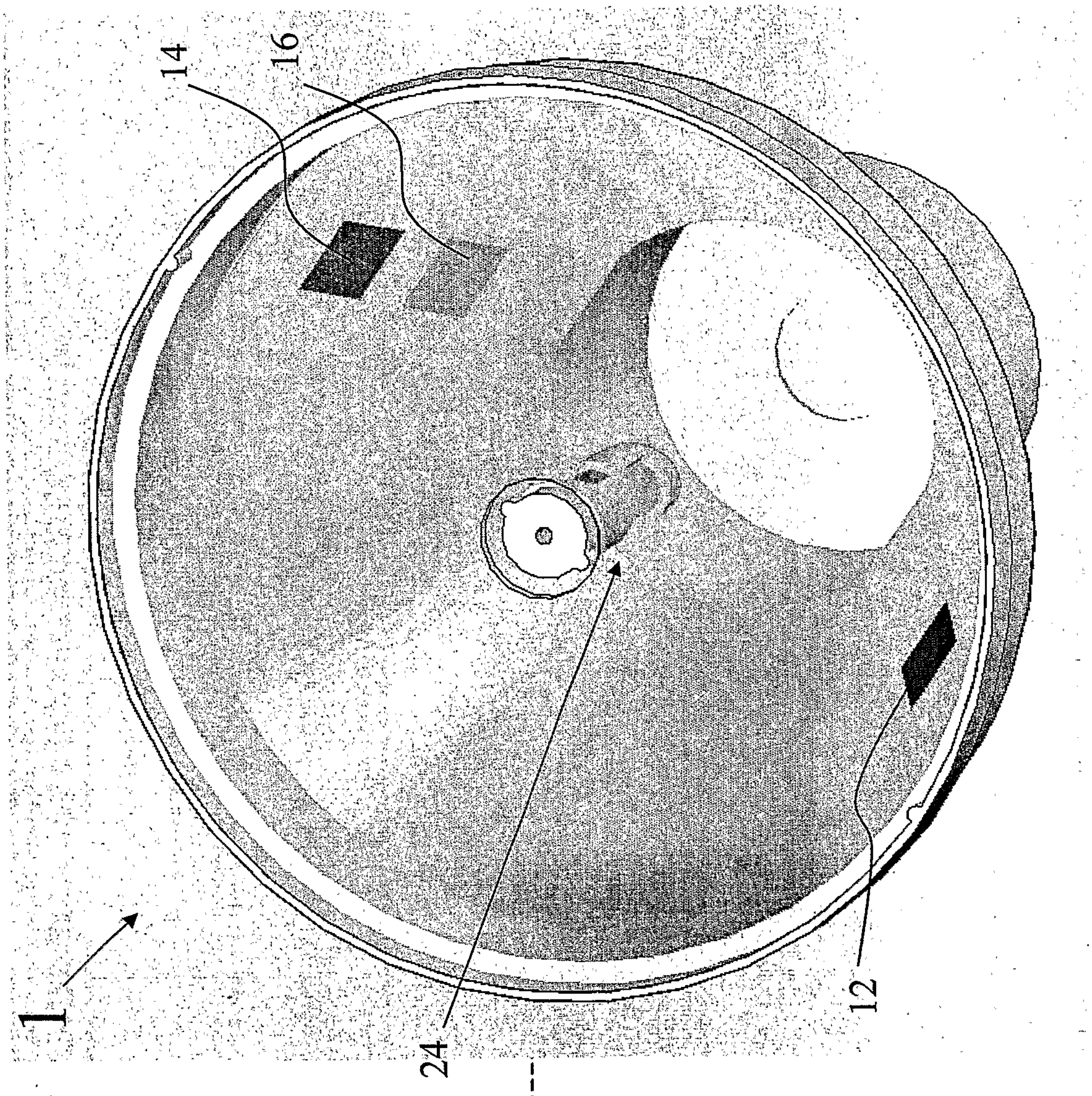
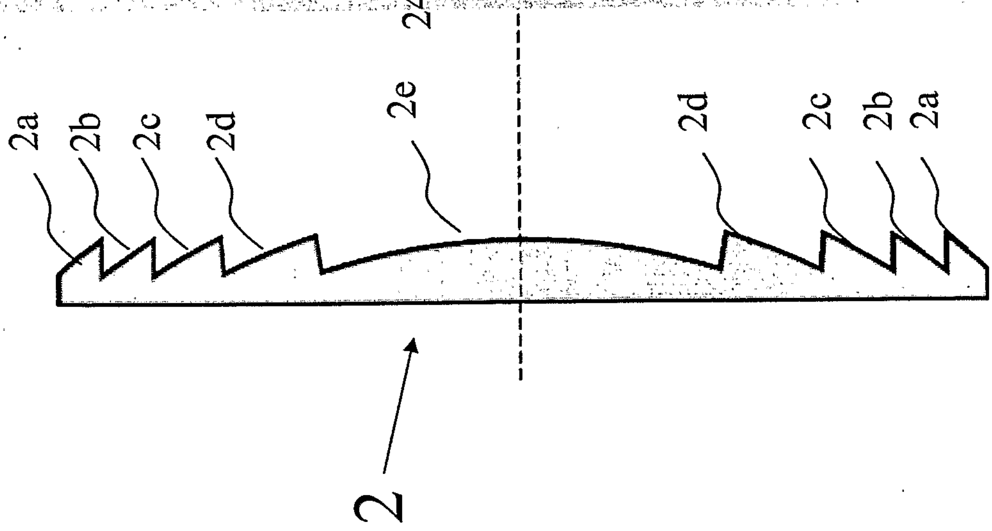


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2007/000273

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L31/052 G02B27/14 F24J2/10

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)
G02B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 469 241 B1 (PENN JAY P [US]) 22 October 2002 (2002-10-22) column 8, lines 18-63; claims 1,4; figures 3,4	1-3,6-9, 11,12, 14-18
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[X] Further documents are listed in the continuation of Box C.

[X] 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

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Date of the actual completion of the international search	Date of mailing of the international search report
7 December 2007	18/12/2007

Name and mailing address of the ISA/	Authorized officer
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	Visentin, Alberto

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2007/000273

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FRAAS L M ET AL: "Toward 40% and higher solar cells in a new Cassegrainian PV module" PHOTOVOLTAIC SPECIALISTS CONFERENCE, 2005. CONFERENCE RECORD OF THE THIRTY-FIRST IEEE LAKE BUENA VISTA, FL, USA 3-7 JAN. 2005, PISCATAWAY, NJ, USA,IEEE, US, 3 January 2005 (2005-01-03), pages 751-753, XP010822819 ISBN: 0-7803-8707-4 the whole document	1,2,6,9, 11,14-18
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A	GB 2 392 556 A (DUNSTAN DUNSTAN [GB]; PROBERT DOUGLAS [GB]) 3 March 2004 (2004-03-03) the whole document	1-3,6,9, 14-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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