(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
31 January 2008 (31.01.2008)

PCT

(10) **International Publication Number**
WO 2008/012777 A2

(51) **International Patent Classification:**
F24J 2/06 (2006.01) ***F24J 2/08*** (2006.01)

(21) **International Application Number:** PCT/IB2007/052982

(22) **International Filing Date:** 27 July 2007 (27.07.2007)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
2006/06284 28 July 2006 (28.07.2006) ZA
2006/08651 17 October 2006 (17.10.2006) ZA

(71) **Applicant** *(for MW only)*: **BROWN, Keith Edwin Frank** [ZA/ZA]; Building No. 13, Highgrove Office Park Oak Avenue, 0001 Centurion (ZA).

(71) **Applicant and**
(72) **Inventor: SCRIMGEOUR, Angus Muir Edington** [GB/US]; 3134 P Street, Washington, District Of Columbia 20007 (US).

(74) **Agents: SPOOR & FISHER** et al.; PO Box 454, 0001 Pretoria (ZA).

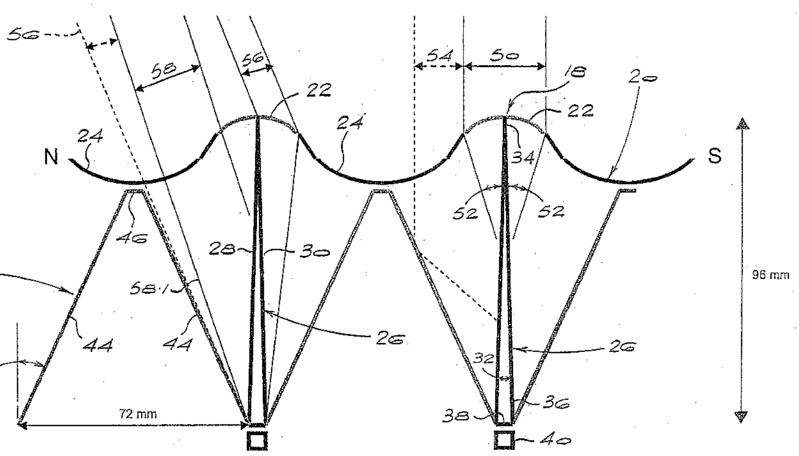
(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, 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.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** NON-TRACKING SOLAR COLLECTORS



(57) **Abstract:** The invention concerns a non-tracking solar collector which includes laterally spaced, radiation-transmitting prisms (26) which are wedge- shaped in cross-section. Each prism has major side surfaces (28, 30) converging at an acute angle to a relatively narrow end (34) of the prism, and an opposite, relatively wide end (36). For each prism there is a refractor (22), typically a linear refractor such as a linear Fresnel lens, arranged over the prism to refract solar radiation incident thereon onto the major side surfaces of the prism, as the sun moves relative to the earth, at angles allowing such radiation to enter the prism and be internally reflected towards a target at the relatively wide end of the prism. The refractors are spaced laterally apart from one another, possibly by intermediate, radiation transmitting panels which are continuous with the refractors. In the preferred construction, the refractors and intermediate panels form an integral part of a roof or wall cladding structure.

WO 2008/012777 A2

NON-TRACKING SOLAR COLLECTORS

BACKGROUND TO THE INVENTION

THIS invention relates to non-tracking solar collectors.

There exist numerous devices designed to concentrate solar radiation for the purpose of generating electricity or heat. In the case of electricity generation, the function of the solar collector is to concentrate the radiation onto relatively small photovoltaic (PV) cells, while in the case of heat generation, the function of the collector is generally to concentrate the radiation onto a conduit or container conveying or storing a fluid, such as a liquid or gas, the temperature of which is to be elevated.

In the known devices it is recognised that for efficient collection and concentration of the solar energy it is necessary for the device to track the sun as the position of the sun relative to the earth changes during the year and/or as the position of the sun relative to the earth changes during the day. A single-axis system aligned N-S (north-south) should track the sun E-W (east-west) during the day, while a single axis system aligned E-W should track the sun N-S during the year.

Concentrator systems that employ focussing lenses for primary concentration require either biaxial tracking, i.e. both N-S and E-W, or a secondary tracking system that varies the position of the lens or target in order to ensure that the collected radiation is focussed correctly on the target, i.e. PV cells or fluid conduit or container. The latter type of system, frequently referred to as a 1.5 times tracking system, typically moves the assembly of lenses, associated reflectors and/or target either individually or in arrays. The apparatus required to achieve such movement can however be expensive and complicated.

Where electricity is to be generated with the use of PV cells an added disadvantage of systems which employ a focussing lens is the fact that dirt particles on the lens create shadows which result in uneven distribution of radiation on the PV cells. Apart from the fact that this reduces the efficiency of the PV cells, it can also cause permanent damage to the cells. Dirt particles on the reflectors of a reflector-type concentrating system can also be problematical.

One example of a known solar collector, described in US 4,282,862, uses an assembly of parallel wedges to reduce the angular dispersion of incident solar radiation. Radiation refracted by the wedges is then transported to the target by internal reflection in thin modules composed of wedge-shaped glass elements. A disadvantage of the system is however a relatively low concentration ratio of around 2:1. “Concentration ratio” refers to the ratio of the area of the solar aperture, i.e. the area on which the solar radiation is incident, to the area of the target onto which the radiation is concentrated. The low concentration ratio is indicative of a low level of efficiency. Another example, described in US 4,344,417, makes use of a narrow, wedge-shaped collector to receive incident radiation and reflect it internally to the target area. The concentration ratio is however again relatively low, indicating a low level of efficiency.

Further examples of prior art collectors are described in JP 11305130 and JP 62266879. In the former case, the collector has wedge-shaped prisms and external reflectors arranged at a divergent angle with respect to one another in order to collect radiation over a larger solar aperture and to concentrate such radiation, by both internal reflection in the prisms and external reflection from the reflectors, onto a solar battery. In the latter case N-S aligned, connected wedge-shaped prisms are again used to concentrate incident radiation by internal reflection. The prism assembly is used in conjunction with a conventional solar panel.

An additional disadvantage of each of the known systems described above is the necessity for a tracking system to enable the system to track the sun.

Yet another disadvantage is the fact that each of these systems provides an independent collector which must be mounted externally on a roof or other supporting structure where it will be appropriately exposed to solar radiation.

It is an objective of the present invention to provide an efficient solar collector which does not require any independent tracking system.

SUMMARY OF THE INVENTION

According to the present invention there is provided a non-tracking solar collector comprising:

- a plurality of laterally spaced, radiation-transmitting prisms which are wedge-shaped in cross-section and which have major side surfaces converging at an acute angle to a relatively narrow end of the prism, each prism having an opposite, relatively wide end; and

- for each prism, a refractor arranged over the prism to refract solar radiation incident thereon onto the major side surfaces of the prism, as the sun moves relative to the earth, at angles allowing such radiation to enter the prism and be internally reflected therein towards a target at or adjacent the relatively wide end of the prism, the refractors being spaced laterally apart from one another.

The preferred refractor is a linear refractor, such as a linear Fresnel lens.

The refractors can be spaced apart from one another by radiation-transmitting panels which are continuous with the refractors, and in this event the collector may be configured to form part of a roof or wall cladding structure, such as a corrugated expanse of roof or wall cladding in which the linear refractors are arranged at the crests of the corrugations and the radiation-transmitting panels at the valleys thereof.

Typically the narrow edges of the prisms will extend in the pitch direction of an expanse of roof cladding. In one preferred configuration, the narrow ends of the prisms extend E-W in a pitched roof cladding structure the ridge cap of which extends N-S.

In an alternative arrangement the linear refractors and light-transmitting panels form a flat expanse of roof or wall cladding.

The narrow ends of the prisms can be adjacent to or in contact with the linear refractors, and there may be reflector structures between the prisms. In this case each reflector structure may include a pair of convergent reflector panels arranged to reflect radiation which is transmitted by the radiation-transmitting panels onto the prisms for collection and concentration by the prisms.

The preferred embodiments of the invention include a radiation transmitting secondary solar concentrator at the wider end of each prism. This concentrator may have side walls, typically planar or concave, which converge towards one another to a width less than that of the wider end of the prism.

The secondary solar concentrator should be made of a material with a higher refractive index than the material of which the prism is made and the prism and secondary solar concentrator should meet one another at a curved interface where a convex surface of the secondary solar concentrator mates with a concave surface of the prism.

In electricity generating applications, there may be a PV cell at the wider end of each prism or at the end of the secondary solar concentrator.

In heating applications, there may be a pipe conveying a fluid which is to be heated at the wider end of the prism or at the end of the secondary solar concentrator.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 diagrammatically illustrates a pitched roof cladding structure incorporating a solar collector according to this invention;

Figure 2 shows a diagrammatic cross-sectional detail of a portion of the solar collector forming part of the roof cladding structure seen in Figure 1; and

Figure 3 illustrates the use of a secondary solar radiation concentrator.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Figure 1 shows a roof cladding structure 10 comprising pitched sections 12 and 14 aligned in an E-W direction with the ridge cap 16 of the roof structure extending in a N-S direction, i.e. into the plane of the paper in Figure 1.

As shown in the diagrammatic cross-section of Figure 2, the roof cladding structure has a corrugated profile, with arcuate crests, peaks or high points 18 alternating with arcuate valleys, troughs or low points 20. The cladding structure incorporates a solar collector or concentrator in which the crests 18 of the corrugations are provided by arcuate strips 22 designed as linear refractors, for example as linear Fresnel refractors. The refractors may be made of a suitable radiation refracting material such as glass, acrylic or polystyrene and are treated with ultraviolet (UV) filter material in view of their exposure to solar radiation. The valleys 20 of the corrugations are provided by radiation-transmitting strips or panels 24 made of a clear acrylic or other suitable material, treated with UV filter material if necessary.

Located beneath each linear refractor 22 is a prism 26 made of, for instance, glass, acrylic or polystyrene. The individual prisms 26 are elongate both vertically and in the pitch direction of the roof cladding structure 10, i.e. in the E-W direction. Each prism has major, planar side surfaces 28 and 30 which converge at an acute angle 32, in this case about 3°, to one another towards a relatively narrow end 34 of the prism. The opposite end 36 of the prism is relatively wide and has mounted to it a heat transmitting coupler 38 in heat transmitting contact with a pipe 40 conveying a fluid, such as water or a gas, which is to be heated by concentrated solar radiation.

The narrow ends 34 of the prisms point to and are attached to the underside of the linear refractors 22. Although the narrow ends are shown as sharp edges, they may in practice be slightly truncated. The prisms are arranged with their narrow edges 34 extending E-W, i.e in the pitch direction and the linear refractors are designed to refract solar radiation incident thereon onto the major side surfaces 28 and 30 of the prisms.

Located between adjacent prisms 26 are reflector structures 42 each composed of upwardly inclined pairs of reflectors 44. By way of example, these reflectors may be of polished aluminium or they may be of steel with external surfaces carrying reflective films. At their lower ends the reflectors are connected to the wider ends 36 of the prisms and their upper ends are joined to one another and to the valleys 20 of the corrugations by connecting strips 46. In the preferred arrangement, the reflectors 44 are inclined at a latitude angle 48.

Preferred dimensions for the solar collector components are shown in Figure 2.

During each day the sun moves in an E-W direction relative to the earth and to the illustrated roof cladding structure. During each year, the sun moves in a N-S direction relative to the earth and to the illustrated roof cladding structure, between limit solstice positions at latitude angles of 23.5° north and 23.5° south. The numeral 50 designates exemplary, parallel solar rays which are incident on each of the linear refractors at mid-day i.e. 12h00 and an overhead latitude angle. Such rays are refracted by the linear refractors onto the side surfaces 28 and 30 of the associated prism 26. With the prism having a refractive index of the order of 1.4 to 1.5, eg acrylic or glass, the refracted rays are incident on the side surfaces 28 and 30 at angles 52 of about 20°. This is within the acceptance range for the prism, so the radiation enters the prism rather than being externally reflected off a surface 28 or 30. The surfaces 28 and 30 may be treated with a non-reflective coating to increase the acceptance range if necessary.

Radiation which enters the prisms undergoes normal refraction at the air/prism material interface and thereafter undergoes total internal reflection within the prisms for eventual concentration on the pipes 40 in order to heat the fluid conveyed in the pipes.

The numeral 54 indicates solar rays which are incident on the roof cladding structure but which do not fall on the refractors 22. These may for instance be solar rays at around 08h00 and 16h00 during the day with the sun at an overhead latitude angle. Such rays pass through the intermediate panels 24 and are incident on the reflector panels 44 which reflect the rays onto the surfaces 28 and 30. These rays also enter the prisms and are internally reflected therein for eventual concentration on the pipes 40. Thus the reflector structures provide a means for collecting radiation which would otherwise be lost and for directing it into the prisms for eventual concentration.

The numeral 56 indicates solar rays which are incident on the linear refractors at mid-day and emanate from the sun at a limit solstice latitude angle of 23.5°. It will be noted that such rays pass, parallel to the adjacent reflector panel 44, to the wider end of the prism where acceptance and internal reflection concentrates them on the pipes 40.

The numeral 58 indicates solar rays, emanating from a 20° latitude angle, which are incident at mid-day on the roof cladding structure. Rays 58 which pass through the panels 24 are directly incident on the wider ends of the prisms, which accept them for internal reflection and concentration.

From the above it will be understood that irrespective of the time of day or time of the year the illustrated combination of linear refractors, intermediate light-transmitting panels and reflector structures ensures that a substantial portion of all available radiation which is incident on the roof cladding structure is directed to the prisms at appropriate angles for acceptance by the prisms, whereafter the prisms act, through internal reflection of the radiation, to concentrate the radiation onto the pipes 40. Thus efficient solar heating of the pipe contents is achieved without the need for any independent tracking system to move the concentrating components in order to track the sun as its position relative to the earth changes.

It will furthermore be understood that the solar collector effectively forms an integral part of the actual roof cladding structure and there is no requirement, as with conventional solar collectors, to mount a separate collector externally on a roof or other supporting structure.

In the embodiment described above, the concentrated solar radiation is used to heat up a fluid conveyed in a pipe. It will however be understood that the apparatus could equally well be used for electricity generation, in which case the radiation could be concentrated on PV cells located at the wider ends of the prisms. The random internal reflection of the radiation also ensures that there is an equal distribution of radiation on the PV cells.

It is envisaged that relatively high concentration ratios of the order of 8:1 can be achieved with the solar collector described above and illustrated in the drawings.

Although the roof cladding structure in the illustrated embodiment has a corrugated profile it is also envisaged that embodiments in which alternating linear refractors and intermediate, radiation-transmitting panels are arranged in a flat configuration would also operate efficiently. In such a configuration the refractors and intermediate panels would be flat and would, in combination, form a flat expanse of roof or wall cladding. Further embodiments are also envisaged in which the reflectors 44 are offset for use as wall cladding structures.

Figure 3 illustrates a modified version of the apparatus. In this version a secondary solar radiation concentrator is indicated by the reference numeral 70. The concentrator extends for the full length of the prism 26 and is of a solid or liquid material having a higher refractive index than the material of which the prism is made. In one example, the prism is made of an acrylic having a refractive index of less than 1.5 and the secondary concentrator 70 of polystyrol or glass having a refractive index of more than 1.5. The secondary concentrator is placed at the wider, lower end of the prism 26 and is intimately connected to the prism at an upwardly convex interface defined by a convex surface 72 of the secondary concentrator and a concave surface 74 of the prism. The secondary concentrator 70 has planar side surfaces 76 and 78 and a planar lower surface 80 to which the coupler 38 is intimately attached. As before the coupler 38 is in intimate contact with the pipe 40.

The numeral 82 indicates a solar ray which enters the prism 26 through the side surface 30, is refracted at the prism/air interface, travels through the lower part of the prism to the convex interface between the prism and the solar concentrator 70 where it is refracted into the secondary concentrator, and is thereafter reflected internally off the side surface 76 of the secondary concentrator and onto the coupler 38. It will be understood that other solar rays that have been internally reflected in the prism will likewise be refracted into the secondary concentrator 70 for subsequent passage directly or through internal reflection onto the coupler.

To ensure that all rays which enter the secondary concentrator 70 are reflected onto the coupler 38, inwardly facing mirrors 84 (only one shown) may be placed against the surfaces 76 and 78 or these surfaces may themselves be mirrored.

Instead of side surfaces 76 and 78 which are planar, the side surfaces of the secondary concentrator may be concave as indicated diagrammatically by the numeral 86, or convex.

The convex interface defined by the surfaces 72 and 74 is preferred to a planar, horizontal interface because it will tend to refract radiation in the appropriate direction for subsequent reflection onto the coupler 38. A secondary concentrator having a convex interface as illustrated may be referred to as a secondary convex concentrator (SCC).

It will be understood that the SCC seen in Figure 3 will increase the concentration ratio further, implying high levels of solar concentration efficiency.

It will be appreciated that the SCC of Figure 3 could equally well be used to achieve highly efficient concentration of solar radiation onto a PV cell in place of the coupler 38 and pipe 40.

CLAIMS

1.
A non-tracking solar collector comprising:

- a plurality of laterally spaced, radiation-transmitting prisms which are wedge-shaped in cross-section and which have major side surfaces converging at an acute angle to a relatively narrow end of the prism, each prism having an opposite, relatively wide end; and

- for each prism, a refractor arranged over the prism to refract solar radiation incident thereon onto the major side surfaces of the prism, as the sun moves relative to the earth, at angles allowing such radiation to enter the prism and be internally reflected therein towards a target at or adjacent the relatively wide end of the prism, the refractors being spaced laterally apart from one another.

2.
A non-tracking solar collector according to claim 1 wherein the refractor is a linear refractor.

3.
A non-tracking solar collector according to claim 2 wherein the refractor is a linear Fresnel lens.

4.
A non-tracking solar collector according to any one of the preceding claims wherein the refractors are spaced apart from one another by radiation-transmitting panels which are continuous with the refractors.

5.

A non-tracking solar collector according to claim 4 wherein the collector is configured to form part of a roof or wall cladding structure.

6.

A non-tracking solar collector according to claim 5 wherein the linear refractors and radiation-transmitting panels form a corrugated expanse of roof or wall cladding.

7.

A non-tracking solar collector according to claim 6 wherein the linear refractors are arranged at the crests of the corrugations and the radiation-transmitting panels at the valleys thereof.

8.

A non-tracking solar collector according to claim 6 or claim 7 wherein the narrow edges of the prisms extend in the pitch direction of an expanse of pitched roof cladding.

9.

A non-tracking solar collector according to claim 8 wherein the narrow ends of the prisms extend E-W in a pitched roof cladding structure the ridge cap of which extends N-S.

10.

A non-tracking solar collector according to claim 4 or claim 5 wherein the linear refractors and radiation-transmitting panels form a flat expanse of roof or wall cladding.

11.

A non-tracking solar collector according to any one of claims 4 to 10 wherein the narrow ends of the prisms are adjacent to or in contact with the linear refractors.

12.

A non-tracking solar collector according to claim 11 comprising reflector structures between the prisms.

13.

A non-tracking solar collector according to claim 12 wherein each reflector structure includes a pair of convergent reflector panels arranged to reflect radiation which is transmitted by the radiation-transmitting panels onto the prisms for collection and concentration by the prisms.

14.

A non-tracking solar collector according to any one of the preceding claims comprising a radiation transmitting secondary solar concentrator at the wider end of each prism.

15.

A non-tracking solar collector according to claim 14 wherein the secondary solar concentrator has side walls which converge towards one another to a width less than that of the wider end of the prism.

16.

A non-tracking solar collector according to claim 15 wherein the side walls of the secondary solar concentrator are planar or concave.

17.

A non-tracking solar collector according to any one of claims 14 to 16 wherein the secondary solar concentrator is made of a material with a higher refractive index than the material of which the prism is made.

18.

A non-tracking solar collector according to any one of claims 14 to 17 wherein the prism and secondary solar concentrator meet one another at a curved interface.

19.

A non-tracking solar collector according to claim 18 wherein a convex surface of the secondary solar concentrator mates with a concave surface of the prism at the interface.

20.

A solar collector according to any one of claims 1 to 13 comprising a PV cell at the wider end of each prism.

21.

A solar collector according to any one of claims 14 to 19 comprising a PV cell at an end of the secondary solar collector remote from the prism.

22.

A solar collector according to any one of claims 1 to 13 comprising a pipe conveying a fluid which is to be heated at the wider end of the prism.

23.

A non-tracking solar collector according to any one of claims 14 to 19 comprising a pipe conveying a fluid which is to be heated at an end of the secondary solar concentrator remote from the prism.

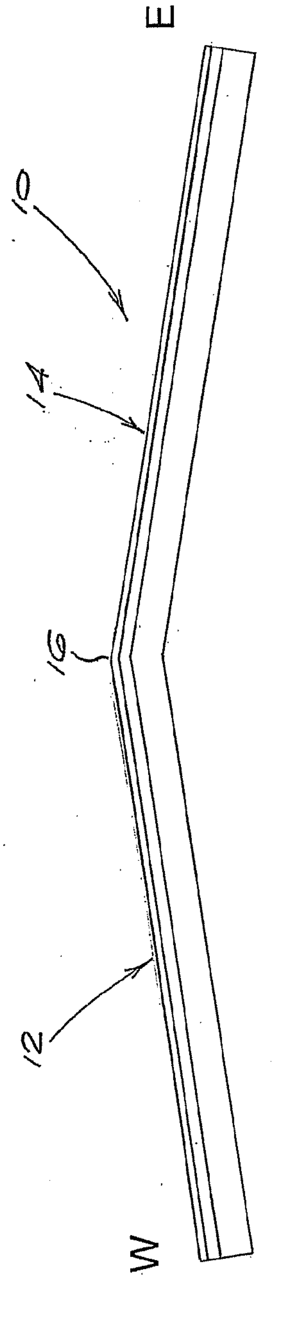

10
14
16
12
E
W

Fig.1

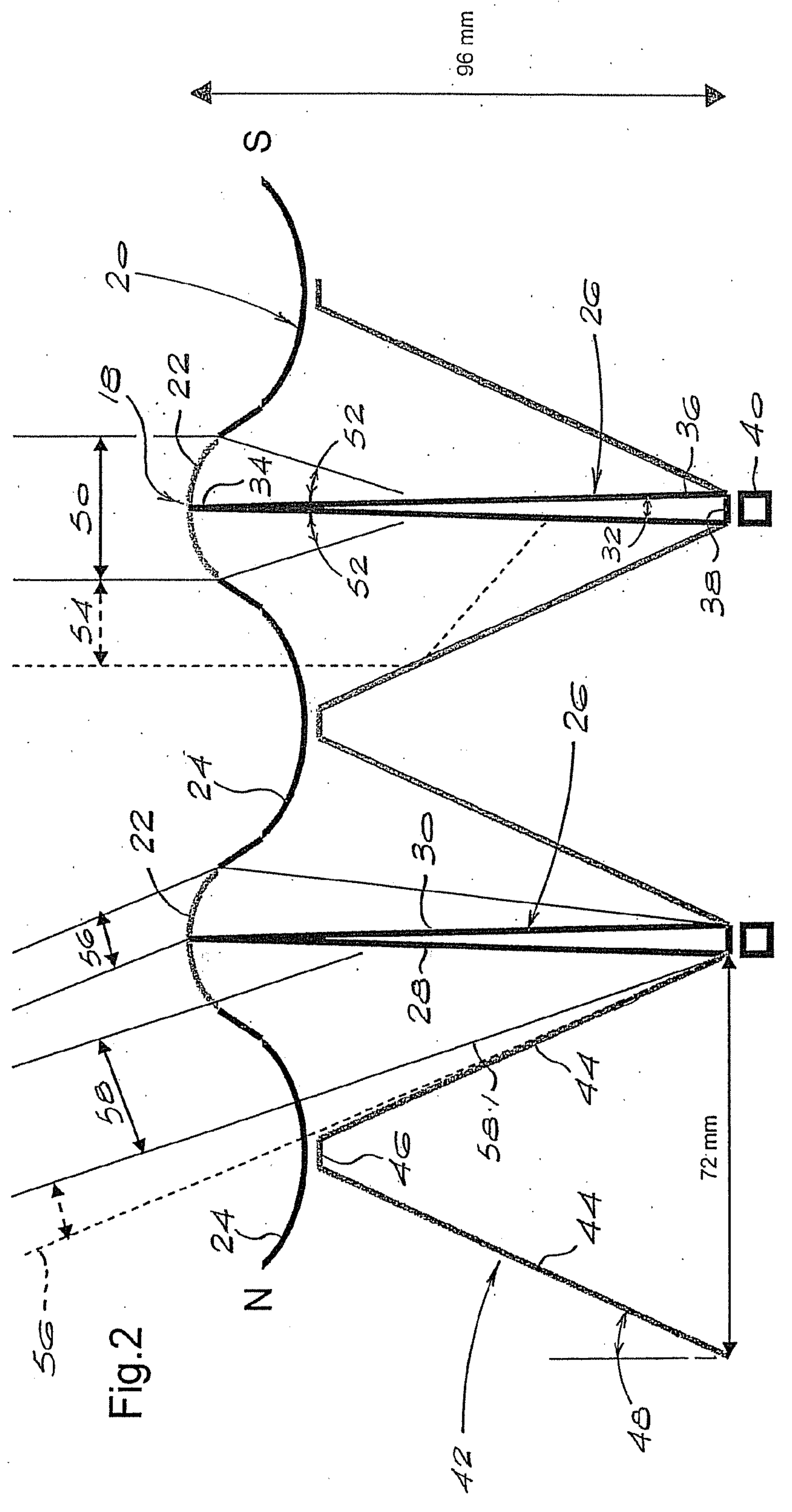

96 mm
S
N
20
22
18
34
52
50
54
36
40
32
38
26
24
30
28
56
58
58'
44
46
72 mm
42
48

Fig.2

Fig. 3