

ELECTROMAGNETIC RADIATION COLLECTION DEVICE

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates generally to electromagnetic radiation collection.

5 Related Art

[0002] The collection and concentration of electromagnetic (EM) radiation is well known. Radio waves are typically collected and concentrated using parabolic dishes. Solar radiation is collected and concentrated using parabolic mirrors or lenses. The former devices suffer from requiring a relatively
10 high height-to-collection area ratio and the latter being expensive, heavy and fragile. Both these types of device also suffer from the requirement to track the source in order to function properly.

BRIEF SUMMARY OF THE INVENTION

[0003] The invention seeks to overcome at least some of the
15 deficiencies in the prior art by providing an EM radiation collection device which can cover a large area, have a low profile, have no requirement to track the source and be constructed so as to be relatively light and inexpensive.

[0004] There is a pressing need to be able to generate energy from renewable energy sources. Solar energy is one such resource which has potential
20 to be exploited. Conventional devices for collecting radiant energy to generate energy in a useful form suffer from a high capital cost and/or the inability to generate high enough temperatures to be useful for many applications. The

invention seeks to overcome these deficiencies in the prior art by providing a radiant energy concentration device that can gather energy from a relatively large area and concentrate it onto a small target area. The device is relatively inexpensive to produce, can be light in construction and has the potential to
5 generate high target temperatures or, in the case of conversion to electricity by photovoltaic cells, require only a small area of cells, thus saving cost.

[0005] The invention is directed to a device that can cover relatively large collections areas at relatively low cost, does not necessarily require materials of particular refractive index and can be made of light construction.

10 [0006] The invention is capable of being less massive and having a lower profile than prior art concentration devices. It is also capable of having high concentration factors. It is suitable in any application where it is desired to collect and concentrate EM radiation, with particular utility in the collection and concentration of solar radiation. In the case of solar radiation, a device in
15 accordance with the invention can be used in conjunction with photovoltaic cells or to heat a fluid to harness the solar energy for a desired purpose. In the case of radio frequency radiation, the subject device could be used to collect, focus and tune the radiation.

[0007] An example of a device in accordance with the invention is an
20 electromagnetic radiation collector that includes a channeling area having an entry end for receiving the electromagnetic radiation, an exit end, and at least one reflective wall between the entry end and the exit end; and a radiation collection element near the exit end of the channeling area, the radiation collection element being adapted to collect the electromagnetic radiation.

[0008] Another example of a device in accordance with the invention is a control mechanism for a radiation collector where the radiation collector is adjustable to track a moving radiation source and where the control mechanism comprises a first sensor to monitor the ambient radiation conditions and a second
5 sensor to monitor the output of the radiation collector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The foregoing and other features and advantages of the invention will be apparent from the following, more particular description of
10 preferred embodiments of the invention, as illustrated in the accompanying drawings wherein like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements.

[00010] Figure 1 shows an example of a channeling area;

[00011] Figure 2 shows an example of a device having multiple
15 channeling areas;

[00012] Figure 3 shows a cross-sectional view of an array of channeling areas;

[00013] Figure 4 shows a cross-sectional view of a different array of channeling areas;

20 [00014] Figure 5 shows a first embodiment of the invention;

[00015] Figure 6 is a cut-away view of the embodiment shown in Figure
5;

[00016] Figure 7 shows a second embodiment of the invention;

[00017] Figure 8 shows a side view of the embodiment shown in Figure 7;

[00018] Figure 9 shows an alternate embodiment related to the embodiment shown in Figures 7 and 8;

5 [00019] Figure 10 shows a third embodiment of the invention;

[00020] Figure 11 shows an alternate embodiment related to the embodiment shown in Figure 10; and

[00021] Figure 12 shows a fourth embodiment of the invention.

10 DETAILED DESCRIPTION OF THE INVENTION

[00022] An exemplary embodiment of the invention is shown in the drawings and described herein.

[00023] An example of a device in accordance with the invention has an assembly of channeling areas wherein the EM radiation can be internally reflected within the channeling areas. In one embodiment, the channeling areas are constructed such that at least some of the EM radiation that enters a broad end of the channeling areas will be steered within the channeling areas to exit a narrow end of the channeling areas. The broad ends of the channeling areas are assembled to form a surface that is herein termed the collection surface. EM radiation falls on the collection surface and enters the broad ends of the channeling areas. The EM radiation is reflected from the walls of the channeling areas so as to be directed to exit from the narrow end of the channeling areas. This is achieved by ensuring that at each reflection point the angle of incidence of the EM

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radiation to the reflecting surface is less than 90° . A method for ensuring that this is the case for a wide arc of angles of the EM radiation incident on the collection surface is to shape the channeling areas such that they are much longer than they are broad at their broad end. This provides, in some embodiments, a small angle of taper of the walls of the channeling area thus fulfilling the reflection angle requirements for a broader range of incident EM radiation angles. The ratio of length of the channeling area to the breadth of its broad end should desirably be between 2 and 1000, more preferably between 5 and 100, and most preferably between 10 and 50. Figure 1 shows an example of a single channeling area and a typical path that EM radiation might take within the area.

[00024] The channeling areas can be made of solid material that is capable of transmitting the EM radiation that is to be collected and concentrated and with walls that reflect the EM radiation back into the channeling area. In another embodiment of the invention, the channeling areas are formed as cavities, where the walls of the cavities are capable of reflecting the EM radiation back into the cavity.

[00025] In one embodiment of the invention, the narrow ends of an assembly of channeling areas are gathered together into an area that is smaller than the area of the broad ends of assembled channeling areas. In such an example, the EM radiation collected over the broad ends area is concentrated into the narrow ends area. An example of this embodiment is shown in Figure 2.

[00026] In some embodiments of the invention, the channeling areas are tapered in only one dimension, that is they take the form of tapered slots. In other embodiments, the channeling areas are tapered in two dimensions so that they take

the form of tapered rods, where the rods can be of any cross-sectional shape that is suitable for packing together at high density. Examples of such shapes are circles, squares, rectangles, triangles and other multi-sided polygons.

[00027] When the channeling areas take the form of tapered rods, to aid
5 in accommodating the curvature of the rods, maintain a high packing density for the broad ends of the channeling areas and enhance the strength of an assembly of the channeling areas, the channeling areas can be assembled such that each channeling area is staggered relative to its neighbors. In a particular embodiment of this aspect of the invention, rows of channeling areas are assembled such that
10 the channeling areas in each row are offset from the row in front such that the narrow end of each channeling area is between the narrow ends of the neighboring channeling areas in the rows immediately in front of and behind the subject row. By assembling the channeling areas in this way it is possible for the narrow end of each channeling area to curve into the space between the neighboring channeling
15 areas in the row in front of it. This allows the channeling areas to be curved while maintaining high packing density of the broad ends of the channeling areas.

[00028] It is desirable to maintain a high packing density of the broad ends of the channeling areas at the collecting surface so that the highest fraction of the EM radiation incident on the collecting surface enters a channeling area and is
20 not reflected back.

[00029] In one embodiment of the invention, the channeling areas are circular in cross-section and the broad ends are assembled in a packing arrangement as is shown in Figure 3, where a top view of the assembled rows of the broad ends of the circular channeling areas are shown offset from one another.

Triangles are superimposed on the view to show the relationship of the centers of the circular ends. This arrangement increases packing density and allows space for the channeling areas to be curved as disclosed above. With this arrangement, a maximum fraction of $\pi/2\sqrt{3}$ (approx. 90%) of the incident radiation is collected.

- 5 In a particular embodiment of this aspect of the invention, channeling areas with a square or rectangular cross-section are used. A top view of this arrangement is shown in Figure 4. With this shape of channeling area, the broad ends of the channeling areas can be packed such that close to 100% of the incident radiation enters the channeling areas and is thus collected. Note that in the embodiment
- 10 shown in Figure 4 it is possible, but not necessary, for the channeling areas to be of rectangular cross-section down their full length. For example, the channeling areas may be square or rectangular at the collecting surface but then transition to a circular area as we move down the channeling area toward its tip.

- [00030] Devices in accordance with the invention are useful in
- 15 applications where EM radiation concentration devices have been used in the prior art, in particular solar radiation and radio frequency radiation. Examples of such uses particularly relevant to the collection and concentration of solar radiation are to heat fluid circulating through a tube or pipe, to generate electricity directly using photovoltaic cells or to produce hydrogen from water. Note that the
- 20 invention has particular utility in the application of producing electricity using photovoltaic cells as it allows the light to be collected from an extended area using the relatively inexpensive device of the invention and concentrate it on to a relatively small area of the relatively expensive photovoltaic cells. This potentially allows electricity to be generated at lower capital cost. Also, this

device addresses deficiencies in the conventional art when attempting to use a concentrator with photovoltaic cells. Apart from expense and weight, the conventional devices suffer from relatively low concentration factors of typically less than 10 and the problem of the photovoltaic cells overheating and becoming
5 less efficient.

[00031] A low profile collector and concentrator is desirable in applications for radio frequency (RF) radiation. In these applications, the device could be used to focus the RF radiation onto an RF receiver. Also, by careful choice of the dimensions of the channeling areas, the subject device could be used
10 to tune the collected RF radiation to a frequency that can be received more easily by a receiver. For example, the device can be used to tune the RF radiation to a higher frequency, which requires a smaller and more easily implemented receiver.

[00032] The subject devices can be made by any suitable method. The channeling areas can be solid elements transmissive of light and made from
15 materials such as polymers or glass. For these solid elements, the walls of the elements can be coated with a reflective material or the refractive index of the material can be such that in most cases the incident angle of the EM to be reflected to the wall of the element exceeds the critical angle so that total internal reflection occurs. This embodiment has potential advantages in ease of fabrication but can
20 also tend to be heavy. This embodiment could be constructed by manufacturing many elements and assembling them into arrays as disclosed above.

[00033] A particular embodiment is one where the channeling areas are cavities formed in a monolithic block made of metal or polymer material. This may be somewhat harder to fabricate but will be lighter. A method of

manufacturing this embodiment is to form an assembly of curved elements, for example tapered elements, from a malleable material such as copper or nickel. The assembly can be one of individual elements or of rows of elements formed into combs where each tapered element is a "tooth" of the comb. Each comb
5 forms a row or portion of a row of the elements and the "teeth" of the combs of successive rows in the assembly are staggered to give the arrangements shown in Figures 3 or 4. Before being assembled into an array, the elements can be straight or already curved. If the elements are straight, a bar can be passed over the assembly of the narrow ends of the elements as a convenient method of
10 introducing the desired curvature. The assembled elements can be held in their assembly by being clamped into a frame or other similar device. The curved assembled elements, in conjunction with side walls and, if applicable, a top and/or base, can then be used as a mold for the final monolithic shape. The shape with the desired assembly of cavities can be molded by any applicable method. It may
15 be cast by pouring polymer into the mold and letting it set or by injection molding techniques. In this process it is desirable to first coat the mold with a suitable release agent to facilitate removal of the mold elements from the cast shape. After the cast shape is set the mold elements can be removed. This can most easily be achieved by first removing the cast shape from the mold side walls, top and/or
20 base then unclamping the assembly of elements and removing them separately or in groups as is most convenient and practical. Note that in most cases the elements will need to be straightened somewhat to be withdrawn from the cavities so it is desirable that the material from which the tapered elements are made be malleable so that in can undergo the straightening process without breaking or

distorting the shape of the cavity from which it is being withdrawn. This process results in a cast shape that contains an assembly of densely packed curved, light guiding cavities, wherein the broad ends of the cavities all open onto one face of the shape and the narrow ends of the cavities all open on to a different face of the shape.

[00034] If the shape is not cast from an intrinsically reflective material such as metal or metal filled polymer, then the external faces of the shape and/or the walls of the cavities can to be coated with a reflective layer. For polymer material this is most easily achieved with an electroless metal deposition process such as electroless chrome or nickel deposition. A further transparent coating could be applied over the reflective coating if desired to protect the reflective coating.

[00035] An alternative embodiment for creating an assembly of channeling areas for collecting the EM radiation is to use a series of mirrors that focus the light into a series of spots or strips. In the case of a strip, the optimal mirror shape is parabolic in the plane of the strip and normal to it. In the case of spots, the mirror is optimally a parabolic dish. According to this embodiment, the channeling areas are formed by the space between the adjacent mirrors where, rather than the adjacent mirrors forming a tapering space, the tapering space is defined by the tapering shape of the radiation beam reflected from the rear wall of the channel. Also, the exit to the channel according to this embodiment is the strip or spot which is the focal point of the rear mirror. Therefore, in this embodiment it is not necessary for the walls of the channel to taper in order for the radiation beam to be tapered. This has advantages in flexibility of design and in minimizing

the number of reflections that the radiation undergoes before exiting the channel.

The strips or spots that form the exit to the channel are arranged to be at the focal line or point of the mirror such that EM radiation reflected off the mirror is substantially concentrated onto them. To allow for different angles of EM

5 radiation incident on the mirrors, the mirrors can be rotated about their focal line or point such that the focus of the light remains co-incident with the strips or spots. A control mechanism can perform the rotation whereby a signal, which could be the output from an EM radiation target or from a separate sensor, is monitored and the rotation of the mirrors performed so as to maximize the amount

10 of EM radiation impacting the target. A particularly preferred embodiment of sensor configuration is where the output of a separate sensor can be used in combination with the output of the radiation target, or a sensor that correlates to the output of the radiation target, to achieve the control. According to this embodiment a separate sensor is configured to respond to the ambient conditions

15 with the target sensor output responding to the focusing configuration of the mirrors. In the example of when PV cells form the target to generate electricity from solar radiation, a separate light sensitive sensor would be mounted away from the mirrors such that it monitored the ambient incident radiation on to the panel. This sensor would for example detect a change in the radiation level due to

20 a cloud or other object passing between the sun and the panel. The target sensor on the other hand would monitor the output of the light impinging on to the target PV cells. So, the control mechanism would monitor both the ambient and the target sensor and if the output of the two sensors varied in a similar way over time, then the control system would take no action as it would assume that the change in

output of the target was due to a change in the ambient conditions. If, on the other hand, the target sensor output changed in a different way to the ambient sensor output then the control system would move appropriately to maximize the output of the target sensor.

5 [00036] The mirrors may have a rear reflecting surface that reflects EM radiation onto one of the focusing mirrors.

 [00037] An assembly of parabolic louvers that can be made to rotate about their focal line have been described above. The focal line of each louver impinges upon a receiving area in which one or more receiving elements are
10 placed. The receiving elements can be in the form of openings into a concentration chamber, as disclosed in co-pending application PCT/IB2005/003838, herein incorporated in its entirety by reference. Alternatively, the receiving elements may be adapted to directly convert the incident radiation. The receiving elements may be adapted to convert the radiation
15 into electrical energy, for example photovoltaic cells could be placed in the receiving areas. Alternatively the receiving elements maybe adapted to collect the thermal energy, thus transferring heat to a fluid medium whereby the energy can be utilized elsewhere. In the embodiment where PV cells are used as the receiving elements it is desirable to be able to cool the PV cells for their efficient operation.
20 According to the current invention, cooling can be provided by having heat dissipation areas between the areas of PV cells. Since these in-between areas are shaded from the incident EM radiation by the parabolic louvers they can readily be adapted to radiate heat efficiently, for example by coating them with a radiating coating such as a black coating. In an alternative embodiment, a fluid layer can be

placed in a space below the plate containing the PV cells and in thermal contact with the back of the PV cells. The fluid can be permanently contained within the space and allowed to circulate within the space, such that the fluid aids in the transfer of heat from the PV cells to the heat dissipation areas. In a further
5 embodiment the fluid can be allowed to, or made to, flow through the space beneath the PV cells wherein the heat is dissipated external to the plate containing the PV cells. Preferably, the PV cells could be connected in series to a sufficient extent to obtain the output voltage that is desired.

[00038] An advantage of particular embodiments of the present
10 invention is that there is space between the lines of PV cells. This allows room for the rows of cells to be connected in the desired fashion. For example each row of cells, or a portion of each row of cells under a particular focal line can form a series element. An electrically conductive connection band can be placed in the spaces between each row of PV cells wherein the connection band extended
15 beneath one row of PV cells to effect electrical connection to the underside of that row of cells and a series of thin connection bands extended across the upper surface of the second row of PV cells and out to make connection with the connection band between the two rows of PV cells. Alternative methods for forming an electrical connection to the upper surface of the PV cells are discussed
20 later in this disclosure. Preferably at least the lower connection bands would be made of material of high electrical and thermal conductivity, for example copper or aluminum. The bands can be a single band made of one material or can be a composite band made of one or more materials. For example, the portion of the band that extends under the row of PV cells can be made of aluminum and the

portion of the band between the rows of PV cells can be made of copper or another suitable material. Preferably the bands of material can be deposited. The width of the band that is allowed by the space between the rows of PV cells allows a relatively thin film of connection band to have a relatively large surface area and cross-sectional area. The latter allows for low electrical resistive losses and the former allows for efficient heat dissipation of the heat generated by the EM radiation impinging upon the PV cells. The bands that extend across the top of the cells can be of any suitable material and in general would be of thin width so as to cover a minimum area of the PV cells.

10 **[00039]** In the case of the collection of thermal energy, a conduit containing a fluid to be heated could be placed at the focal line of each parabolic louver. Preferably this conduit is adapted such that it receives energy on one surface from absorption of the concentrated EM radiation and its other surfaces are insulated to minimize heat loss. There could be multiple conduits or could be one or more conduits that extend to pass under two or more parabolic louver focal lines. The conduits would be made of thermally conductive material such as copper. Since it is desired to have thermally insulating areas between the conduits, unlike the prior art, there is no need to have a plate such as a copper plate extend between the conduits. This reduces the cost and weight of the device.

15 The thermally insulating areas can be filled with air or with insulating materials such as, for example, foams.

[00040] The profile of the reflective surface of the louvers is preferably parabolic in shape. The profile of the parabola can be defined by the equations below. In these equations the focal point of EM radiation reflected from the

parabolic profile is defined to be at the x, y point (0, 0). Also where x_0 and y_0 are defined to be the x and y coordinates respectively of the upper tip of the parabolic profile when the profile is rotated such that EM radiation normal to the x-coordinate is focused on the focal point (0, 0). The profile is then defined by the equation:

[00041]
$$y = \frac{\tan \alpha_0}{2x_0} x^2 - \frac{x_0}{2 \tan \alpha_0}$$

[00042] Where
$$\alpha_0 = -\frac{\frac{\pi}{2} - a \tan\left(\frac{y_0}{x_0}\right)}{2}$$

[00043] It is to be understood that due to manufacturing imperfection and changes over time and temperature, the louver profile will only ever approximately conform to the profile give by the equations above. The degree of conformance of the profile to the equation above will determine the width of the focal line that results in practice in the device. The louvers can be manufactured by any method that results in a reflective surface with a profile along its length that reflects an acceptable portion of the incident radiation on to a focal line of the desired width. An acceptable portion of the radiation is determined by considerations of the overall cost of producing electrical or thermal energy from a specified area. This includes considerations of cost of manufacture of the device, its useful life, the efficiency of the energy conversion process and the capabilities of competitive technologies. The desired width of the focal line is decided upon by a combination of factors balancing cost, practicality of manufacture, device longevity and ability to dissipate heat. These factors taken together will determine the optimum width of the focal line for a particular manufacturing method and

cost structure. For example, to reduce the cost of the PV cells, an expensive component of the system, it is desirable to reduce their area, however, past a certain point the cost of producing a reflector capable of the fineness of focus required and the ability to dissipate heat from the PV cells for their efficient
5 operation becomes compromised, thus creating an optimum width.

[00044] The louvers can be constructed of metal plates which are bent to conform to the desired profile. The plates can be intrinsically reflective or polished or coated and polished to form a suitably reflective surface. These metal plates could be mounted in suitable mounts to hold the plate at the right location
10 and to allow them to rotate about their focal lines. Alternatively, the louvers can be cast from metal, preferably with the mounting means integral, with the reflective surface being polished or coated and polished after the casting. In yet another alternative, the louver, preferably with integral mounting means, could be cast or molded from plastic and subsequently metal plated to yield at least the
15 front parabolic surface reflective. Optionally, the part could then be post coated with a clear layer to protect the reflective surface from environmental degradation.

[00045] Figure 5 depicts one embodiment of the current invention. Figure 5 depicts a partially assembled device 100 to illustrate the various components. Reference number 110 denotes the front parabolic reflective surface
20 of an exemplary louver 105. Pins 150 locate the louver in side block 120 (only one side shown) such that the focal line of the louver is coincident with the target area 140. Pins 160 locate in tie rods 130 to link the louvers together. Pins 150 and 160 are free to rotate in the location holes in side blocks 120 and tie rods 130, such that when tie rods 130 are moved upward and forward in unison the louvers

are rotated about the centre of the pins 150. Note that the centre of the pins 150 are coincident with the focal line of the corresponding louver such that the louver rotates about its focal line. This insures that for any angle of incident light in the desired range the louvers can be rotated such that the focal line remains coincident with the target area 140.

[00046] Figure 6 depicts a further cut-away illustration of the current invention showing how incident radiation is reflected towards the target area. The arrows in Figure 6 show exemplary radiation paths. Note that the louvers are spaced such that radiation that is not captured by one louver is captured by the louver in front of or behind it, thereby maximizing the collection efficiency.

[00047] Example 1: Louvers were designed with a parabolic reflector shape according to equation (1) where x_o and y_o were -37 mm and 40 mm respectively, with a louver pivot point separation of 22 mm. End mounting clamps were constructed with the computed shape by wire cutting the shapes out of aluminum. The mount clamps were made in two pieces with the concave parabolic shape cut into the front of the rear half of the clamp and the corresponding convex parabolic shape formed as the rear surface of the front portion of the clamp. 0.2 mm thick brass sheet was nickel plated and polished to give a highly reflective surface and the plate cut into widths corresponding to that needed for a louver. The plated brass sheet was clamped at either end between the two halves of the mounting clamps. Steel pins were used to mount the mounting clamps to side plates, where the pins were located in holes coincident with the focal line of the louver. Pins in the upper end of the mounting clamps were mounted in holes in a

tie rod, as shown in Figure 5. Ten louvers with a length of 200 mm were assembled in this way.

[00048] Example 2: Louvers manufactured by injection molding were fabricated. The parabolic shape was computed according to equation 1 with x_0 and y_0 as -35 mm and 60 mm respectively, with a louver separation of 20 mm and the base of the louver being 7.15 mm above the focal plane of the louvers. The dimensions were chosen such that the louvers could be rotated to be able to accommodate incident radiation angles from 20 degrees to 115 degrees, measured from the x-coordinate, without the base of the louvers having to impact the focal plane. End mounts with integral pins were designed to be molded with the louver shape in one piece. The mold was constructed to give a mirror smooth finish on the front parabolic surface. The louver was injection molded from an ABS/polycarbonate blend Bayblend® T 45 PG (Bayer MaterialScience) and then metallized to form the reflective coating.

[00049] In one embodiment of the invention, narrow strips of PV cells are placed at the focal lines to receive the concentrated radiation to convert it to electricity. To gather the current generated from the PV cells, it is necessary to make electronic connection to the upper and lower surface of the PV cells. It is also often desirable to connect a number of the strips of PV cells in series to generate a higher voltage and decrease the current that needs to be carried for a particular power output.

[00050] According to the present invention, the lower connection to a strip of PV cells is made by a conductive plate on which the PV cell sits. The plate can be made from any material with sufficiently low electrical resistance.

Non-exclusive examples of suitable materials are aluminum, copper, tin and copper covered with a layer of tin.

[00051] If it is desired that two or more PV cell strips are to be connected in parallel then the lower connection plate is common to those strips of
5 cells or individual plates are brought into electrical connection by other means such as by separate wires.

[00052] If it is desired that the strips of PV cells be connected in series then there is a separate lower connection plate for each strip of PV cells. The connection plate would extend beyond the edge of the strip of PV cells to allow
10 other electrical connections and to act as a heat dissipation device to cool the PV cells when in operation.

[00053] According to the present invention, the electrical connection to the upper surface of the PV cell strip is made by an electrically conductive layer placed in contact with the upper surface of the PV cell. In a preferred
15 embodiment, the upper surface connector is a continuous strip that runs the length of the PV cell strip, overlapping and in electrical contact with the upper surface of the PV cell strip along one lengthwise edge of the connector strip, in the area of the PV cell strip that is in shadow in operation. For the embodiment where the PV cells are to be connected in series the other lengthwise edge of the connector strip
20 overlaps and is in electrical contact with the extension of the lower connection plate of the next strip of PV cells. The connector strip in this embodiment thus makes a bridging electrical connection between the top surface of one strip of PV cells and the lower surface of the next strip of PV cells.

[00054] Suitable materials for the upper connector strip are any materials that can form a layer and have sufficiently low electrical resistance. Non-exclusive examples of such materials are metals, metals coated with electrically conductive adhesive, metals coated with a non-conductive adhesive

5 but where the metal is textured such that areas of the metal penetrate through the non-conductive adhesive, conductive inks, unsupported conductive adhesives and solder. Non-exclusive examples of suitable metals are aluminum, copper, tin, tin coated copper or silver. Non-exclusive examples of suitable conductive adhesives are pressure sensitive adhesives filled with silver or carbon such as

10 ARclad@90038 (Adhesives Research Inc, Glenn Rock, USA) and silver doped epoxy. An example of a suitable conductive tape with a conductive adhesive is 1181 Tape Copper Foil with Conductive Adhesive (3M Corporation). An example of a suitable conductive tape coated with a non-conductive adhesive is 1245 Tape Embossed Copper Foil (3M Corporation) where the embossed features

15 on the foil penetrate through the non-conductive adhesive layer. Examples of suitable conductive inks are carbon or silver filled inks. Note that the upper surface connector must only be capable of forming a continuous electron conduction path from the PV cell to the next lower connector plate with acceptably low electrical resistance. It need not be a continuous connection path

20 along the length of the PV cell strip, as long as the overall resistance of the connection of the upper surface of the PV cell with the lower connection plate of the next strip of PV cell is desirably low. For example, the connection could be a series of wires or dots bridging the gap to achieve the electrical connection. However, a continuous connection layer down the length of the PV cell strip is

usually preferred as in general it will lower the electrical resistance of the connection and will aid in heat transfer away from the PV cell to cool it for more efficient operation.

[00055] An additional advantage of the present invention is that there is
5 a small distance between any area of the upper surface of the PV cell exposed to the concentrated sunlight and the current collector. The width of the PV cell strip exposed to the concentrated sunlight is small, at best equivalent to the width of the focal line from the parabolic louver mirror. A typical width is less than 5 mm and more preferably less than or equal to 2 mm. So the current collected by the upper
10 surface connector only has to travel a short distance through the PV cell before entering the low resistance connector. This reduces resistive losses in the device without the need to have any of the sunlight blocked from the PV cell by the upper surface connector.

[00056] Optionally, after the array of connections has been constructed
15 as illustrated above, part or all of the array could be overlaid with a layer of transparent material (as is known in the art) to protect the device from water ingress, corrosion and mechanical damage. As a further option, the transparent protective layer need not cover all of the array, but only cover the PV cells. The upper surface connector and the lower surface connector could be covered with a
20 layer to protect against corrosion and to aid the radiation of heat, for example a black paint or other thin polymer layer. Preferably there would be a good seal between the transparent coating and the heat radiating coating to prevent the ingress of moisture into the device.

[00057] Figures 7 and 8 give a top view and cross-sectional view respectively showing three strips of PV cells connected in series in one embodiment of the present invention.

[00058] If it is desired to connect the strips of PV cells in parallel then the upper surface connector layer from one strip of PV cells is connected to the upper surface connector layer of the next strip of PV cells. One embodiment of the connection method for parallel connection is shown in Figure 9.

[00059] In figures 7, 8 and 9, 210 denotes the lower surface connectors, 220 denotes the PV cell strips and 230 denotes the upper surface connectors. In operation, light is concentrated onto the areas pointed out by 220. In Figure 8, 240 denotes a support base which is electrically non-conductive or at least electrically insulated from 210 and 230. In Figure 9, 250 denotes side connection bars. These bars 250 serve to connect the strips of upper surface connector together in parallel fashion. In this configuration the lower surface connector is a continuous plate, connecting the lower surfaces of the strips of PV cells in parallel fashion.

[00060] To connect an external circuit to the array of PV cells shown in Figures 7 and 8, one connection would be made to the lower surface connector 210 at one end of the array and the other connection to 260, the plate connected to the upper surface of the last strip of PV cell. Optionally, the second connection could be made directly to the last upper surface connector in the array, in which case 260 is not necessary. To connect an external circuit to the parallel array shown in Figure 9, one connection would be made at any suitable location or locations on 210 and the other connection at any suitable location or locations on one or both bars 250. The bars 250 are made of a material with low electrical

resistivity. They could be made from the same material as the upper surface connectors 230 or they could be made for example from copper wire or tinned copper wire that is soldered to each upper surface connector strip 230.

[00061] According to another embodiment, a solid electrically
5 conductive wire or ribbon is laid abutting one edge of the strip of PV cell(s). The wire or ribbon is of suitable cross-section such that it overlaps at least a portion of the adjacent conductive pad to which it is desired to connect the top surface of the PV cell(s). A bead of solder or conductive ink can then be applied to form an electrically conductive bridge between the top surface of the PV cell(s) and the
10 conductive wire or ribbon. Optionally, an additional bead of solder or conductive ink can be applied to form a conductive bridge between the conductive wire or ribbon and the conductive pad. In the absence of this second bead, the fact that the conductive wire or ribbon overlaps and rests against the conductive pad can be used to provide sufficient electrical connection. A cross-sectional schematic
15 illustrating this aspect of the invention using a wire of substantially circular cross-section is given in Figure 10 and the situation when using a ribbon of substantially trapezoidal cross-section is given in Figure 11.

[00062] In Figures 10 and 11, the lower surface of the PV cell 320 is placed in contact with a conductive pad 310, which is formed on an electrically
20 insulating substrate 340. A wire 330 (of circular cross-section in Figure 1 and of trapezoidal cross-section in Figure 2) is placed so as to abut one side of 320 and to also overlap a portion of a second conductive pad 315. A bead of conductive bridging material 350 increases the area of electrical connection between wire 330 and the top surface of the PV cell 320. A second, optional bead of conductive

material 360 can be formed between 330 and 315 to increase the robustness of the connection if necessary.

[00063] It is to be understood that this aspect is not restricted to any particular cross-section of wire or ribbon but that any cross-section that allows
5 bridging between the top surface of the PV cell(s) and the adjacent conductive pad is within the scope of this invention. Examples of other suitable cross-sectional shapes are, oval, triangular, square, rectangular, rhomboid, among others.

[00064] Suitable materials from which the wire or ribbon can be constructed are any materials with suitably low electrical resistance through the
10 cross-section of the wire or ribbon. Examples of suitable materials are copper, aluminum, steel, stainless steel, brass and bronze.

[00065] The bead forming the bridge between the conductive wire or ribbon and the top surface of the PV cells(s) can be made of any material and applied by any method that is capable of laying down the bead within a pre-
15 defined area of the top surface of the PV cell(s) and bridging any gap between the edge of that surface and the adjacent edge of the wire or ribbon. For example, a bead of liquid solder can be applied. Alternatively, a length of solid solder can be laid against the wire and ribbon, such that it overlaps a pre-defined portion of the top surface of the PV cell(s) and the solder subsequently melted using heating
20 methods. In another example, a bead or layer of conductive ink can be applied from a dispensing device such as a nozzle or a printing screen, whereupon the ink is dried or cured to form the finished bridge.

[00066] Another aspect disclosed here is to include reflective side walls as part of the solar concentration module to improve light capture when the

incident radiation is not normal to the focal lines of the louvers. When radiation hits the parabolic mirror at an angle other than normal to its length, the radiation will be reflected at the same angle to the other side of the normal angle. In other words the reflected radiation will travel sideways as well as forward, when
5 looking from the front of the louver. Therefore, if nothing is done, a portion of the reflected light will not hit the receiving section on the focal line of the mirror, but rather travel past the end of the receiving section. There would also be a commensurate portion of the receiving section at the other end of the louver that would receive no concentrated radiation. Therefore, in this situation, a portion of
10 the radiation falling on the louver will not be focused on to a receiving area.

[00067] According to this aspect of the current invention, this situation can be avoided by installing additional reflective walls normal to the focal plane of the parabolic mirrors and normal to the axis running along the length of the parabolic mirrors. If this is done, the radiation that would otherwise be lost is
15 reflected back and focused on to a portion of the receiving section for the parabolic mirror.

[00068] This aspect of the invention is illustrated in Figure 12. Figure 12 depicts a cross-section view of the solar panel 400 when viewed from the front. The reflective side walls 410 and 420 and the focal plane 430 of the parabolic
20 mirrors (not shown) containing the receiving sections, are shown. The radiation 440, is the reflected radiation from radiation incident on the leftmost portion of the parabolic louver. Radiation incident to the left of this radiation will be blocked by the side wall 410, creating a shadowed area 460. The radiation 450, is the reflected radiation from radiation incident on the rightmost portion of the

parabolic louver. The dotted lines depict the path of this radiation if the sidewall 420 was not present. As is illustrated, the radiation 450 will be reflected back on to a portion of the radiation receiving area 470. Thus, this radiation will be captured by the radiation receiver. Further, if the side wall 420 is normal to the focal plane 430 and normal to the axis running along the length of the parabolic mirror, then the length of the ray reflected off 420 to reach the focal plane and the absolute angle of the light ray to 420 is the same as if the radiation were to carry on and be focused on the focal plane past the end of the receiving area (depicted by the dotted lines). Therefore, the radiation 450 reflected from the side wall 420 will be focused onto a portion of the receiving section, and thus be correctly captured. So, according to this aspect of the invention, although a shadowed area 460 is created when radiation incident on the parabolic louver is not normal to the axis running long the length of the louver, a commensurate amount of extra radiation is reflected by side wall 420 on to receiving area 470, resulting in no net loss of radiation. This allows the panel to efficiently concentrate radiation from a wide range of angles without the need to rotate the panel to face the source of radiation, for example the sun.

[00069] The side walls can be made of any suitable material with an internal face that is reflective for the radiation that is being concentrated. Examples are polished aluminum sheet, polished aluminum sheet covered with a transparent coating, nickel coated steel, bright chrome coated steel, nickel coated brass or bronze, bright chrome coated brass or bronze, transparent plastic or glass coated on the back surface with a reflective coating and a back side protective layer applied, plastic with a front surface reflective coating with an optional

transparent over-coat to afford protection for the reflective coating or other methods for creating a planar reflective surface.

[00070] It is to be appreciated that Figure 12 is merely illustrative and that this aspect of the invention works equally well for radiation traveling in from the right side of 400, where 470 would become the shadowed area and 460 the area receiving the extra radiation reflected off 410.

[00071] The invention is not limited to the above-described exemplary embodiments. It will be apparent, based on this disclosure, to one of ordinary skill in the art that many changes and modifications can be made to the invention without departing from the spirit and scope thereof.

WHAT IS CLAIMED IS:

1. An electromagnetic radiation collector, comprising:
a channeling area having
an entry end for receiving the electromagnetic radiation,
an exit end, and
at least one reflective wall between the entry end and the
exit end; and
a radiation collection element near the exit end of the channeling
area, the radiation collection element being adapted to collect the electromagnetic
radiation.
2. The collector of claim 1, comprising a plurality of the channeling
areas and a plurality of the radiation collection elements.
3. The collector of claim 2, wherein the entry ends of the plurality of
channeling areas are adjacent to each other.
4. The collector of claim 2, wherein each of the channeling areas is
formed by a first surface for reflecting the electromagnetic radiation, and a second
surface opposite the first surface.
5. The collector of claim 4, wherein the first surface of each of the
channeling areas is parabolic and the focal area of each parabolic first surface is
one of the plurality of radiation collection elements.

6. The collector of claim 5, wherein the radiation collection elements are photovoltaic cells.

7. The collector of claim 5, wherein the radiation collection elements are pipes for containing a fluid that is for absorbing the radiation.

8. The collector of claim 5, wherein the first surfaces are movable relative to the radiation collection elements.

9. The collector of claim 8, wherein the first surfaces can rotate about their corresponding radiation collection element.

10. The collector of claim 5, wherein the radiation collection elements are sized to be only slightly larger in the surface area they cover than the surface area covered by the radiation reflected onto the radiation collection elements by the first surfaces.

11. The collector of claim 6, wherein the plurality of photovoltaic cells are electrically connected to each other.

12. The collector of claim 11, wherein an upper surface of a first photovoltaic cell of the plurality of photovoltaic cells is electrically connected to a lower surface of a second photovoltaic cell of the plurality of photovoltaic cells.

13. The collector of claim 12, further comprising a lower surface connector electrically connected to the lower surface of the second photovoltaic cell;

an upper surface connector electrically connected to the upper surface of the first photovoltaic cell and electrically connected to the lower surface connector.

14. The collector of claim 13, wherein the upper surface connector comprises a wire.

15. The collector of claim 14, further comprising a first bead that electrically connects the upper surface connector to the upper surface of the first photovoltaic cell.

16. The collector of claim 15, further comprising a second bead that electrically connects the upper surface connector to the lower surface connector.

17. The collector of claim 14, wherein the wire is round in cross section.

18. The collector of claim 14, wherein the wire is trapezoidal in cross section.

19. The collector of claim 1, wherein the channeling area is in the form of a slot and further comprising a reflective wall at each end of the slot.

20. The collector of claim 19, wherein the plane of each of the reflective walls is normal to a lengthwise axis of the slot.

21. The collector of claim 20, wherein each of the reflective walls is planar and the plane of each of the reflective walls is normal to a plane of the radiation collection element.

22. A control mechanism for a radiation collector where the radiation collector is adjustable to track a moving radiation source and where the control mechanism comprises a first sensor to monitor the ambient radiation conditions and a second sensor to monitor the output of the radiation collector.