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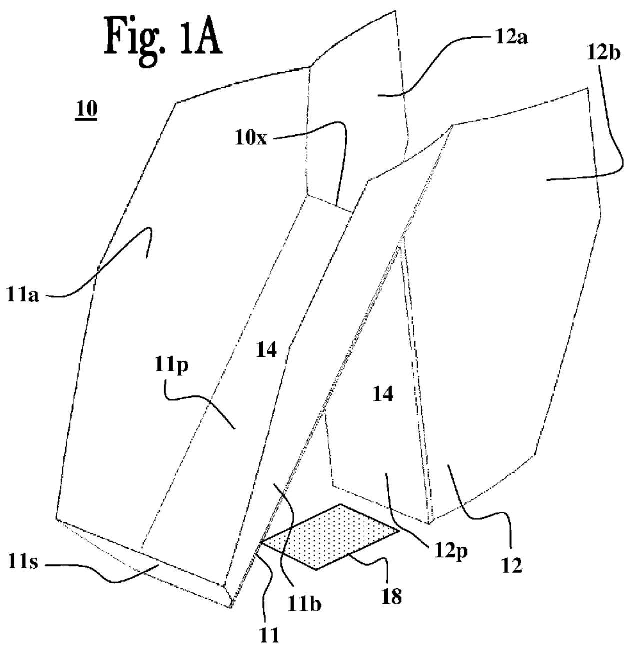
(54) **Title**: SYSTEM FOR COLLECTING ELECTROMAGNETIC RADIATION FROM A MOVING SOURCE

Fig. 1A



(57) **Abstract**: An electromagnetic radiation collecting device (10) is presented, which is particularly useful for collection Sun radiation and provides for optimal radiation collection throughout the day hours. The device comprises a base side (14) having a curved surface of A-shaped configuration defined by two tilted arms (11, 12) located in two intersecting planes and presenting radiation collecting surfaces of the device for collection of radiation and directing collected radiation to one or more radiation receiving elements (not shown here) located within a receiving plane (18); and two opposite sides extending from the base side (14), the opposite sides comprising reflectors (11a, 12a; 11b, 12b) on their inner surfaces facing one another, for collecting incoming radiation and reflecting collected radiation towards the one or more radiation receiving elements.

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SYSTEM FOR COLLECTING ELECTROMAGNETIC RADIATION FROM A MOVING SOURCE

TECHNOLOGICAL FIELD

The present invention is generally in the field of electromagnetic radiation collecting systems, particularly for the collection of solar radiation.

BACKGROUND

In recent years, the quest for renewable energy has promoted interest in solar light collection. The collected solar light may be guided to desired spaces for illuminating them, may be used to heating water, or may be converted to electrical energy via photovoltaic cells.

The collection and guiding of solar light for providing illumination to open or closed spaces is commonly referred to as solar lighting. Many solar lighting products have been developed and are available on the market. Solar lighting techniques are divided into two groups: active and passive. In active solar lighting, sunlight is collected by optical elements that move to track the Sun, while optical light guides transmit the collected light to internal spaces of a building. In passive solar lighting, little or no tracking is effected, and the colleting elements are generally static.

US Patent 5,099,622 discloses a (passive) skylight and a method of constructing a skylight wherein the method comprises the steps of forming an opening in the roof and ceiling respectively of a housing having a cavity therebetween. A tubular skylight is then inserted into the opening. The tubular skylight has a transparent surface protruding throughout the ceiling and roof respectively to pass light therethrough. A reflector is located within the domed transparent surface protruding through the roof, and is angled such that it reflects light that would not have passed into the tubular skylight into same.

US Patent Publication 2001/006066 discloses a solar collection system and method having means for receiving solar radiation through a main refractive interface and means for internally reflecting at least once, at least a portion of the received solar radiation. The refractive medium may be liquid, gel or solid. The device may be integrated with a photovoltaic device, photo-hydrolytic device, a heat engine, a light pipe or a photo-thermal receptor.

Sunlight Direct, LLC (http://www.sunlight-direct.com/hybrid-solar-lighting/), produces an active solar lighting system (named TR5), which includes 128 Fresnel lenses and fibers and is capable of delivering from 20,000 to 60,000 lumens, depending on the length of the fibers used. The TR5 includes an azimuth drive and an elevation drive controlled by a programmable logic controller to move the lens array in order to track the Sun's motion.

Parans Solar Lighting (http://www.parans.com/eng/) also produces active solar lighting systems, where collecting optical elements are moved by an azimuth drive and an elevation drive to track the Sun's motion.

US Patent Publication 2009/277496 discloses devices, methods, systems and apparatus for improving solar energy collection, reducing costs associated with manufacture of solar energy collection and improving the versatility and simplicity of solar collection devices.

GENERAL DESCRIPTION

There is a need in the art for a novel solar radiation collection system in which the radiation collection is optimized throughout the day, by providing substantially uniform light collection profile of the system during the day hours. The solar radiation collection system of the present invention utilizes a novel configuration of a light collecting device, which can be used in a passive / static radiation collection system or in an active / dynamic radiation collection system.

The term "*passive*" or "*static*" used hereinafter interchangeably refer to a light collecting device having no moving parts and control units to track the movement of the source (Sun), while the term *"active"* or *"dynamic"* are used with respect to a light collecting device having moving parts for tracking the source movement.

The present invention takes advantages of the earlier technique developed by the inventor and disclosed in International Patent Application No. PCT/IB2014/058005 assigned to the assignee of the present application, which provides a passive solar lighting system, designed to produce a balanced flux throughout the day. According to this technique, the lighting system includes a radiation collector in combination with a plurality of lenses associated with a plurality of light guiding elements. The radiation collector utilizes two opposite reflectors facing each other via respective reflective inner surfaces and configured for reflecting at least some of input electromagnetic radiation onto the lenses positioned in the focal plane of the reflectors. These reflectors extend from a base surface, and preferably have parabolic shape being arranged substantially symmetrical with respect to the base surface.

The inventor has now found that the operation of a light collector device can be significantly improved by providing a specifically designed curved base surface between the two reflectors for directing input radiation to one or more receiving elements located in a receptor panel.

In one broad aspect, the present invention provides a system for collecting electromagnetic radiation from a moving source, the system comprising:

an electromagnetic radiation collector device comprising a base surface, and two opposite sides extending from said base surface, said opposite sides comprising reflectors on their inner surfaces facing one another, wherein

said base surface is a curved surface of an Λ-shaped configuration defined by two tilted arms located in two intersecting planes and presenting radiation collecting surfaces of the device for collection of radiation and directing collected radiation to one or more radiation receiving elements.

It should be noted that the term *Λ-shaped configuration* refers to a structure having an *Λ-like shape* or *substantially Λ-shape*, i.e. substantially inverted "V" shape, where the term *"substantially"* or *"like"* actually signifies that the apex portion of such structure may or may not be sharp but round and that the arms extending from the apex may or may not be planar but rather curved.

In the most general configuration, the base surface is actually an Λ-shaped frame, defining an Λ-shaped aperture, which may or may not filled with optical elements, such as lenses and/or mirrors. Therefore, the term Λ-shaped aperture used in the description below should be interpreted broadly as described above.

The radiation receiving element may be a light guide configured as an optical fiber, e.g. having a lens at its input edge; or as a reflecting tube or tubular-like member.

The two opposite surfaces are preferably configured as truncated tilted parabolic troughs (TTPTs) having reflecting inner surfaces facing one another. Practically, each of the surfaces is formed by a pair of TTPT reflectors, which may be interconnected by a triangle-like reflecting bridge. Thus, the opposite surfaces / reflectors form two symmetrical reflector pairs, extending from, respectively, the two sides/arms of the Λ-shaped base surface, where the reflectors of each pair faces one another.

The angle between the arms of the Λ-shaped base side is selected such that, when the device is put in operation, i.e. is exposed to radiation coming from the moving source, each of these two arms can be oriented in a plane substantially normal to the general direction of propagation of the incoming radiation for a corresponding position of the source at the start and end of the collection period. Considering the Sun radiation, such general direction of propagation of the incoming radiation refers to the direction of propagation of most of Sun radiation during different halves of the day. For example, by providing the angle of about 60° angle between the arms of Λ-shaped base surface, while orienting the device such that the two arms of the Λ-shaped base surface face, respectively, East and West, the Sun radiation can be optimally collected with substantially uniform amount of the collected radiation, during the day hours between 8:00 and 16:00.

In some embodiments, the radiation collector device further includes arrays of optical elements (typically, lenses) located along the base surface (e.g. along the arms of the Λ-shaped aperture), and directing light towards one or more receivers.

In some embodiments, the radiation collector device further includes a V-shaped stationary mirror having two tilted reflecting surfaces located in respective two intersecting planes and partially protruding through the arms of the Λ-shaped aperture, respectively, such that the reflecting surfaces of the mirror are directly exposed to incoming radiation to which the collector device is exposed. In this configuration, light reflected from the two opposite reflectors and from the V-shaped stationary mirror is directed to one or more receivers.

It should be understood that, similarly, the term *"V-shaped"* refers to a structure having a *V-like shape or substantially V-shape*, where the term *"substantially"* or *"like"* actually signifies that the apex portion of such structure may or may not be sharp but round and that the arms extending from the apex may or may not be planar but rather curved.

The V-shaped structure and the Λ-shaped base side may be configured such that portions of the tilted arms of the Λ-shaped base side are directly exposed to incoming radiation, and portions of the outer reflecting surfaces of the tilted arms of the V-shaped structure are directly exposed to incoming radiation.

The V-shaped structure may be accommodated such that its apex portion is substantially aligned with the apex portion of the Λ-shaped base side.

In some embodiments, the receiving element comprises a reflecting tubular member for guiding collected received radiation to one or more targets.

Thus, the light collecting device, as described above, may be configured as a passive collector for collecting radiation from the moving source while in a static mode of the light collecting device.

In some other embodiments, the light/radiation collecting device may further include arrays of rotatable mirrors, which extend along the aperture tilted arms of the Λ-shaped base surface, each being mounted for a pivotal/rotational movement with respect to the frame of the Λ-shaped base surface. The rotation of the mirrors of the array provides that at least some of the mirrors of said array selectively operate in the substantially/almost reflecting mode or combined reflecting and transmitting mode. In the "pure-reflective" mode, the mirrors have angular orientation such that there are no radiation transmitting spaces between them and they can only reflect radiation incident thereon, being either incoming external radiation or radiation reflected by the opposite mirror array, while in the combined reflecting and transmitting mode, the mirrors reflect incident radiation either directly to the receiving plane or to the mirrors of the opposite array, and are angularly oriented with spaces between them through which incoming radiation can enter the collecting device and propagate either directly to the receiving plane or to the mirrors of the opposite array.

The rotational/pivotal movements of the mirrors are synchronized in such a manner that the arrangement of mirrors (i.e. their angular orientation defining also the radiation transmitting spaces between them) provides that most of radiation interacting with mirrors is directed by the mirrors toward a relatively small / narrow radiation receiving region / target (typically 300 x 60 mm) on the receiving plane (being a base plane defined by the Λ-shaped structure of the base side.

A plurality of radiation guiding elements may be provided being optically coupled to said small / narrow receiving region for receiving the collected radiation and directing it to one or more remote targets.

According to another broad aspect of the invention, there is provided an electromagnetic radiation collector device comprising:

a base surface being a curved surface of an Λ-shaped configuration defined by two tilted arms located in two intersecting planes and presenting radiation collecting surfaces of the device for collection of radiation and directing collected radiation to one or more radiation receiving elements; and

two opposite sides extending from said base surface, said opposite sides comprising reflectors on their inner surfaces facing one another, for collecting incoming radiation and reflecting collected radiation towards the one or more radiation receiving elements.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings. Features shown in the drawings are meant to be illustrative of only some embodiments of the invention, unless otherwise implicitly indicated. In the drawings like reference numerals are used to indicate corresponding parts, and in which:

Figs. 1A to **1G** schematically illustrate an example of a radiation collecting device according to some embodiments of the invention, wherein **Fig. 1A** to **1C** respectively show side, front, and perspective views of the device, and **Figs. 1D** to **1F** demonstrate simulated collection of light incoming in various different directions from a moving source, and **Fig. 1G** shows graph plots of simulation results obtained for the amount of light collected with the collecting device;

Fig. 2 schematically illustrates an arrangement of optical elements, e.g. lenses within a Λ-shaped base side of the device of Figs. 1A-1C;

Figs. 3A to **3F** schematically illustrate another example of the radiation collecting device according to some embodiments of the invention, wherein **Fig. 3A** to **3C** respectively show perspective, side and top views of the device, and **Figs. 3D** to **3F** demonstrate simulated collection of light incoming in various different directions from a moving source;

Figs. 4A to **Fig. 4H** schematically illustrate yet another example of the radiation collecting device according to some embodiments of the invention further employing rotating mirrors, wherein **Fig. 4A** to **4C** respectively show perspective, side and from views of the device, **Figs. 4D** to **4F** demonstrate collection of light incoming in various different directions from a moving source, and **Figs. 4G** and **4H** show possible cross-sectional shapes of the rotating mirrors; and

Fig. 5 illustrates simulation results comparing operation of the light collecting devices of Figs. 1A-1C and 3A-3C, wherein the device operation is presented in the form of a radiation flux being collected throughout the day hours, and simulated radiation flux correspond to different locations of the receiving plane.

DETAILED DESCRIPTION OF EMBODIMENTS

The various embodiments of the present invention are described below with reference to the drawings, which are to be considered in all aspects as illustrative only and not restrictive in any manner. Elements illustrated in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the invention. This invention may be provided in other specific forms and embodiments without departing from the essential characteristics described herein.

Figs. 1A to **1C** schematically illustrate a radiation collecting device **10** according to some embodiments of the present invention. With reference to **Figs. 1A** and **1B**, the radiation collecting device **10** includes two opposite sides **10a** and **10b** extending upwardly from the opposite sides of a base surface **14** and including reflectors **11a-12a** and **11b-12b** on its inner surfaces respectively arranged in a substantially symmetric manner with respect to the base surface **14**. The sides **10a** and **10b** are preferably configured as truncated tilted parabolic troughs (TTPTs).

According to the invention, the base surface **14** is a curved surface of an Λ-shaped configuration defining an Λ-shaped aperture **14'**. The base surface is in the form of Λ-shaped frame having two tilted arms/sides **11** and **12** (located in two respective intersecting planes) extending from an apex portion **10x**, and each such arms is formed with the respective arms-side of the Λ-shaped aperture **14'** serving for collection of radiation incident onto the tilted arms and directing collected radiation to one or more radiation receiving elements (not shown here) located within a receiving plane **18**, in which a receptor panel containing the receiving element(s) can be located.

As shown in the figure, each of the opposite sides **10a** and **10b** is formed by a pair of TTPT reflectors **11a** - **12a** and **11b** – **12b**. Thus, the opposite surfaces / reflectors form two symmetrical reflector pairs **11a-12a** and **11b-12b**, extending from, respectively, the two sides/arms **11** and **12** of the Λ-shaped base surface, and the reflectors of each pair face one another.

As best seen in **Fig. 1B** the reflectors **11a-12a** and **11b-12b** are mounted in a tapering conformation, such that the distance between them is gradually decreased towards their respective sides **11** and **12** of the base surface/aperture **14**. Alternatively, in possible embodiments, the reflectors of each pair are implemented by convex configuration of their facing reflecting surfaces with respect to the corresponding arms of the base surface, i.e. reflectors **11a** and **11b** are two generally parabolic reflecting surfaces in the convex arrangement with respect to aperture arm **11p**, and reflectors **12a** and **12b** are two generally parabolic reflecting surfaces in the convex arrangement with respect to aperture arm **12p**. By this, the amount of input radiation collected due to the reflection from the reflectors **10a** and **10b** towards the apertures **11p** and **12p** and thus towards the receiving plane **18** is optimized.

The inventor of the present invention has found out that by selecting a proper angle 2α between the arms **11p** and **12p** of the aperture **14** (α being an angle that the respective arm forms with respect to a symmetry plane **13** of the device) in such a manner that the respective arms **11** and **12** (light collecting surfaces) of the device are substantially perpendicular to the general propagation direction of incoming radiation at the beginning and end of the collection period, thereby providing that the amount of light collected throughout the day time can be optimized. For example, the angle 2α is about **60°** for a daily angle of 120° of the Sun trajectory which corresponds to roughly 08:00 to 16:00. More specifically, the configuration of the light collecting device **10** can provide substantial uniform amount of collected light, and accordingly substantial uniform flux on the receiving element(s).

As further shown in this specific but not limiting example of Figs. 1A-1C, the light collecting device **10** may optionally include auxiliary side reflectors **11s** and **12s** mounted at the free ends/sides of the base surface arms **11** and **12**. These auxiliary side reflectors **11s** and **12s** are properly inclined with respect to the surfaces **11** and **12** forming an angle **β** which may be about 90° for collecting light at mid-day hours, but may be modified in other configurations not specifically described here, to further amplify the light collection from these panels **11s** and **12s** at other specific desired angles.

In some embodiments, optical elements may be accommodated within the arms/sides of the Λ-shaped base surface / aperture **14**. These may be arrays of lenses. To this end, reference is made to **Fig. 2**, showing one of the arms / sides of the Λ-shaped base surface with the lens array mounted thereon. Actually, the base side of collecting device is configured as a Λ-shaped frame having two tilted aperture arms extending from the apex portion. The arrays of lenses are accommodated within the aperture tilted arms. It should be noted, although not specifically shown, that the lenses may be associated with / optically coupled to radiation guiding elements, such as optical fibers configured to transfer the collected radiation to target location(s) for illumination, and/or energy conversion.

In the figures, the array of optical elements (e.g. lenses) is generally denoted **100**. According to some embodiments, the lenses are arranged such that focal axes of the lenses correspond to different columns and have respective fixed orientations to collect light from a point-like source (Sun). **Fig. 2** illustrates a top view of the optical array. The array **100** includes a plurality of lenses (*e.g.*, **102a, 102b, 102c, 102d**) for collecting electromagnetic radiation. In the array, the lenses (*e.g.*, **102a, 102b, 102c, 102d**) are arranged to form together an elongated structure extending along a long axis **104** of the respective side of the base surface. Each lens is configured for receiving electromagnetic radiation and for concentrating the radiation on a focal region thereof. The focal region may be within the lens or outside the lens. The concentrated radiation can be used for illuminating a desired space, and/or reach photovoltaic cells for conversion to electrical energy, and/or for heating a desired object. The geometry and material of the lenses are chosen so as to enable the lenses to compress (concentrate) light arriving at wide angles into the focal region of the lenses. The lenses may be made of transparent or semitransparent material, such as plastic, glass, injection molded polymer, poly (methyl methacrylate) (PMMA), Polycarbonate, Zeonex, or Topas. Examples of suitable lens geometries are described in international patent application No. PCT/IB2014/058005 of the same applicant hereof, the disclosure of which is incorporated herein by reference.

For example, the length of a region of the tilted arm occupied by the array of lenses (along X-axis, also shown as **104**) may be about 1,100 mm while the width of this region (along Y-axis) may be about 300 mm.

The lenses are arranged in columns substantially perpendicular to the long axis **104**. For example, the lenses **102b, 102c,** and **102d** belong to column **106**. Each lens has a respective focal axis defining the orientation of the lens. The lenses belonging to different columns have respective fixed orientations with respect to the long axis **104**. Optionally, the lenses on the same column have the same orientations of their optical axis with respect to the long axis **104.** In some embodiments, each group is formed by a single respective column, such that the focal axes of lenses belonging to different columns have respective different orientations. The array may be arranged to have a single column. The array may also be arranged in such a manner that each column (for example a zigzagging line in a hexagonal packaging) has a slightly varying angle, as described above. In an embodiment, the lenses face a common region located outside the array. Optionally, the common region is above a central section of the array. In such case, the lenses in the central section (along the long axis) have their focal axes substantially perpendicular to the long axis **104**, while the acute angle between the long axis **104** and the focal axis of a given illuminator decreases as the distance of the given lens and the central section of the array grows. It should be understood, although not specifically shown, that the orientation of the lenses located at different arms of the Λ-shaped surface may be symmetrically identical with respect to the plane of symmetry of the device.

In some possible embodiments the lenses **102** are implemented by parabolic lenses. In fact, parabolic lenses collect a higher portion of light entering as close as possible parallel to their optical axis. Parabolic lenses may be fitted with backwards-reflective coating, to improve the concentration capability of each lens. Thus, selecting the lens inclination/position in the focal plane, according to the incoming flux, improves the static collector's efficiency.

Reference is now made to **Figs. 1D** to **1F** showing schematically the simulation of the light propagation scheme onto and through the light collecting device **10** at different times of the day. This scheme demonstrates the "passive" operational mode of the device **10**, i.e. having no moving parts. The device **10** is intended to be positioned such that its plane of symmetry is substantially perpendicular to the Day-Night trajectory of the Sun movement, such that one of the sides **11p** and **12p** faces the East and the other of sides **11p** and **12p** faces the West.

This specific not limiting example corresponds to the device configuration with the lens arrays at the tilted arms of the Λ-shaped base surface. As shown in **Fig. 1D**, during the morning-to-noon hours, most of radiation **17** to which the device **10** is exposed is collected by reflections from reflecting surfaces **11a** and **11b** (and possibly also reflecting surface **11s**, if any) and passage of the so-reflected radiation through the aperture side **11p**. During the noon hours (**Fig. 1E**), both sides of the device **10** are substantially equally involved in the radiation collection: input radiation **17** is reflected from reflecting surfaces **11a** and **11b** (and possibly also surface **11s**) to pass through side/arm **11p** of the Λ-shaped aperture **14**, and is reflected from reflecting surfaces **12a** and **12b** (and possibly also surface **12s**) to pass through side/arm **12p** of the Λ-shaped aperture **14**, towards the receiving element(s) in the receiving plane **18**. During the afternoon hours (**Fig. 1F**), most of the input radiation is collected by reflectors **12a** and **12b** (and possibly also reflector **12s**) and the side/arm **12p** of the Λ-shaped aperture **14**.

As indicated above, the proper selection of the angle formed by the arms of the Λ-shaped aperture **14** in conjunction with the desired daily angle of effective light collection enables to improve the uniformity of the amount of collected radiation through the day hours. Preferably, such angle is about 60° for 8 hours of collection. In this connection, reference is made to **Fig. 1G**, showing the simulation results obtained by the inventor for the amount of light incident on / collected within the arm of the Λ-shaped structure. The graph corresponds to the half-day period, either before-noon or afternoon day part, during which one of the arms of the Λ-shaped structure is mainly involved in the collection of light. As shown, the graph, which is the time function of the light intensity is substantially smooth. In this simulation, the arm of the Λ-shaped structure was constituted by a receptor panel.

Reference is made to **Figs. 3A to 3C** illustrating schematically the configuration of the a light collecting device, generally denoted **20**, according to some embodiments of the invention. The device **20** is configured generally similarly to the above-described device **10**, namely includes two opposite sides **10a** and **10b** configured as configured as TTPTs with reflective facing surfaces, extending upwardly from the opposite sides of an Λ-shaped base side **14** which is formed a corresponding Λ-shaped aperture, i.e. has apertures tilted arms **11** and **12**, with properly selected angle (e.g. about 60 degrees) between the arms **11** and **12** in such a manner that the arms **11** and **12** are substantially perpendicular to the general propagation direction of incoming radiation at the beginning and end of the collection period. Optionally, the device **20** also includes auxiliary side reflectors **11s** and **12s** mounted at the free ends/sides of the base surface arms **11** and **12**.

The device **20** additionally includes a V-shaped mirror structure **19** mounted between the opposite sides **10a** and **10b** of the device. The V-shaped mirror structure **19** has tilted arms **11m** and **12m** extending from an apex portion **19x**. The outer surfaces of the V-shaped structure are configured as reflectors. The V-shaped structure **19** accommodated such that its tilted arms **11m** and **12m** partially protrude through the apertured arms **11** and **12** of the Λ-shaped base side **14**. The outer reflecting surfaces of the V-shaped structure **19** are at least partially directly exposed to incoming radiation thereby collecting radiation and directing collected radiation towards the one or more receiving elements (i.e. towards a receiving plane **18**). As better seen in **Figs. 3A** and **3C**, the V-shaped mirror structure **19** and the Λ-shaped aperture in the base side **14** are configured such that portions of the tilted arms of the Λ-shaped base side are directly exposed to incoming radiation, and portions of the outer reflecting surfaces of the tilted arms of the V-shaped structure **19** are directly exposed to the incoming radiation.

The V-shaped mirror structure **19** and the Λ-shaped aperture frame **14** may be accommodated substantially symmetrical, such that their apex portions are aligned being spaced from one another along the symmetry plane of the device.

Reference is made to **Figs. 3D** to **3F** illustrating schematically simulation results for the light propagation scheme utilizing the light collecting device **20** for respectively before noon, noon, and afternoon day hours. In this example, the light collecting device **20** is associated with a receiving element in the form of a reflecting tube **21**, which guides the received light towards a remote target (not shown). As shown in the figures, during the morning-to-noon hours (Fig. 3D), the part of the device **20** mainly involved in the collection of Sun radiation is the one facing the East and including truncated parabolic reflector pair **11a-11b**, the tilted arm **11** (aperture **11p**) of the Λ-shaped base side **14**, and the reflecting surface of the tilted arm **11m** of the V-shaped structure **19**. Incoming radiation is partially **17** incident on and passes through the part of the aperture arm **11**, and partially **17a** incident on and reflected from the outer surface of the tilted arm **11m**. Also, Sun radiation is incident on the truncated parabolic reflectors at the opposite sides, which is not specifically shown here. The radiation **17a** that have directly passed through the aperture **11p** propagates towards the reflecting tube **21**. The radiation part **17** that interacts with the tilted reflecting surface **11m**, either directly or while passing through the aperture **11p**, is reflected therefrom and, while partially passing back through the aperture **11p**, propagates towards the reflecting tube **21**.

As shown in **Fig. 3E**, during the noon hours, the parts of the device **20** mainly involved in the Sun light collection include the parts of the apertures **11p** and **12p** (which are not overlapped with the tilted arms of the V-shaped mirror **19**), as well as parabolic side reflectors and possibly also auxiliary reflectors.

As shown in **Fig. 3F**, in the afternoon hours, the West-facing part of the collecting device is mainly involved in the Sun light collection, in a manner similar to that described above with reference to Fig. 3D.

Fig. 5 illustrates simulation results comparing operation of the light collecting device **20** configured with the V-shaped mirror **19** and without such mirror (i.e. similar to device **10**) while being mounted at the entry of the reflecting tube **21**. Graphs **31-34** show the radiation flux collected throughout the day hours. Here, graphs **31**, **33** and graphs **32**, **34** correspond to the flux measurements at respectively the receiving plane **18** and at a 5 meter distance of the light propagation from the receiving plane through the reflecting tube (i.e. simulated for 5 meter reflecting tube output), and graphs **31** and **32** correspond to the device configuration without the V-shaped mirror, while graphs **33** and **34** correspond to the device with the V-shaped mirror.

Reference is made to **Figs. 4A to 4C** exemplifying a light collecting device **30** according to yet another embodiments of the invention. The device **30** is configured generally similarly to the above-described device **10**, namely includes two opposite sides **10a** and **10b** configured as configured as TTPTs with reflective facing surfaces, extending upwardly from the opposite sides of an Λ-shaped base side **14** which is formed a corresponding Λ-shaped aperture, i.e. has apertures tilted arms **11** and **12**, with properly selected angle (e.g. about 60°) between the arms **11** and **12** in such a manner that the arms **11** and **12** are substantially perpendicular to the general propagation direction of incoming radiation at the beginning and end of the collection period. Optionally, the device **20** also includes auxiliary side reflectors **11s** and **12s** mounted at the free ends/sides of the base surface arms **11** and **12**.

The device **30** additionally includes arrays **11v** and **12v** of mirrors accommodated within the tilted arms **11** and **12** of the Λ-shaped base side **14**. In this embodiment, the mirrors **11v** and **12v** are controllably pivotal with respect to the Λ-shaped base side **14**. More specifically, each mirror is pivotal / rotatable such that its reflecting surface changes an angular orientation with respect to the plane of symmetry of the device.

The movement of the mirrors **11v** and **12v** is controlled to provide proper dynamically changing orientation thereof. As shown, the mirrors at one tilted arms, e.g. mirrors **12v** at the tilted arm **12** may be oriented such that they reflect one part of the incoming radiation directly towards the receiving plane, while another part of the incoming radiation is directed towards the mirrors **11v** at the other tilted arm **11** by reflection from mirrors **12v** and/or passage through apertured spaces between locally adjacent mirrors **12v**. Mirrors **11v** further reflect this radiation towards the receiving plane.

The rotational/pivotal movements of the mirrors are synchronized in such a manner that the arrangement of mirrors (i.e. their angular orientation defining also the radiation transmitting spaces between them) provides most of radiation interacting with the mirrors' arrangements to be directed by them towards a relatively small / narrow radiation receiving region / target (typically 300 x 60 mm) **18**' on the receiving plane **18**. The receiving plane **18** is typically a base plane defined by the Λ-shaped structure of the base side.

It should be noted, although not specifically shown, that a plurality of radiation guiding elements may be provided being optically coupled to the target **18** for receiving the collected radiation and directing it to one or more remote targets. The receiving plane may thus be constituted by entry plane of such guiding elements, typically optical fibers. Also, lenses may be located at the entries of the fibers.

The geometrical shapes of at least some of the rotatable mirrors **11v** and **12v** may be adapted to provide desired radiation collection properties. As shown in **Figs. 4H and 4G**, the mirrors may include those having a substantially planar structure and/or a curved structure. Generally, the mirrors, or at least some of them, may be 180 degrees rotatable, or pivotal within smaller angles. In the latter case, only one surface of such structure needs to be reflective/mirror, as exemplified in **Fig. 4G**.

Generally, at least some of the rotating mirrors may be substantially planar structures, in which one or both of the opposite parallel surfaces are reflective (mirrors), and/or at least some of the rotating mirrors may have at least one curved (concaved) surface. In the latter case, only the concaved surface may be reflective.

Figs. 4D to 4F show simulation of the light propagation through the light collecting device **30**, during, respectively, before-noon, noon and afternoon day hours. The light propagation is illustrated in a self-explanatory manner, showing that all the mirrors are controllably rotatable to direct the incident radiation towards a target region in the receiving plane. During the beforenoon and afternoon hours (Figs. 4D and 4F), the mirrors **11v** and **12v** are differently oriented with respect to the symmetry plane such that during the beforenoon hours the East-facing arrangement of mirror array **11v** operates in both reflecting and transmitting modes, while the arrangement of the other mirror array **12v** operates only in the reflective mode. More specifically, mirrors **11v** are oriented such that they reflect the incident radiation towards the mirrors **12v** and spaces between them are provided for passing incident radiation towards the mirrors 12v, while the mirrors **12v** are oriented with no spaces between them (as they are relatively not exposed to direct incoming radiation) but reflect the radiation towards the receiving plane. During the afternoon hours (**Fig. 4F**), the operation of the mirrors arrays **11v** and **12v** is *vice versa*. During the noon hours (**Fig. 4E**), the mirrors **11v** and **12v** are arranged symmetrical with respect to the plane of symmetry of the device, and are oriented such that all mirrors reflect radiation towards the target, either directly or indirectly. More specifically, as shown in **Fig. 4E**, upper mirrors **11u** and **12u** (located closer to the apex portion of the Λ-shaped base side of the device) receive light with relatively small incidence angles, mirrors **11w** and **12w** within the acceptance wedge reflect incident radiation directly to the target (receiving region **18**), and mirrors **11q** and **12q** outside this wedge reflect indirectly, via reflection from so-called secondary mirror(s) of the opposite array.

CLAIMS:

1. A system for collecting electromagnetic radiation from a moving source, the system comprising:

an electromagnetic radiation collector device comprising a base surface, and two opposite sides extending from said base surface, said opposite sides comprising reflectors on their inner surfaces facing one another, wherein

said base surface is a curved surface of an Λ-shaped configuration defined by two tilted arms located in two intersecting planes and presenting radiation collecting surfaces of the device for collection of radiation and directing collected radiation to one or more radiation receiving elements.

2. The system of Claim 1, wherein the base surface is configured as an Λ-shaped frame defining said two tilted arms extending from an apex portion and being formed with apertures, thereby defining an Λ-shaped aperture.

3. The system of Claim 1 or 2, further comprising optical elements accommodated along said tilted arms of the base surface.

4. The system of any one of the preceding Claims, further comprising one or more guiding elements for guiding collected radiation to one or more remote targets.

5. The system of any one of the preceding Claims, wherein said opposite sides are configured as truncated tilted parabolic troughs (TTPTs) with the reflectors on their inner surfaces facing one another.

6. The system of Claim 5, wherein each of the inner surfaces is formed with a pair of the reflectors, forming together two symmetrical reflector pairs, extending from, respectively, the two arms of the Λ-shaped base surface, the reflectors of each pair facing one another.

7. The system of any one of the preceding Claims, wherein an angle between the intersecting planes in which said tilted arms are located is selected such that, when the device is put in operation, being exposed to radiation coming from the moving source, each of the two intersecting planes is oriented substantially normal to a general direction of propagation of the incoming radiation for a corresponding position of the source at the start and end of the collection period.

8. The system of Claim 7, for collecting solar radiation, wherein the angle between the two intersecting planes in which said tilted arms are located is about 60°, thereby optimizing collection of the solar radiation.

9. The system of any one of Claims 2 to 8, wherein the radiation collecting device further comprises a V-shaped structure having tilted arms extending from an apex portion, outer surfaces of the V-shaped structure being configured as reflectors, the V-shaped structure being accommodated such that the tilted arms thereof partially protrude through the apertured arms of the Λ-shaped base surface, and the outer reflecting surfaces of the V-shaped structure are directly exposed to incoming radiation thereby collecting radiation and directing collected radiation towards the one or more receiving elements.

10. The system of Claim 9, wherein the V-shaped structure and the Λ-shaped base surface are configured such that portions of the tilted arms of the Λ-shaped base surface are directly exposed to incoming radiation, and portions of the outers reflecting surfaces of the tilted arms of the V-shaped structure are directly exposed to incoming radiation.

11. The system of Claim 9 or 10, wherein the V-shaped structure is accommodated such that its apex portion is substantially aligned with the apex portion of the Λ-shaped base surface.

12. The system of any one of the preceding Claims, wherein said one or more of the receiving elements comprises a reflecting tubular member for guiding collected received radiation to one or more targets.

13. The system of any one of Claim 3 to 8, wherein said optical elements comprise arrays of lenses directing collected light towards one or more radiation receiving elements.

14. The system of Claim 13, wherein said one or more radiation receiving elements comprises one or more optical fibers.

15. The system of any one of the preceding Claims, wherein said light collecting device is configured as a passive collector for collecting radiation from the moving source while in a static mode of the light collecting device.

16. The system of any one of Claims 2 to 8, wherein the radiation collecting device further comprises arrays of mirrors extending along the aperture tilted arms of the Λ-shaped base surface, each of said mirrors being mounted for a pivotal movement with respect to the frame of the Λ-shaped base surface, for collecting incoming radiation incident onto the tilted arms and directing collected radiation to the one or more receiving elements.

17. The system of Claim 16, the pivotal movements of the plurality of mirrors are controllably operable to enable the mirrors at one of the tilted arms to reflect a part of the incoming radiation directly towards the one or more of the receiving elements, while another part of the incoming radiation is directed towards the mirrors at the other tilted arm to be reflected towards the one or more of the receiving elements.

18. The system of Claim 17, wherein the pivotal movements of the plurality of mirrors are controllably operable such that said another part of the incoming radiation partially propagates through aperture spaces between locally adjacent mirrors at said one tilted towards the mirrors at the other tilted arm and is partially reflected by the mirrors at said one tilted arm towards the mirrors at the other tilted arm.

19. The system of Claim 18, further comprising a plurality of radiation guiding elements optically coupled to the receiving elements for receiving the collected radiation and directing it to one or more targets.

20. The system of claim 19 wherein at least some of the rotating mirrors are configured as a substantially planar structure having one or both reflective surfaces.

21. The system of claim 19 or 20, wherein at least some of the rotating mirrors are configured with at least one of its surfaces being concaved, at least said concaved surface being the reflective surface.

22. The system of claim 21, wherein said at least some of the mirrors have a substantially concave geometry.

23. An electromagnetic radiation collector device comprising:

a base surface being a curved surface of an Λ-shaped configuration defined by two tilted arms located in two intersecting planes and presenting radiation collecting surfaces of the device for collection of radiation and directing collected radiation to one or more radiation receiving elements; and

two opposite sides extending from said base surface, said opposite sides comprising reflectors on their inner surfaces facing one another, for collecting incoming radiation and reflecting collected radiation towards the one or more radiation receiving elements.

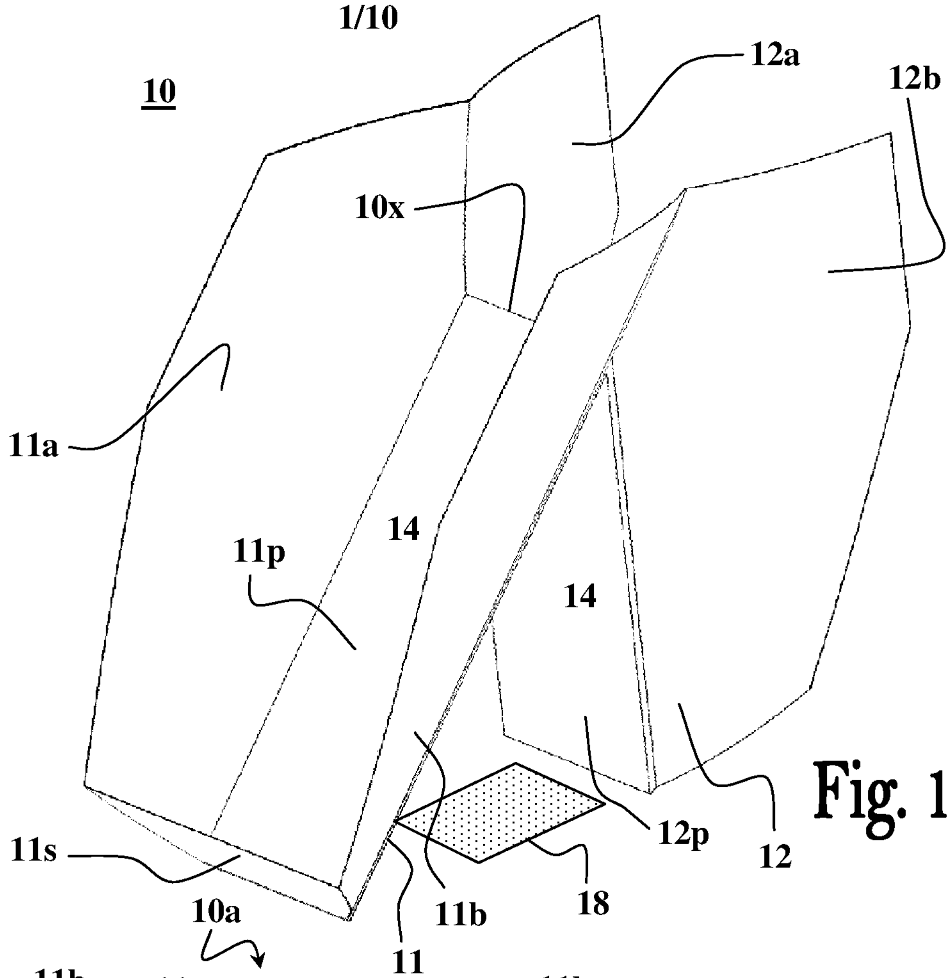


Fig. 1A

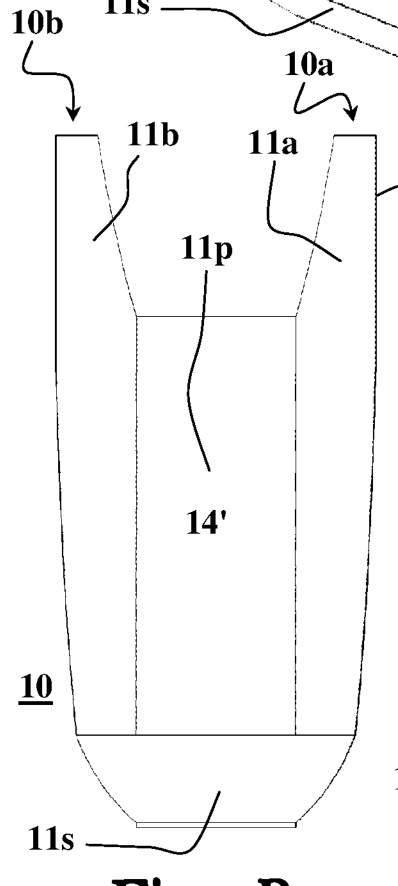


Fig. 1B

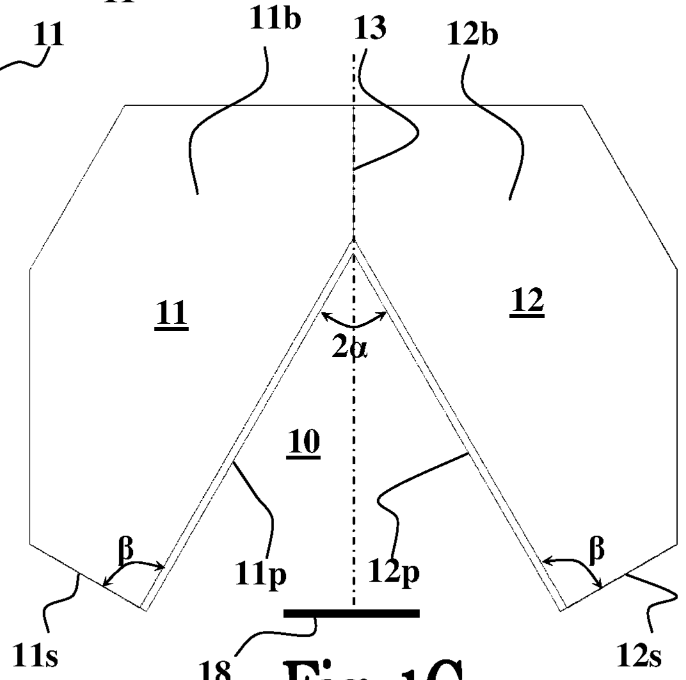


Fig. 1C

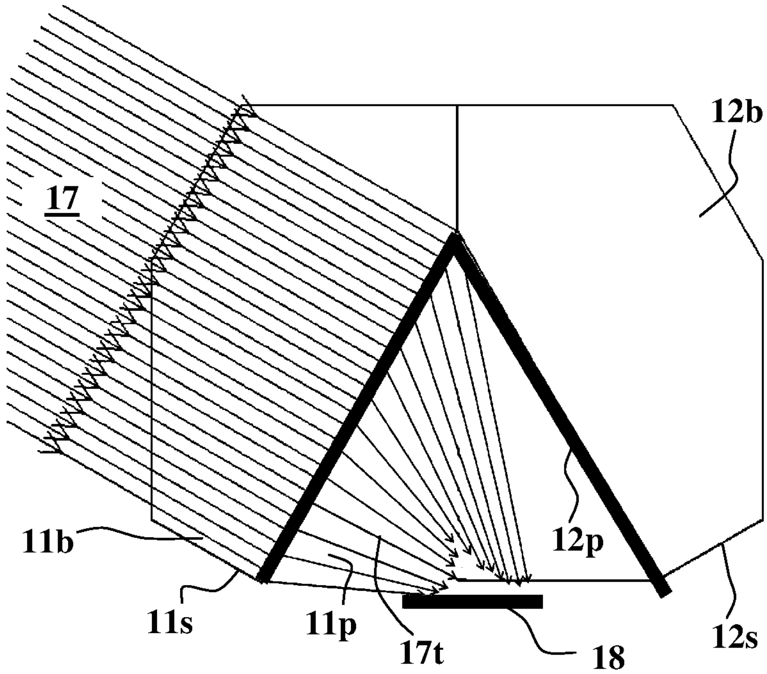

17
12b
11b
12p
11s
11p
17t
18
12s

Fig. 1D

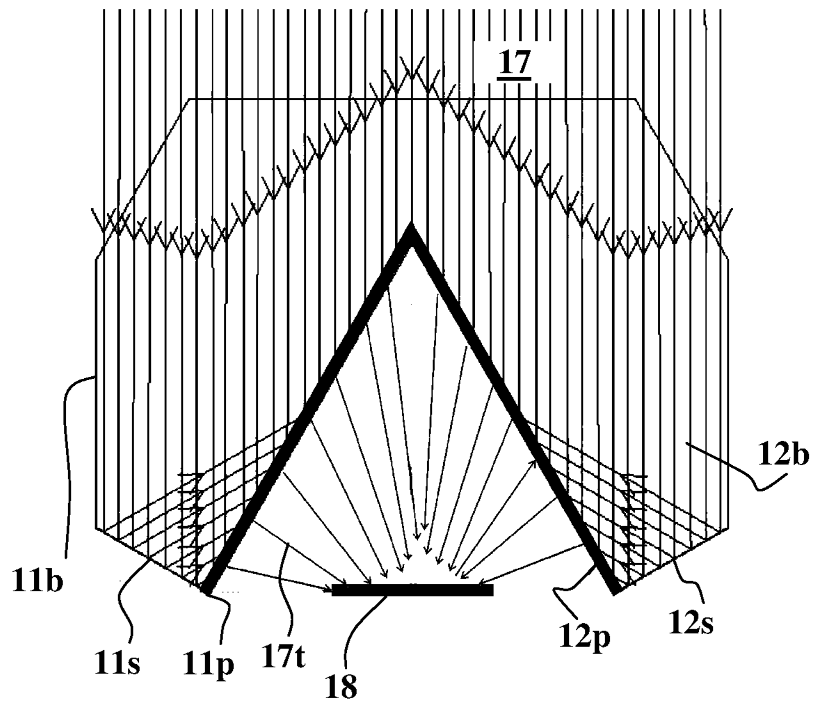

17
12b
11b
11s
11p
17t
18
12p
12s

Fig. 1E

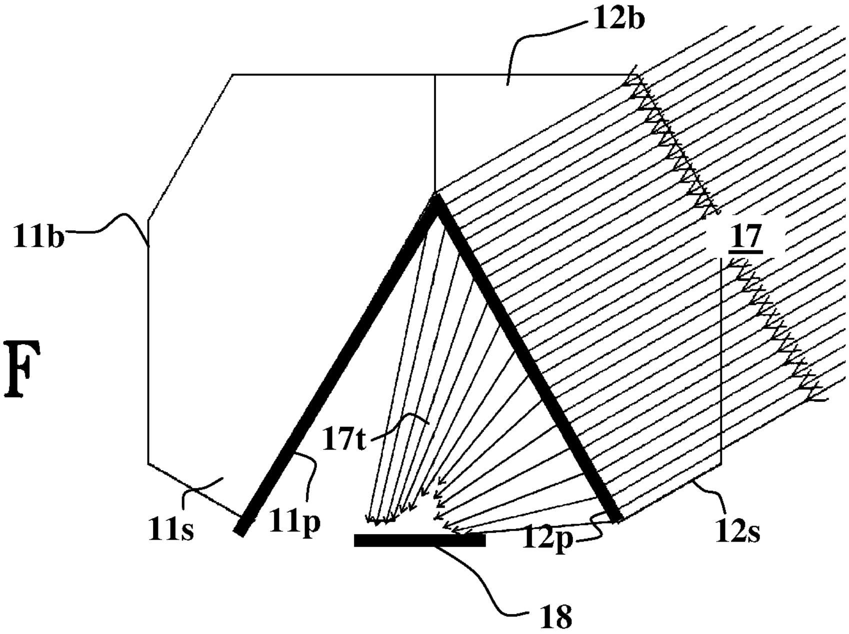

12b
11b
17
17t
11s
11p
12p
12s
18

Fig. 1F


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Light Collected
0
15
30
45
60
Daily Angle

Fig. 1G

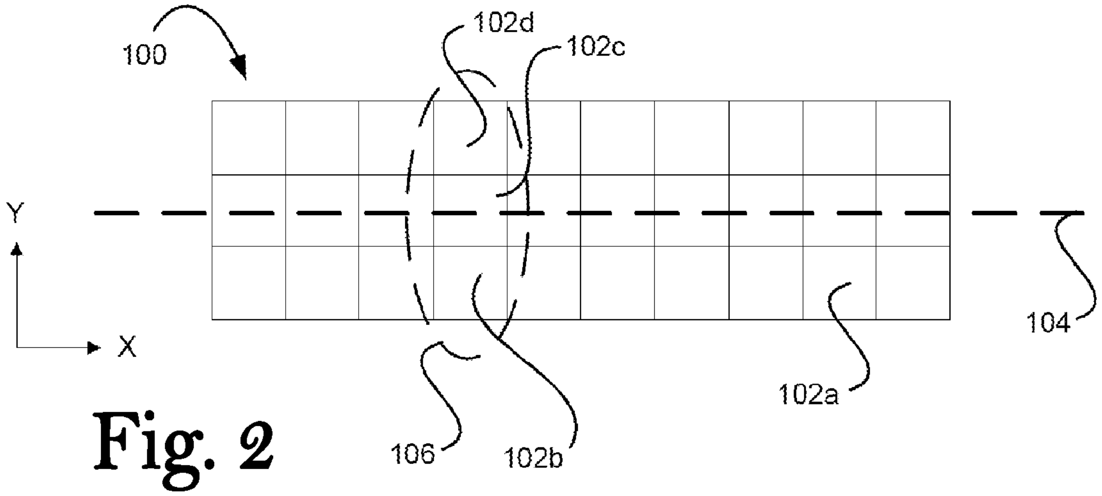


Fig. 2

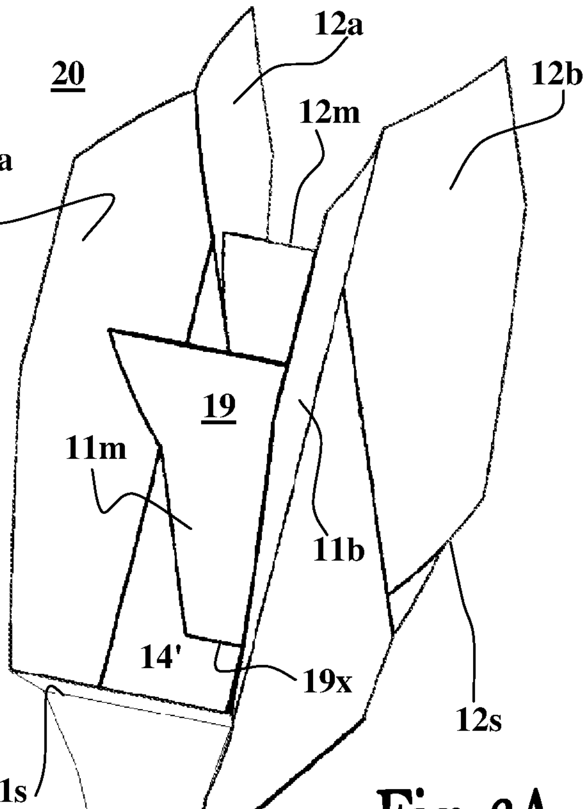


Fig. 3A

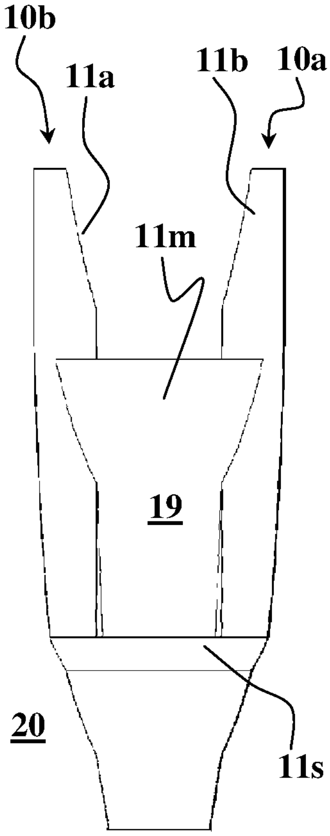


Fig. 3B

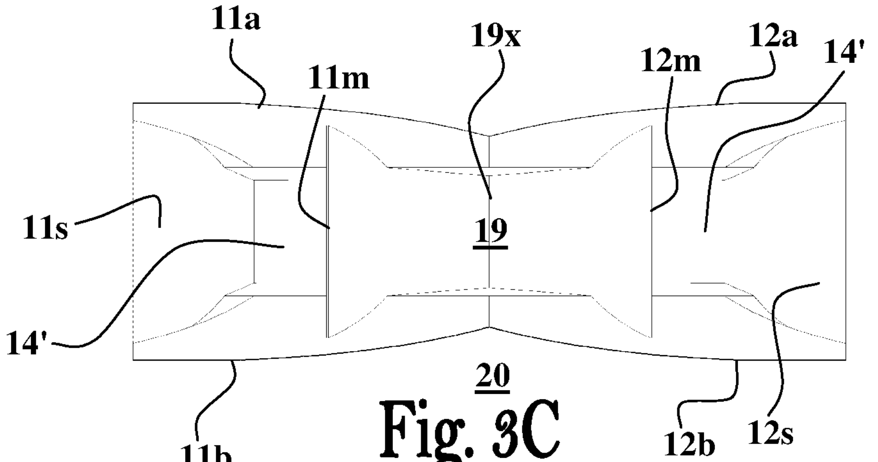
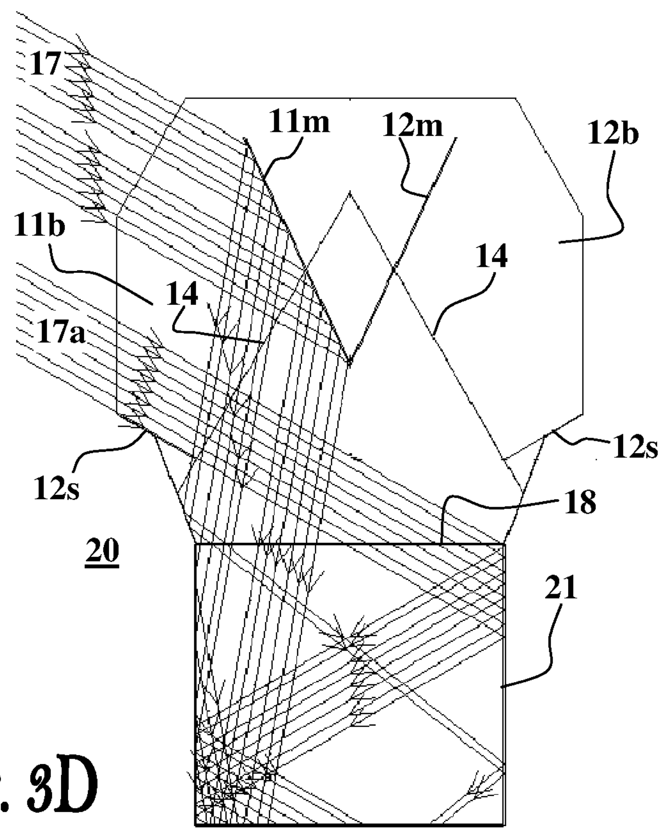

11a
19x
12a
11m
12m
14'
11s
19
14'
20
11b
12b
12s

Fig. 3C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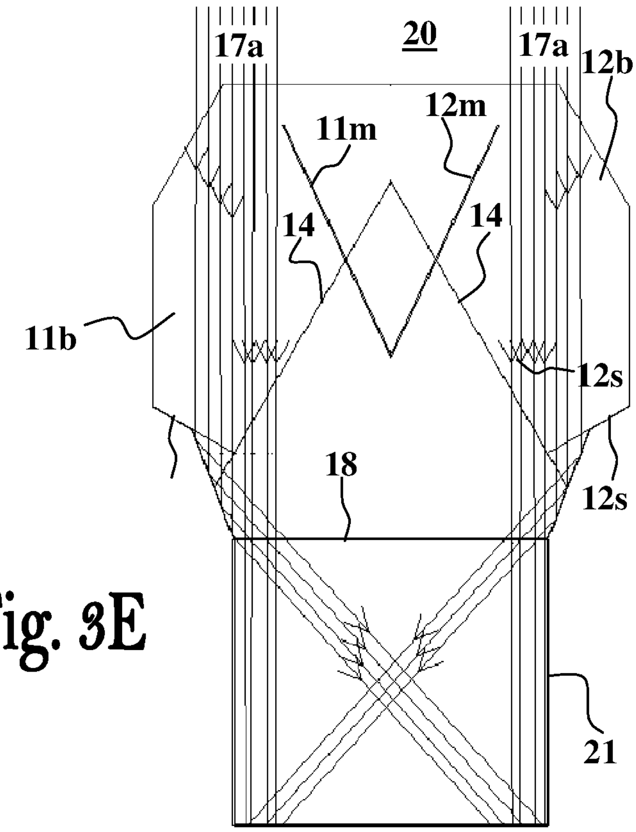
11m
12m
12b
11b
14
14
17a
12s
12s
18
20
21

Fig. 3D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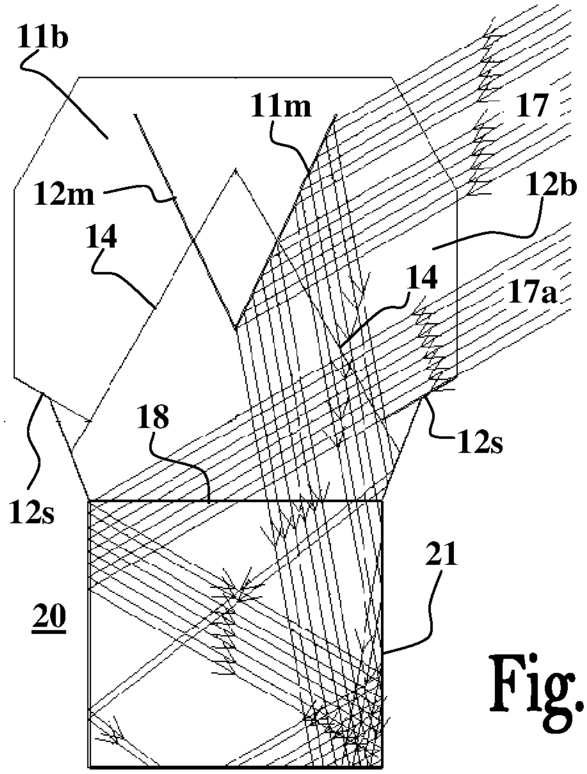
17a
17a
12b
12m
11m
14
14
11b
12s
18
12s
21

Fig. 3E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17
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12b
14
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17a
18
12s
12s
21
20

Fig. 3F

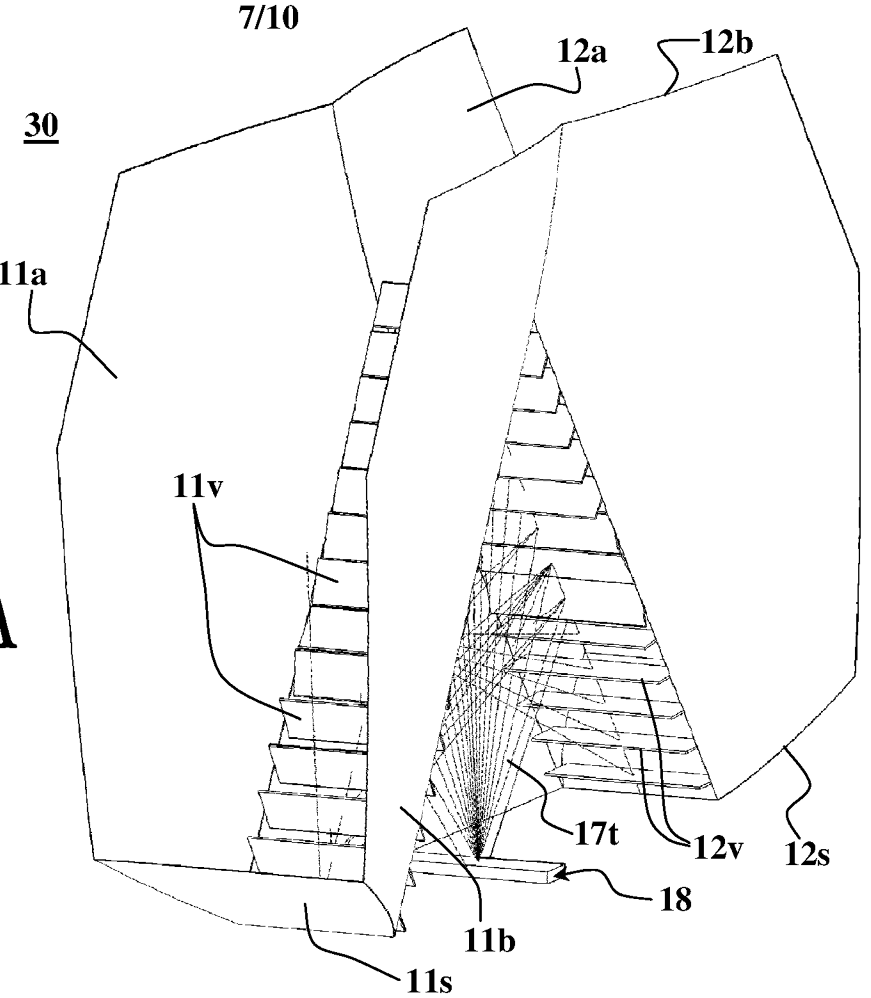

30
11a
12a
12b
11v
17t
12v
12s
18
11b
11s

Fig. 4A

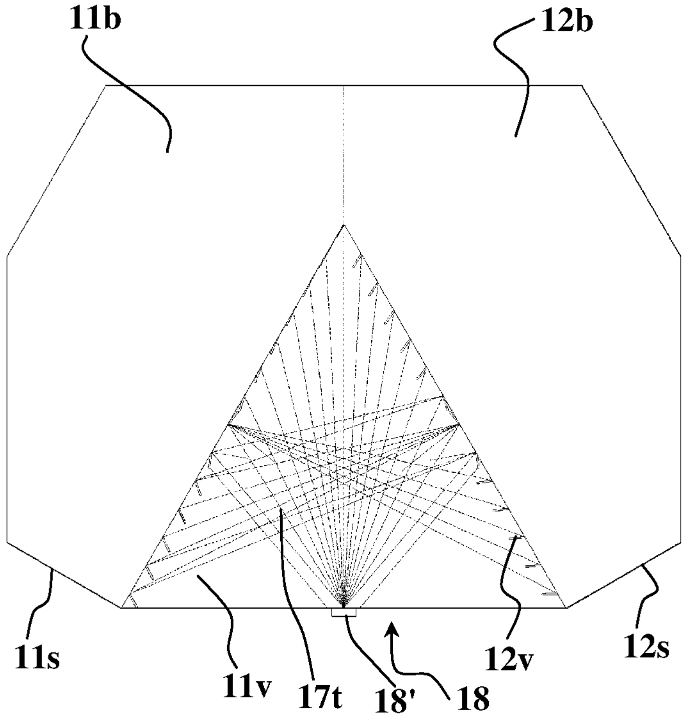

11b
12b
11s
11v
17t
18'
18
12v
12s

Fig. 4C

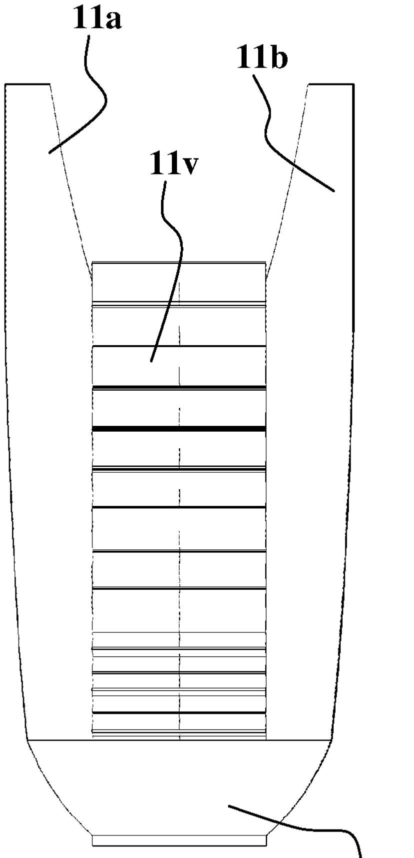


Fig. 4B

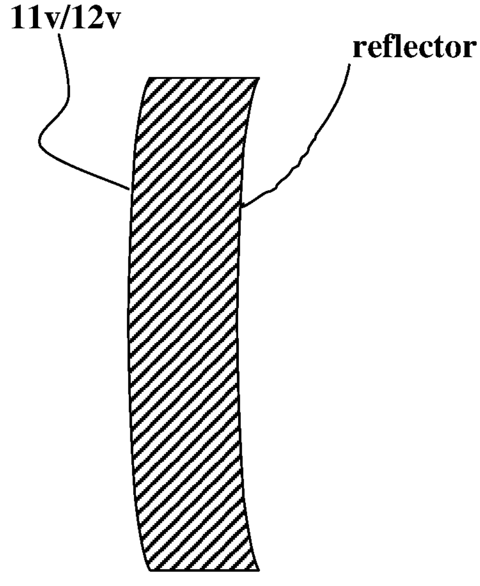


Fig. 4G

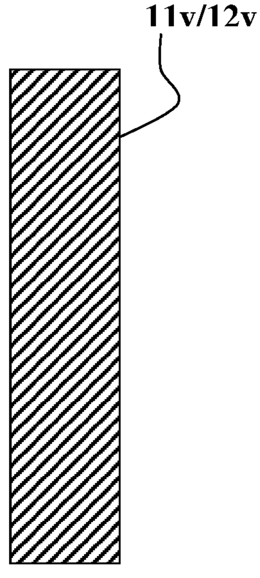


Fig. 4H

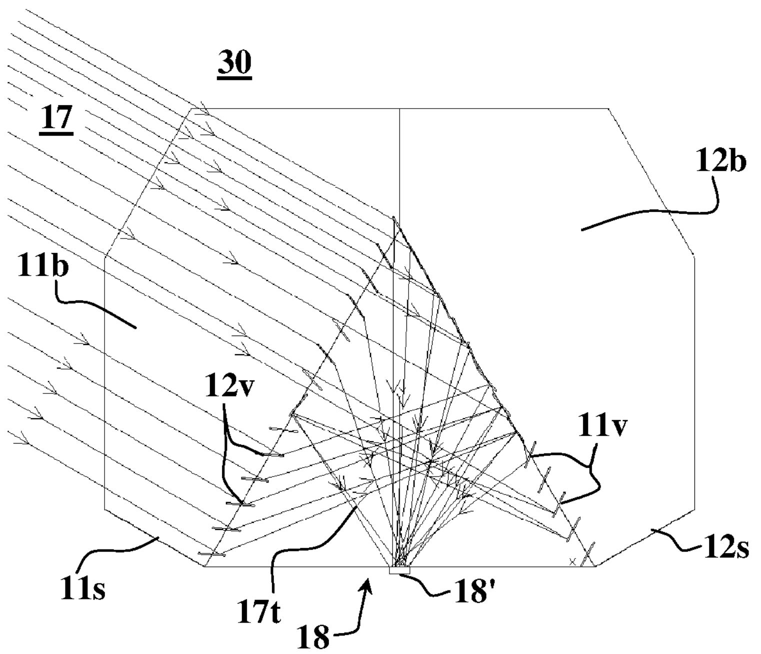

30
17
12b
11b
12v
11v
11s
17t
18
18'
12s

Fig. 4D

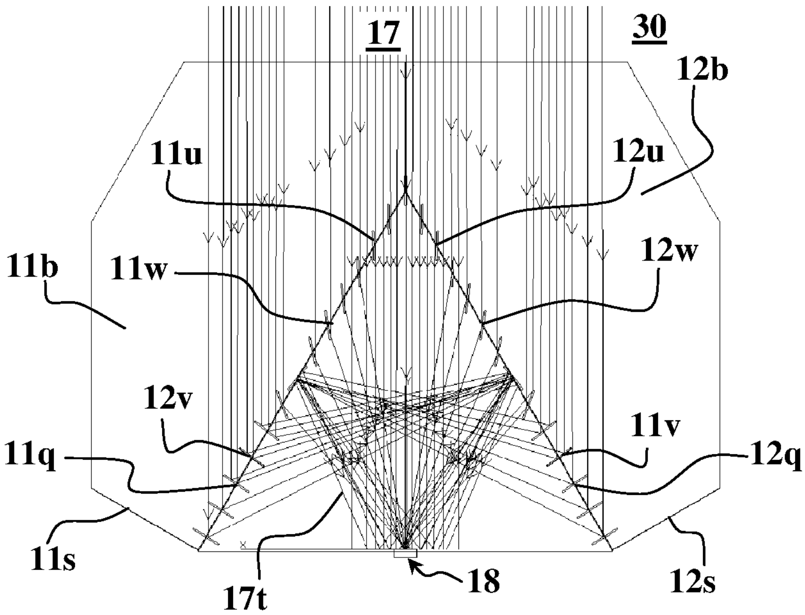
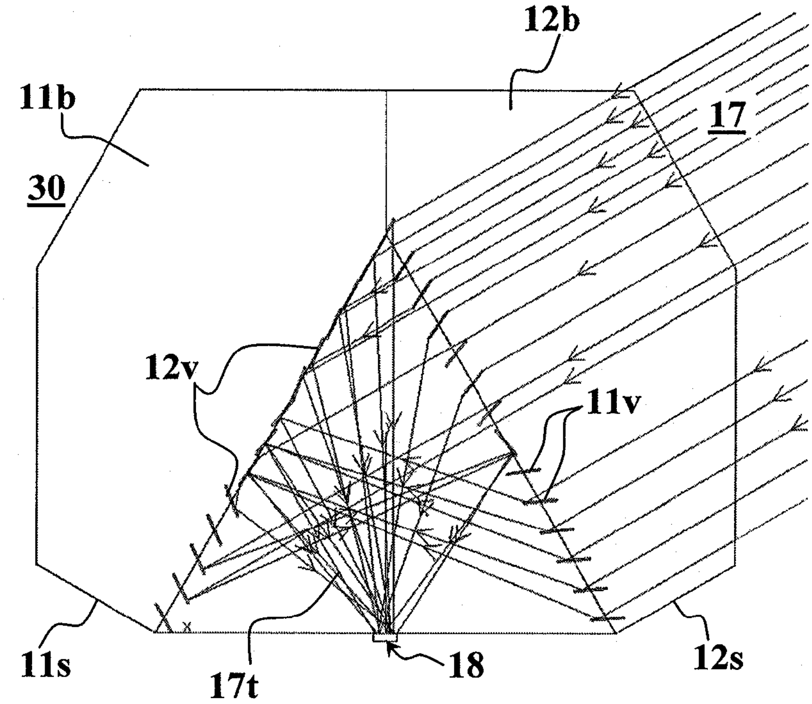

17
30
12b
11u
12u
11w
12w
11b
12v
11v
11q
12q
11s
17t
18
12s

Fig. 4E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11b
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30
12v
11v
11s
17t
18
12s

Fig. 4F

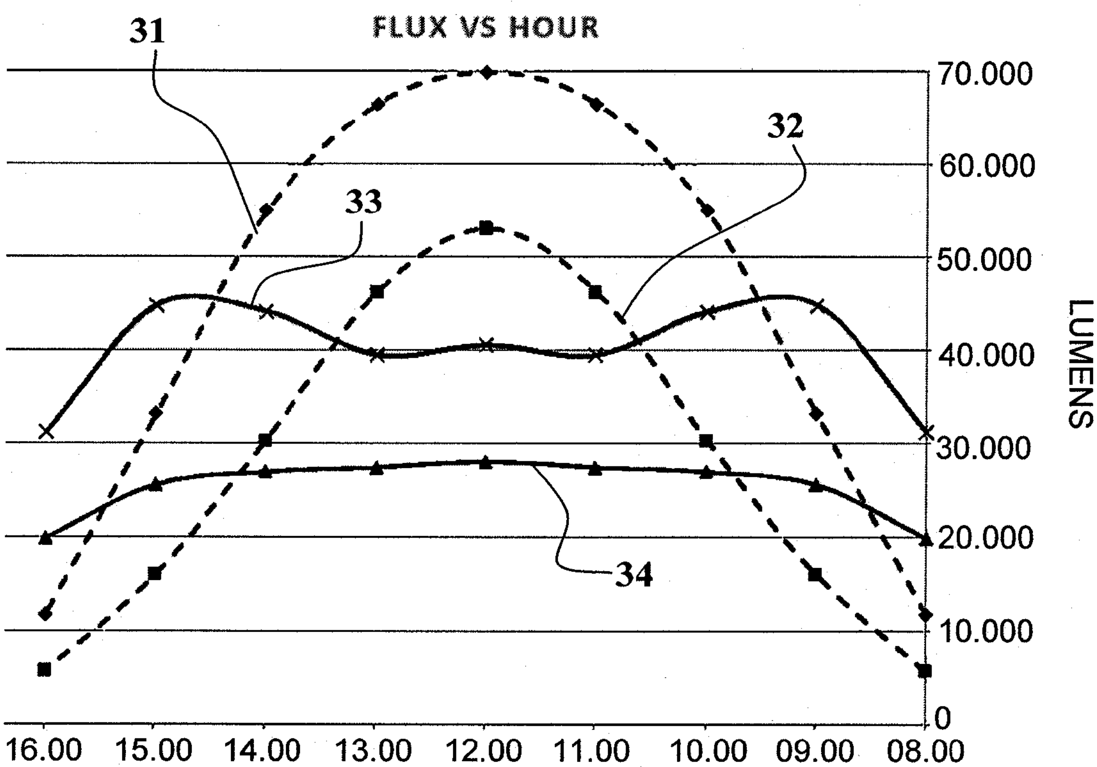
FLUX VS HOUR
31
32
33
34
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0
LUMENS
16.00
15.00
14.00
13.00
12.00
11.00
10.00
09.00
08.00

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2014/050618

A. CLASSIFICATION OF SUBJECT MATTER
INV. F24J2/06 F24J2/18
ADD.

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)
F24J 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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	WO 2007/026311 A1 (VANDERSTRAETEN LUC [BE]; LIPPENS CHRISTIAN [BE]) 8 March 2007 (2007-03-08) abstract; figures -----	1-4,23
Y	US 2001/006066 A1 (CHERNEY MATTHEW [US] ET AL) 5 July 2001 (2001-07-05) cited in the application paragraphs [[0002]], [[0003]], [[0049]] - [[0052]], [[0060]]; figures -----	1-4, 12-15,23
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 February 2015	06/03/2015

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, Fax: (+31-70) 340-3016	Oliveira, Casimiro

2

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2012/097260 A2 (CEWA TECHNOLOGIES INC [US]; FANGMAN JOHN S [US]) 19 July 2012 (2012-07-19) abstract; figures -----	14
A	WO 94/06046 A1 (UNIV AUSTRALIAN [AU]; RODE ANDREI VLADIMIROVICH [AU]) 17 March 1994 (1994-03-17) abstract; figures -----	16-22
A	US 2002/075579 A1 (VASYLYEV SERGIY VICTOROVICH [US] ET AL) 20 June 2002 (2002-06-20) paragraphs [[0036]] - [[0051]]; figures -----	16-22

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2014/050618

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