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(54) THIN SOLAR CONCENTRATOR

(76) Inventor: **Rangappan Anikara**, Torrence, CA (US)

Correspondence Address:
Anikara Rangappan
2317, Santa Fe Avenue
Torrence, CA 90501

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

(57) **ABSTRACT**

The present invention is an electro-optical system for collecting solar energy and converting it into electrical energy. It is an enclosed concentrator that will last long in harsh environment. It is made up of a matrix of modules, each collecting sunlight, concentrating it on a solar chip, and producing an electrical output. It conducts the unwanted heat away because the first radiation receiving surface is made of metal. It is not monolithic, but rather is made of half metal and half glass, and the structures are a parabola and an ellipse. As a result the present invention advantageously fills the aforementioned deficiencies by providing a thin solar concentrator that is light weight, cheaper to manufacture than currently known solar concentrators, and which further can be used in a high powered solar concentrator for hydrogen generation.

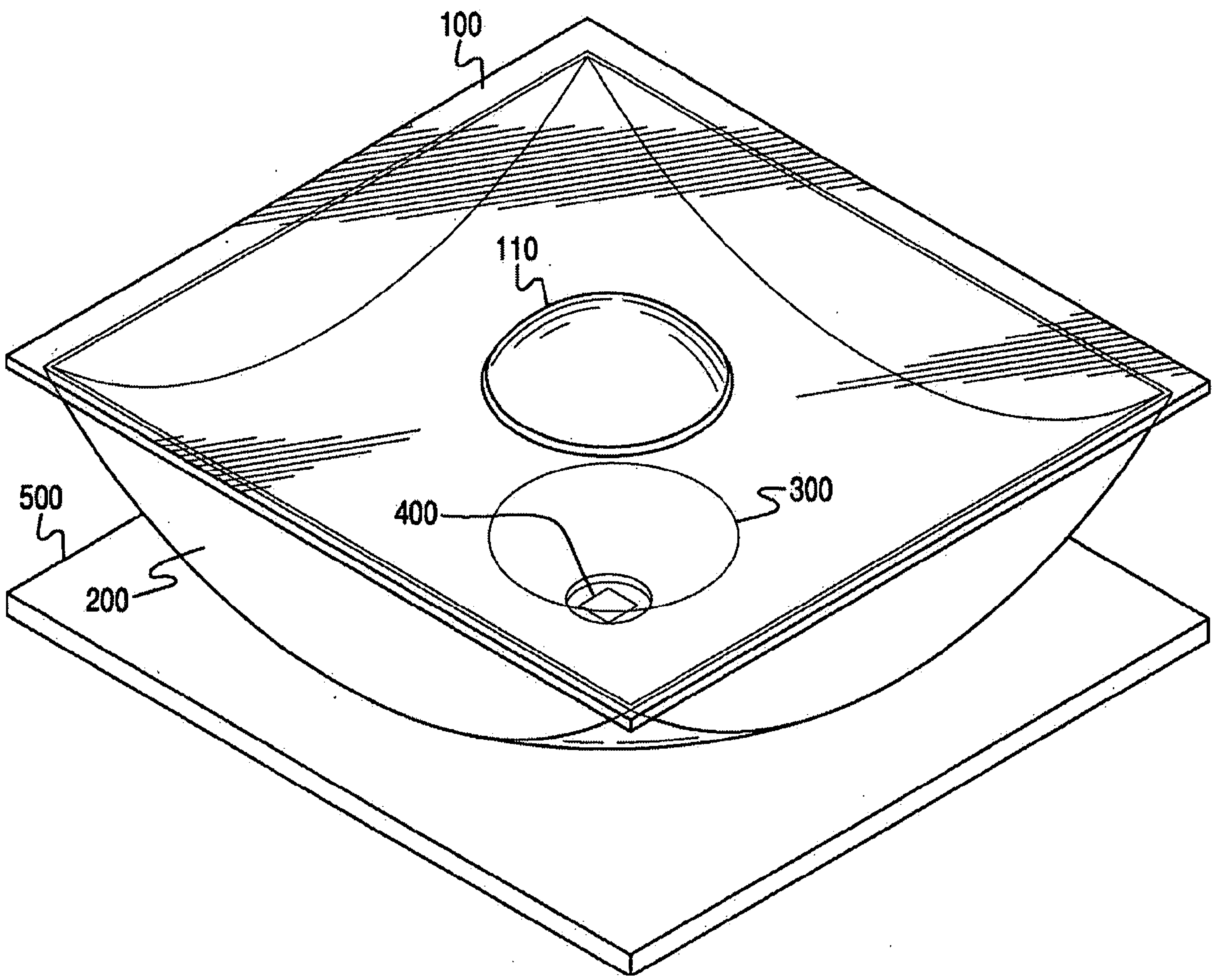


Fig. 1

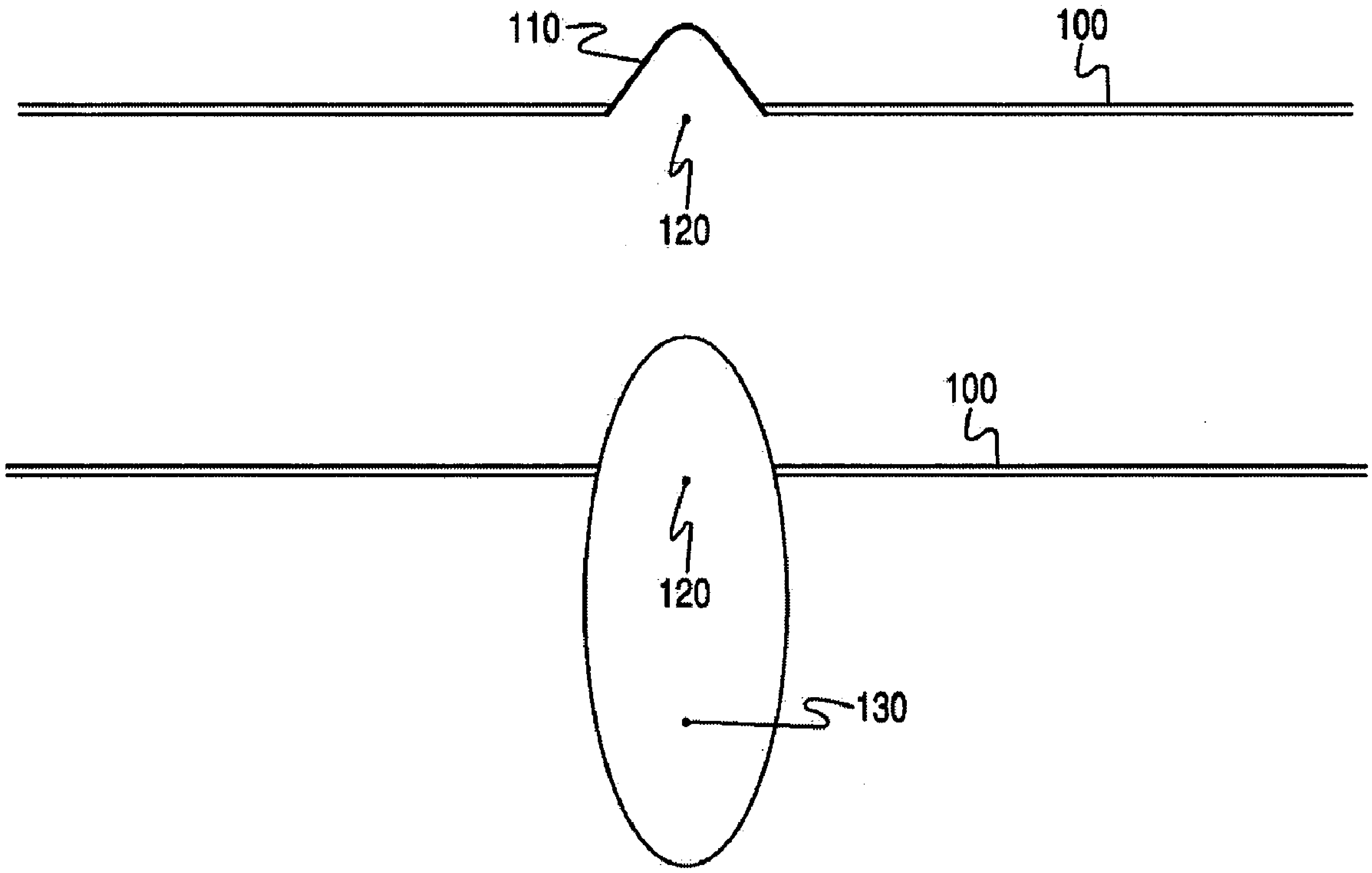


Fig. 2

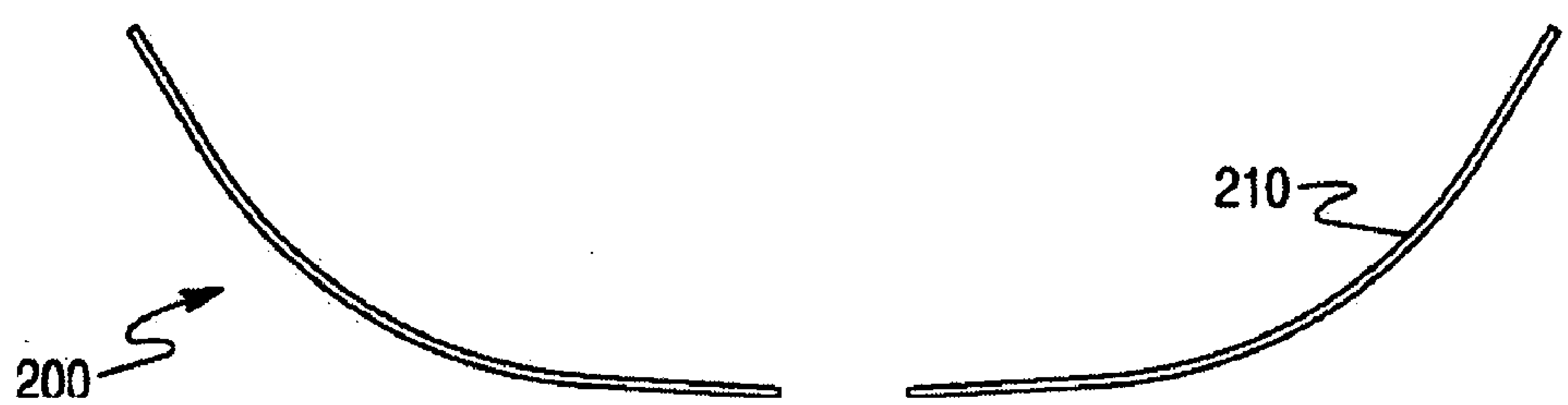


Fig. 3

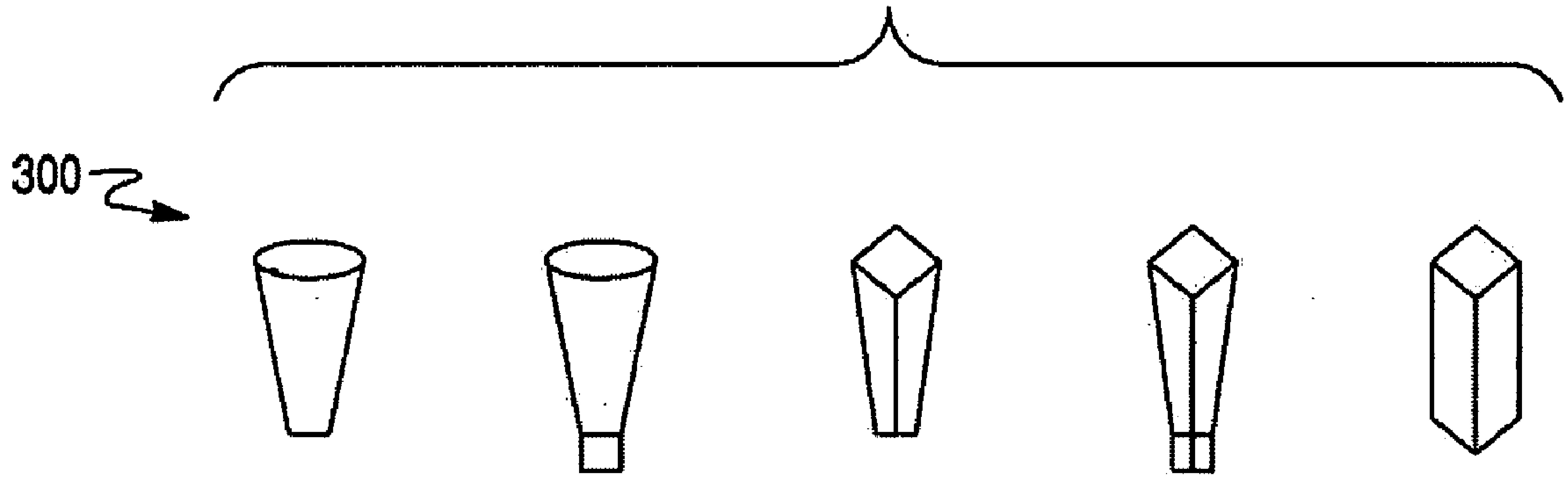


Fig. 4

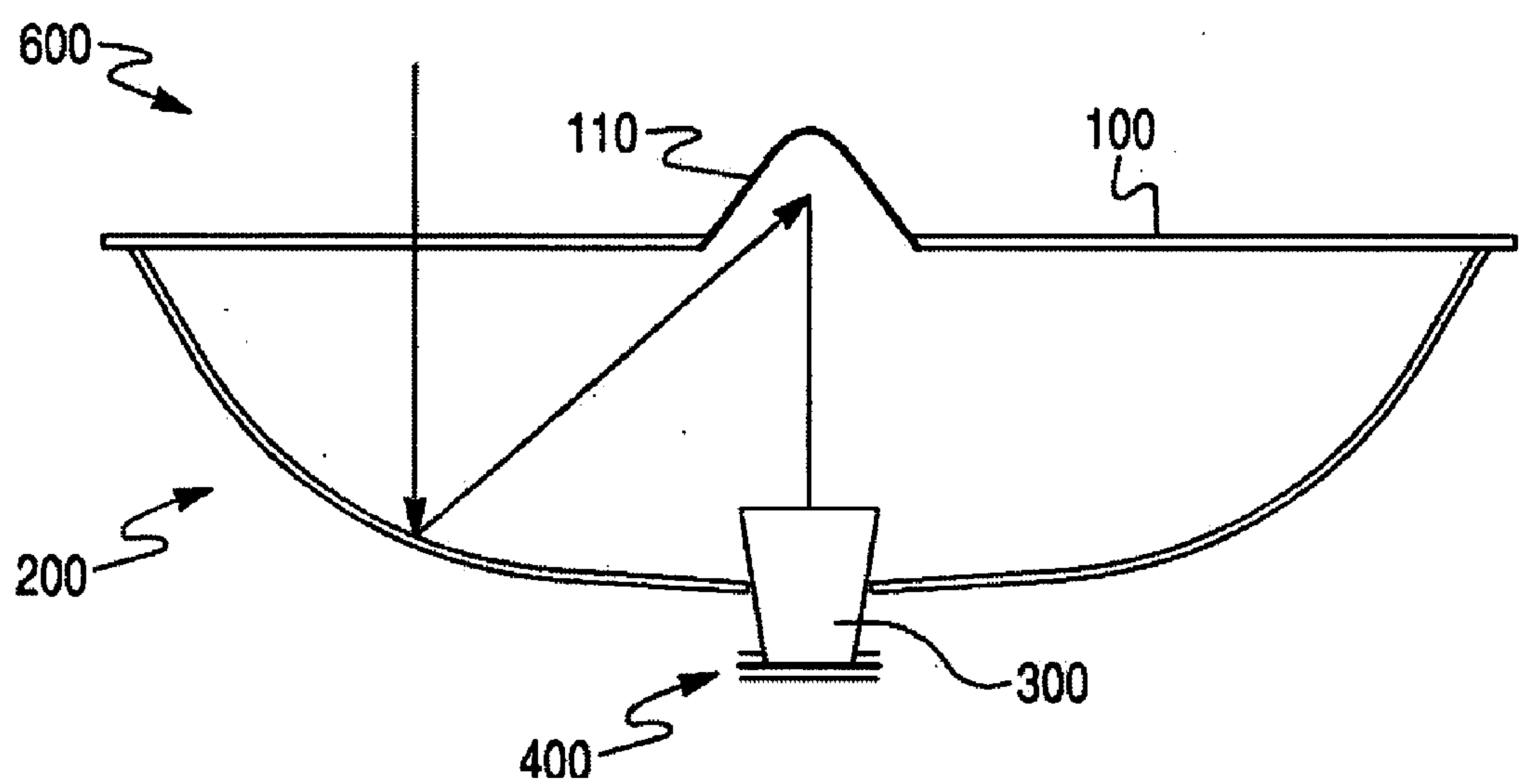


Fig. 5

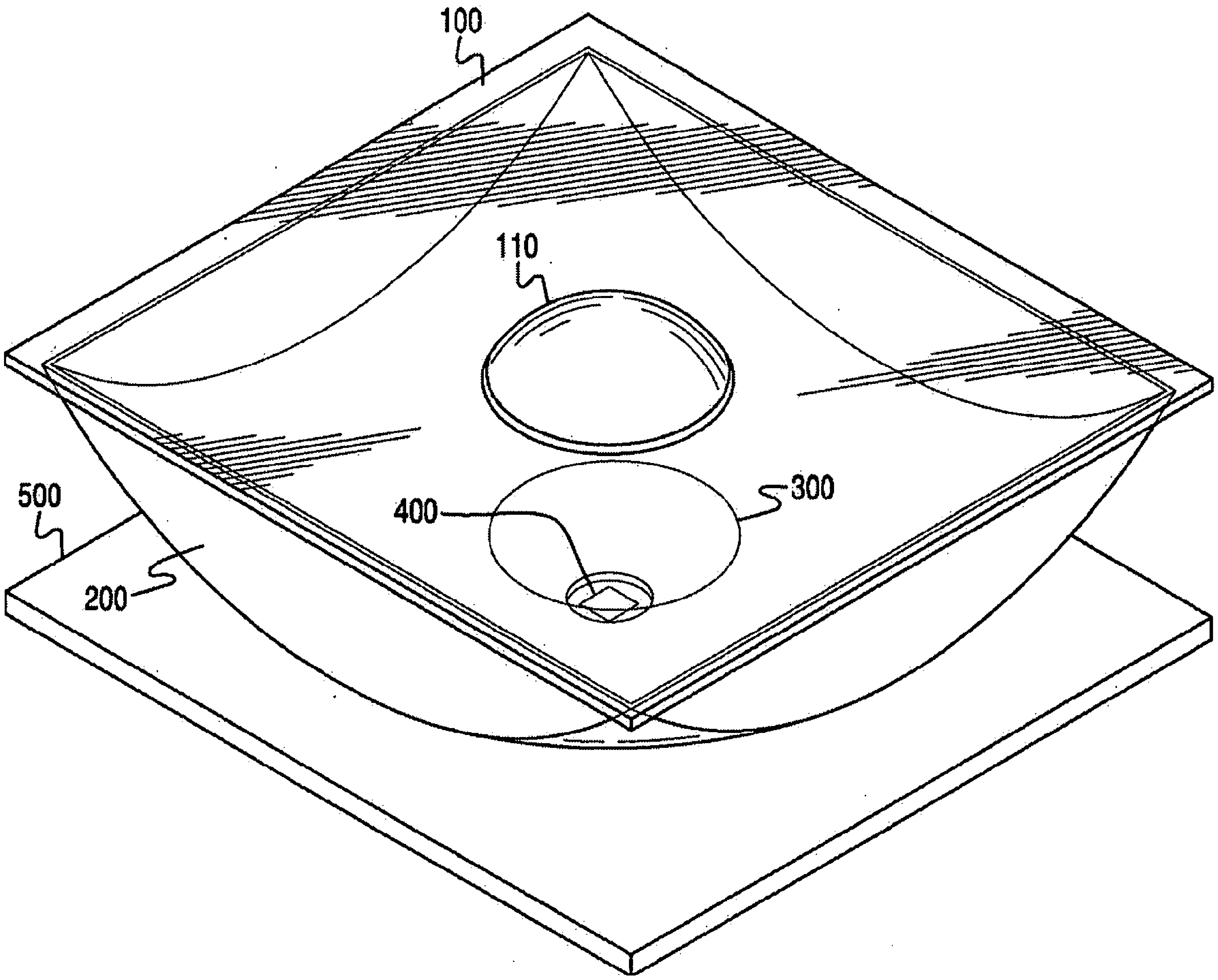


Fig. 6

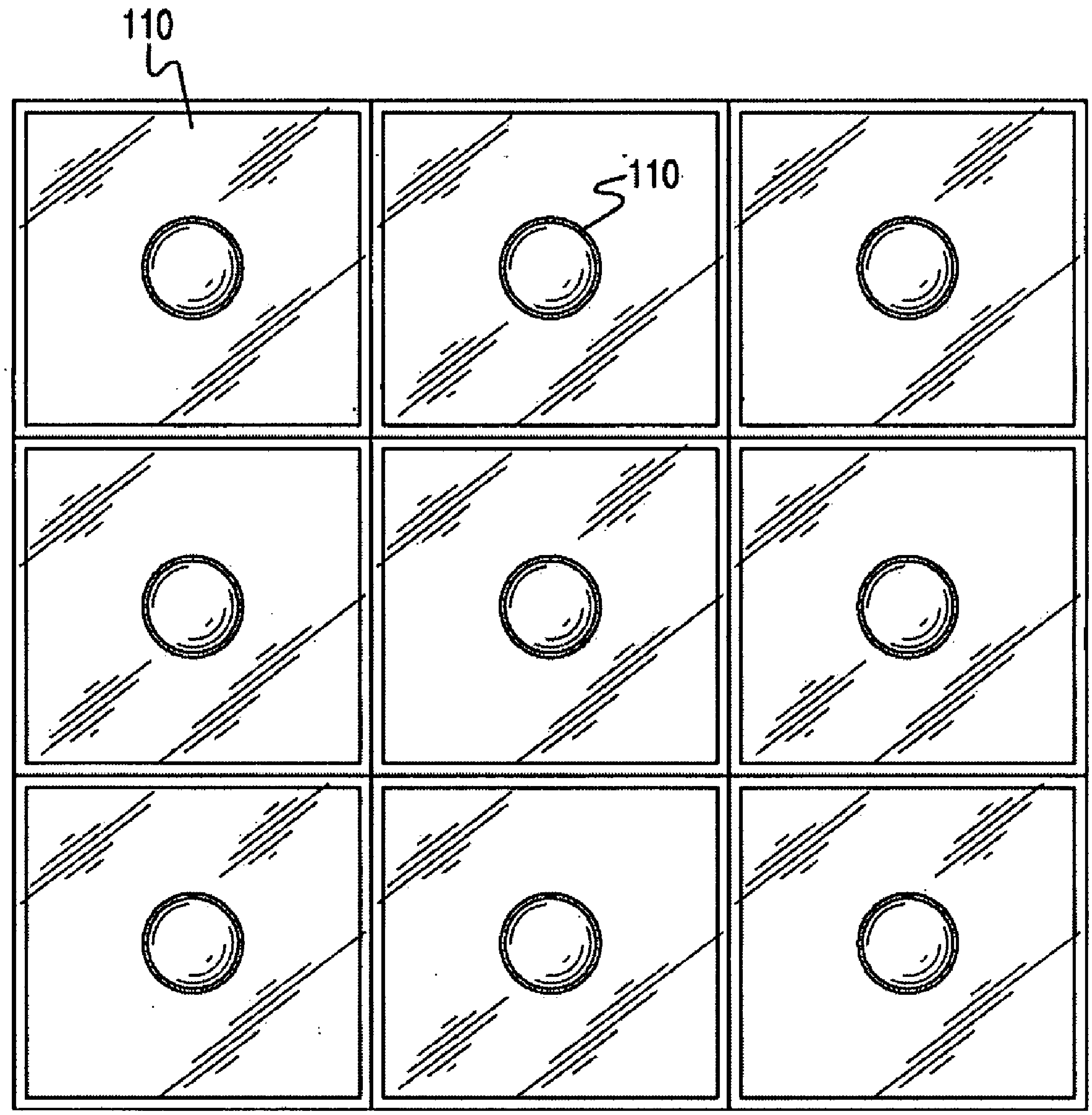


Fig. 7

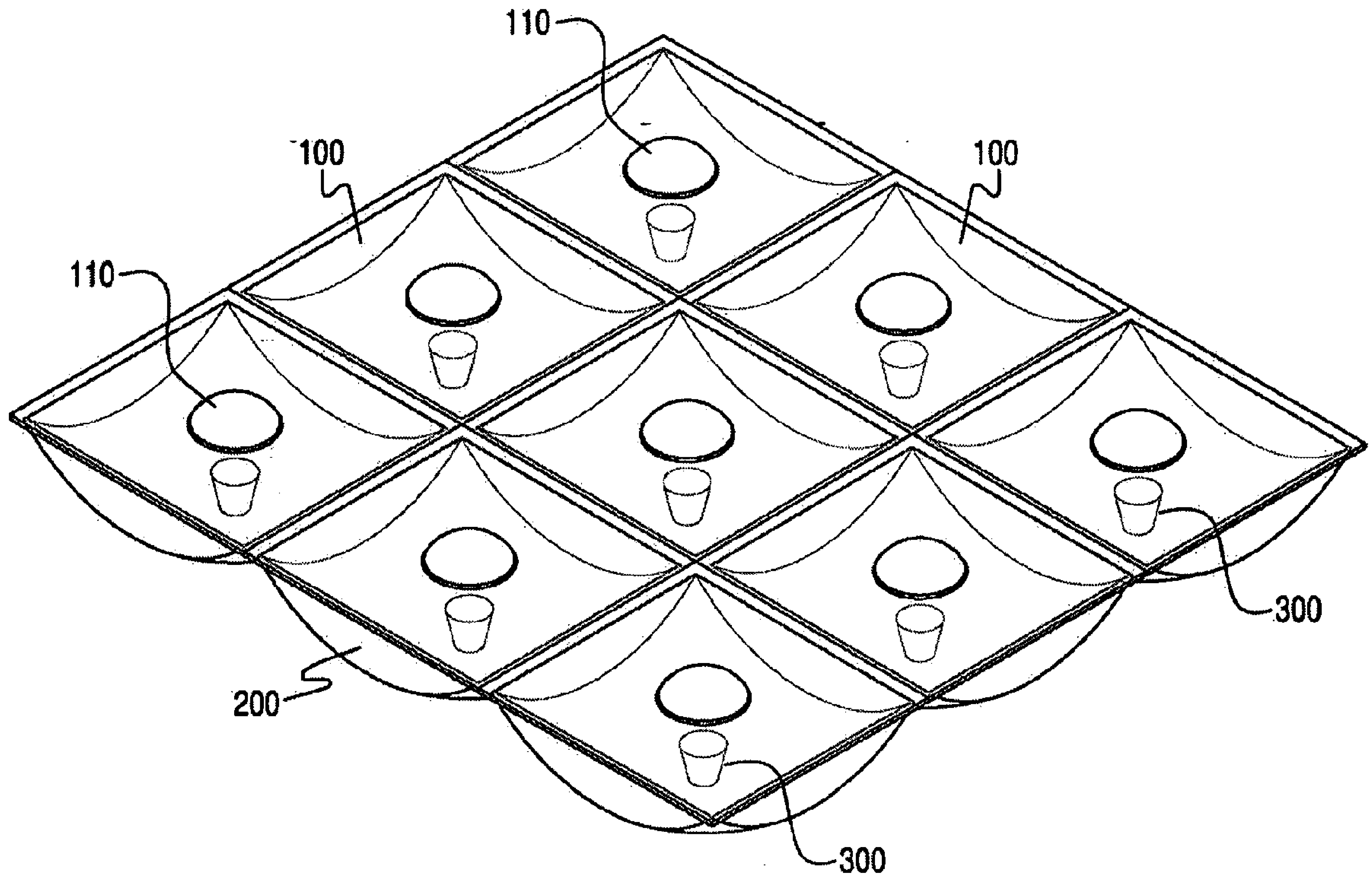


Fig. 8

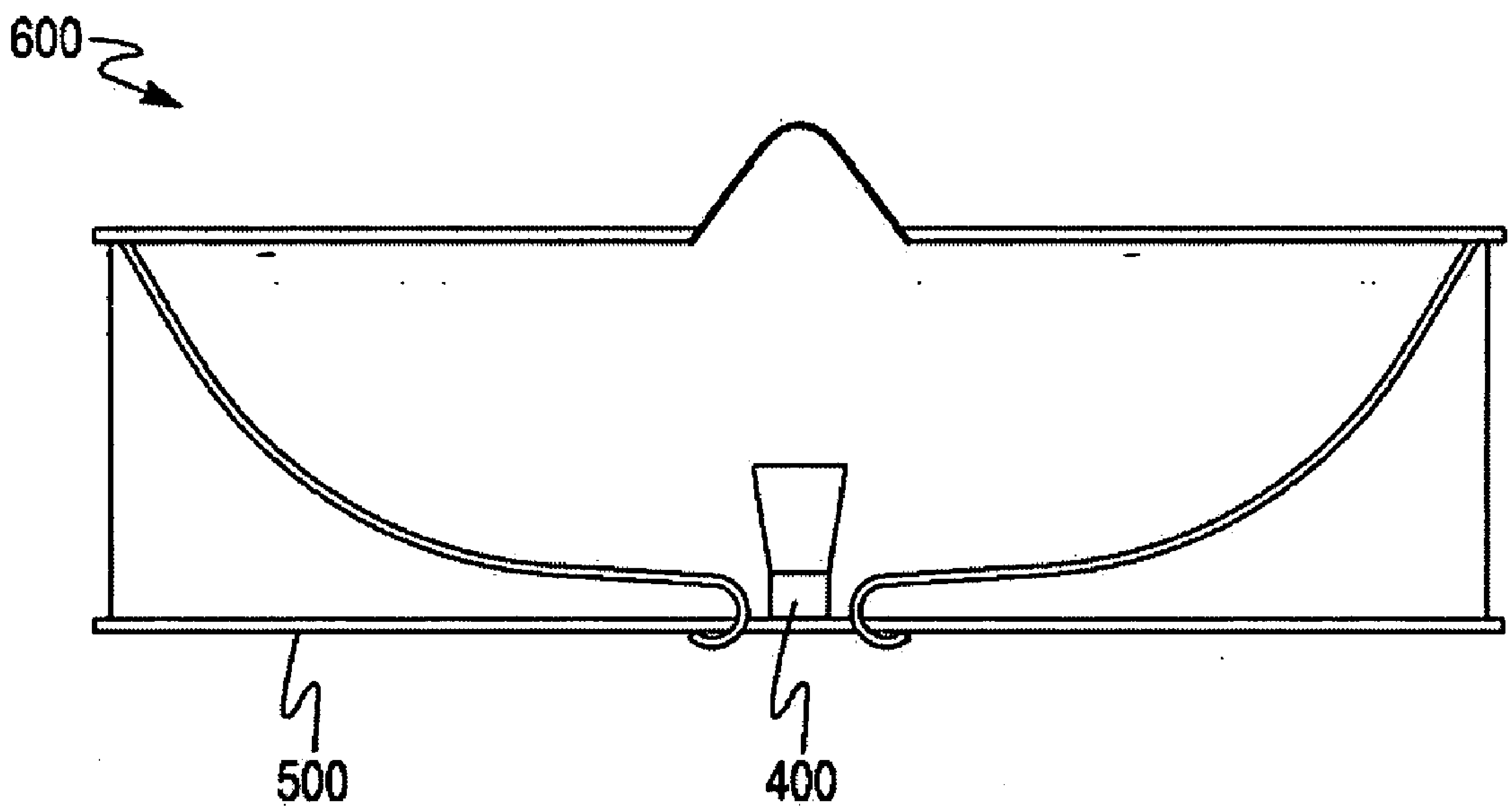


FIG-9

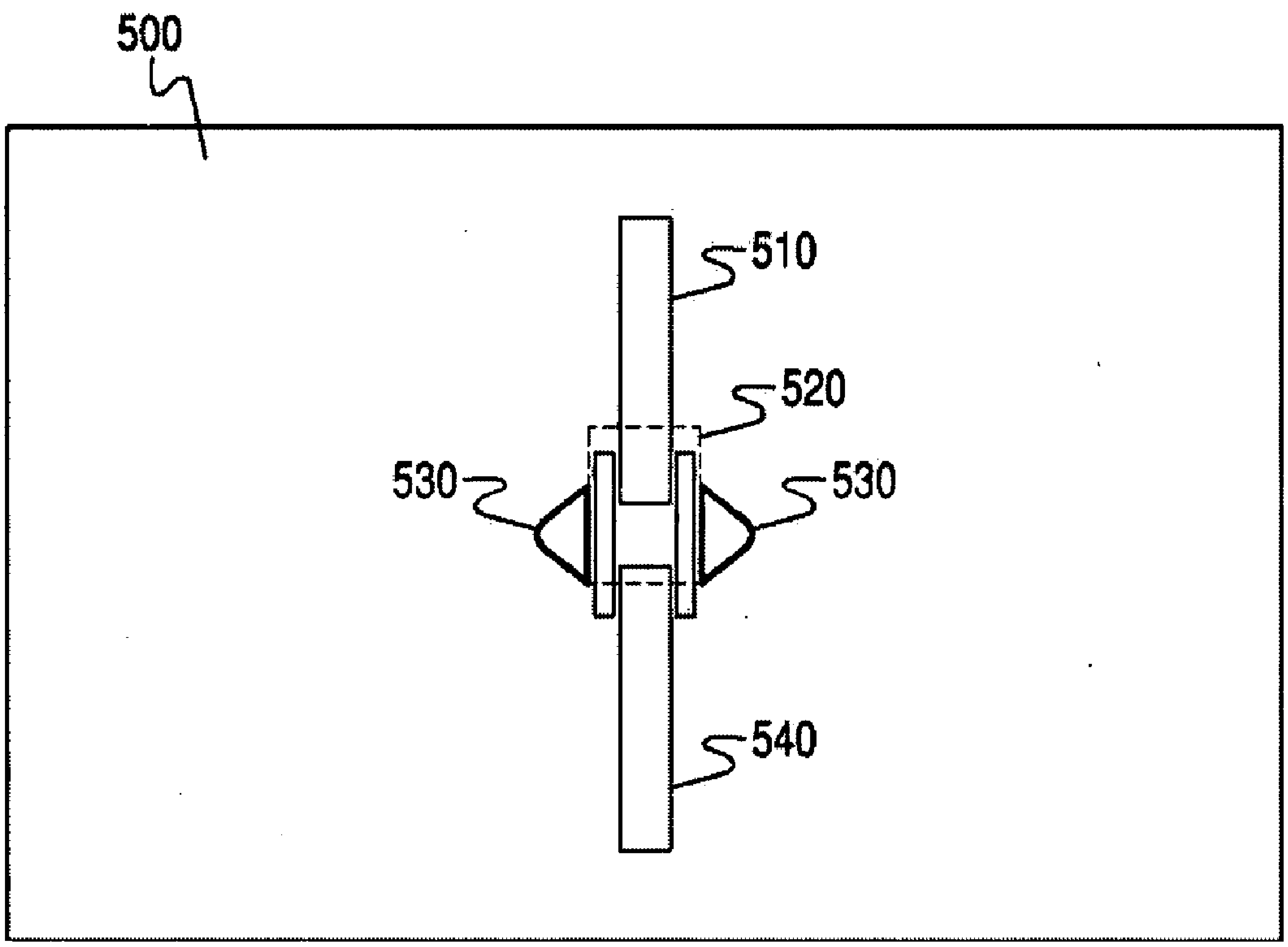


Fig. 10

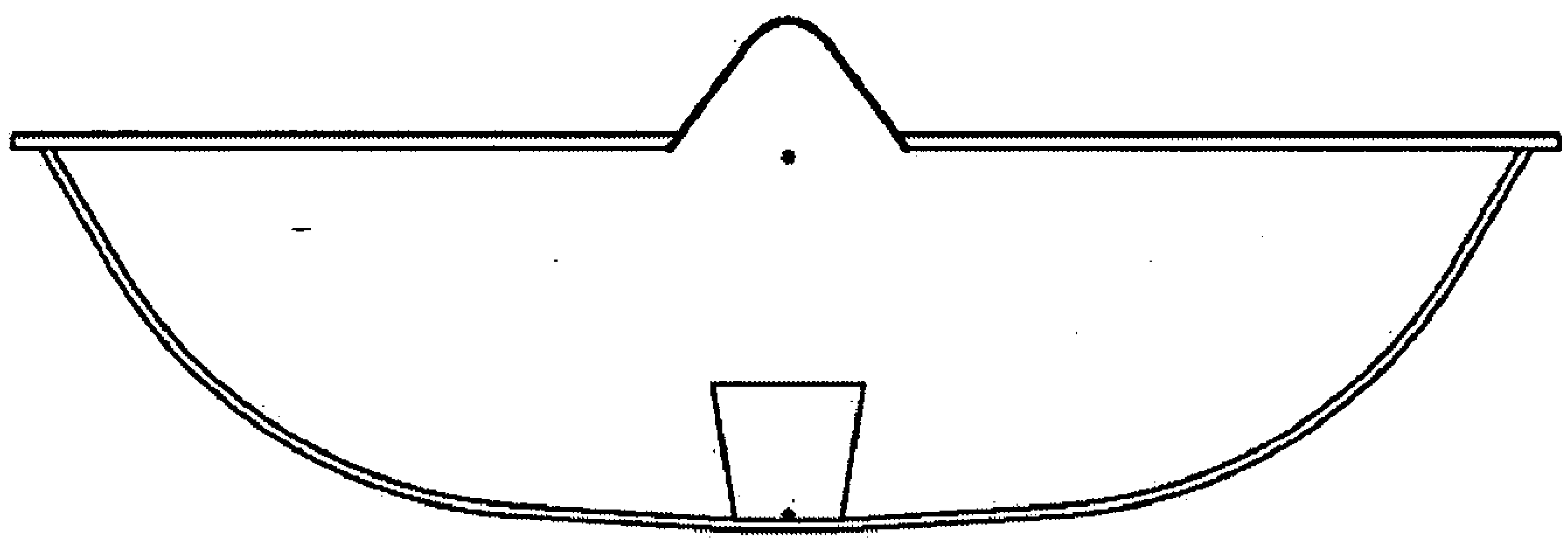


Fig. 11

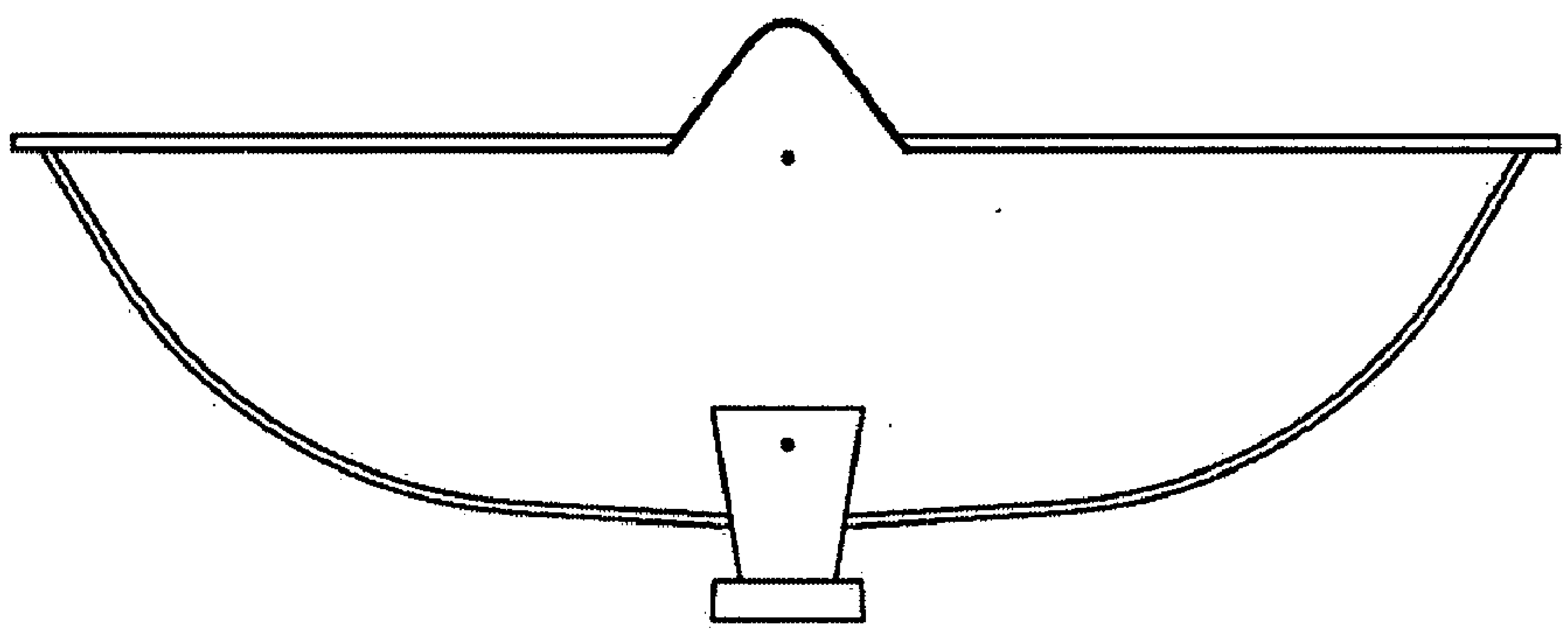
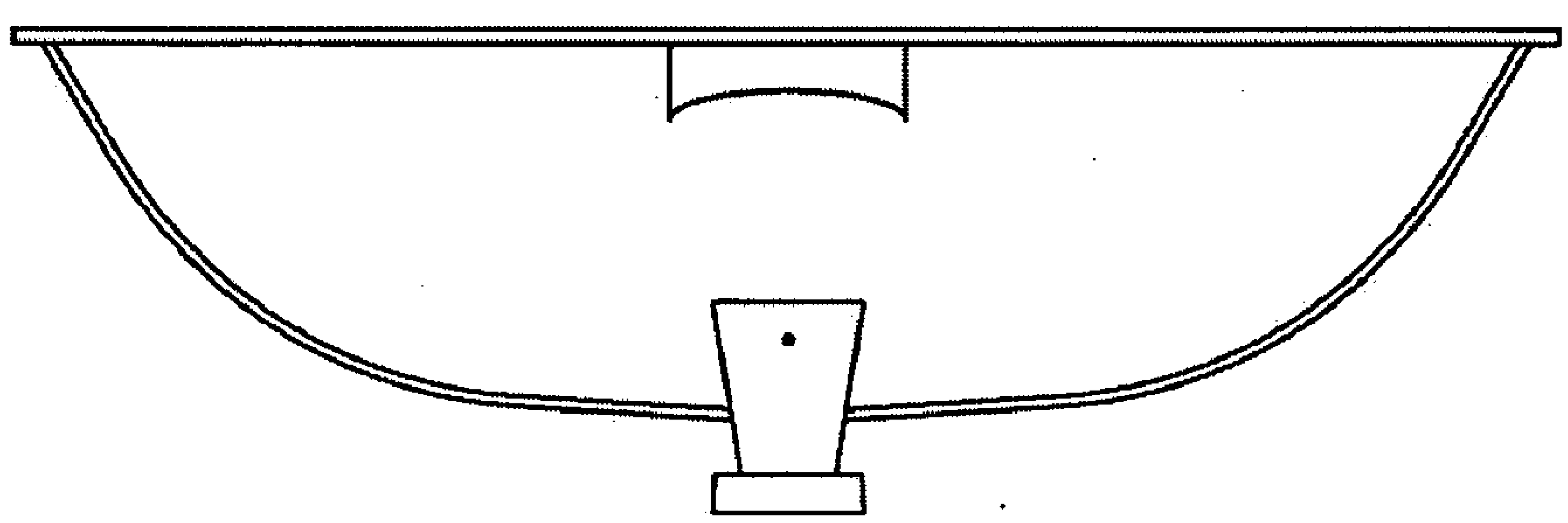


Fig. 12



THIN SOLAR CONCENTRATOR

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of earlier priority based upon the filing of a provisional application, Ser. No. 60/873,779, which was filed on Dec. 8, 2006

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates generally to solar concentrators.

[0004] 2. Background

[0005] Solar concentrators that are known to exist concentrate solar energy via parabolic reflectors and then split the light through a prism to focus the wavelengths onto solar collectors optimized for a particular spectrum. Most systems now in use are based on the classical Cassegrain telescope design, using a hyperbola as the second reflecting surface. The optical properties of a Cassegrain telescope are excellent for the object on-axis, but image quality degrades rapidly for off-axis points. They were intended for looking at stars or objects which subtend maybe a few seconds of arc depending on atmospheric conditions. For a large object like the sun (0.5 degree) the Cassegrain arrangement has no special advantages. In fact, solar concentrators are not trying to make a precise image of the sun. They are trying to deliberately scramble the radiation so that it falls almost uniformly on the cell. Imaging properties are not of primary importance in this implementation. The light gathering shapes introduce significant spread into the "hot spots" which actually improve performance.

[0006] There are two previous designs in use currently, both of which suffer from a number of problems. The first known design is called RX1, but this design has at least five significant problems associated with it, Specifically, the concentrator was made of a solid glass with tailored or custom made surfaces. These surfaces are difficult to mirror coat because one has to lithograph a contoured surface. Second the RX__1 design is quite heavy, which is particularly problematic because the concentrators have to be able to track the sun. Third, because the surface was contoured they have to protect the surface with a plain cover glass, which adds cost. Fourth, since the concentrators were made of glass which is not a good thermal conductor, the solar cell became very hot. Fifth, the solar cell was located on a pedestal in the middle of the glass, which makes it difficult to make electrical connections.

[0007] The second known design is similar to the RX1 in that they are both tailored glass concentrators. What that means is that this second design also suffers from many of the same problems as the RX1. In the second design the circular modules are packed in a hexagonal layout. The spaces in between the hexagons don't collect the solar radiation, resulting in wasted area.

[0008] Therefore, what is needed is a solar concentrator that does not suffer from the aforementioned problems, and which is light weight, cheaper to manufacture, and which further can be used in a high powered solar concentrator for hydrogen generation.

SUMMARY OF THE INVENTION

[0009] The present invention is an electro-optical system for collecting solar energy and converting it into electrical energy. It is made up of a matrix of modules. Each module collects sunlight, concentrates it on a solar chip, and produces an electrical output. It is not monolithic, but rather is made of half metal and half glass, and the structures are a parabola and an ellipse. As a result the present invention advantageously fills the aforementioned deficiencies by providing a thin solar concentrator that is light weight, cheaper to manufacture than currently known solar concentrators, and which further can be used in a high powered solar concentrator for hydrogen generation.

[0010] The solar concentrator is made of three elements: (1) Cover glass and elliptical concentrator; (2) Parabolic metal reflector; and (3) a light pipe. The first surface is the solar radiation entering surface. This is a plain glass at the center of it there is a small elliptical mirror. The second surface is a focusing parabolic mirror. This parabolic reflector focuses the sun light. The focal point of the parabolic mirror is designed to be in the same location of the focal point of the refocusing elliptical mirror. This second elliptical mirror concentrator refocuses the light to an exit opening or a light pipe. A solar cell lies at the end of the light pipe or the opening, below the parabolic reflector. The light pipe, while optional, is preferred because it provides more latitude in tracking, and spreads the light more evenly on the solar cell resulting in a better performance.

[0011] The depth of the parabolic reflector is about 66 mm for a 5 mm square solar cell. The depth of the concentrator should be comparable to the flat solar panels, with a depth of between about 1 cm to about 20 cm being acceptable. A typical 300 times concentrator has a depth of between about 3 cm to about 10 cm, preferably 6 cm. A typical 500 times will have a depth of between about 5 cm and about 15 cm, preferably 12 cm. The aspect ratio of the concentrator is, however, large between 3:1 and 4:1.

[0012] The solar concentrator is used with solar cell to generate electricity alone or sometimes electricity and hot water. In one solar panel an array of these concentrators are arranged. Each element of the array has the concentrator as described above. The solar panel is maneuvered in such a way that the sun is perpendicular to the plane of the panel at all times.

[0013] In one particular embodiment of the present invention the three components are made separately. A plain glass plate is shaped with the central ellipsoid array. Then the glass is masked in such a way that the ellipsoid surface is exposed and the rest of the flat surfaces are covered or protected. Then the ellipsoidal surface is coated with a reflective coating like aluminum or silver. The second paraboloidal metal surface is similarly mirror finished. These surfaces are mated with the alignment features provided and sealed with a metal-to glass sealant such as silicone sealant "construction 1200 sealant" or Torr seal from Varian. An excellent glass to metal sealant is a thixotropic curing type adhesive that is available under the name Chem-seal-CS-3202. The central opening in the parabola is now inserted with the light pipe and secured. This forms the concentrator. The array is then fitted with the solar cell such that the solar cell lies underneath the light pipe openings. There are three unique features associated with the making of these assemblies. First, the design is that the first focal point of the ellipsoid and the focal point of the parabola are coincidental. Second feature is that the second focal point of the ellipsoid is where the exit aperture or the end of the light pipe is located. In this embodiment the present invention advantageously enables, among other things, reduces the loss, enables a very compact design, it enables the reflective coatings to be on the inside of the concentrator and allows a hollow interior of the concentrator resulting in a light weight. The third feature is that the top surface of the concentrator is square and when arrayed, the squares fit perfectly next to each other without wasted space. The solar collection area is over 95%. The solar concentrator has to track the sun. The tracking mechanism carries the weight of the concentrator matrix. Our design, being light weight allows more concentrators to be added to the matrix for a given tracking motor power. The tracking systems are motor driven and the weight of the matrix is determined by the motor size. A typical 4 feet by 3 feet flat solar panel weighs about 30 pounds. The RX1 and other concentrator designs weigh 100 pounds for the similar area. In our embodiment a typical 4 feet×4 feet array will weigh about 25 pounds. This light weight allows the use of smaller slew motors, thus reducing the system cost.

[0014] In one particular embodiment of the present invention is used in solar power generation. An array of these concentrators is assembled with solar cells to form one panel or parquet. The top light receiving surface of each concentrator is square. Further they have alignment features and vertical support struts in all four corners. These support struts are secured to a metal frame with screws at the top surface. The bottom of the concentrator has the exit aperture of the light pipe. This aperture is extended out to a flat surface with an alignment hole for the solar cell. These features allow several concentrators to be secured rather easily on to a support base plate that has already the solar cell mounted. The solar cell is always square. In our embodiment the receiving area and the light pipe are made square. This results in the least wasted space. The support base plate is made of aluminum. A typical size of a panel is 4 feet by 6 feet. The center of this base plate has a securing bolt. This can be attached to the slew motor shaft. Each panel has its own tracking motor. The solar panel structure is controlled by a tracking device that aligns the panels such that they are facing the sun perpendicularly at all given time. The radiation falling on the concentrator is focused by the concentrator and falls on the solar cell positioned at the end of the light pipe. In this particular embodiment the present invention advantageously enables, among other things, a full aerial collection of the radiation, using a shallow and light weight, cost effective collection of solar energy, using very high efficiency solar cells or hydrogen generators solar spectrum converters.

[0015] It is therefore an object of the present invention to provide a solar concentrator that is very thin, light weight, cheaper to manufacture than existing solar concentrators and which can be installed almost anywhere.

[0016] It is another object of the present invention to provide a solar concentrator that has a receiving surface made of metal. The metal surface will act as a heat shield for the solar cell and also act as a heat conductor reducing the Infrared radiation falling on the solar cell.

[0017] It is a further object of the present invention to provide a solar collector that has all the mirrored surfaces shielded (i.e., not exposed) to outside atmosphere. They are semi-sealed and the cover glass serves dual purposes, one as a cover glass and second as the concentrating mirror.

[0018] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, which are intended to be read in conjunction with both this summary, the detailed description and any preferred and/or particular embodiments specifically discussed or otherwise disclosed. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of illustration only and so that this disclosure will be thorough, complete and will fully convey the full scope of the invention to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. **1** illustrates the cover glass with central ellipsoidal mirror.

[0020] FIG. **2** illustrates the bottom metallic parabolic mirror.

[0021] FIG. **3** illustrates the light pipe.

[0022] FIG. **4** illustrates the composite assembly.

[0023] FIG. **5** illustrates a auto-head lamp like solar concentrator.

[0024] FIG. **6** illustrates a top view of a solar concentrator array

[0025] FIG. **7** illustrates a tilted view of a 3×3 array.

[0026] FIG. **8**. illustrates a concentrator connected to a base plate with solar cell.

[0027] FIG. **9**. illustrates the base plate details containing the anode, cathode connections of the cell and the alignment feature.

[0028] FIG. **10** illustrates the focal points of the parabola and the ellipse.

[0029] FIG. **11**. illustrates the focal point of the ellipse inside the light pipe.

[0030] FIG. **12** illustrates the focal point of the ellipse inside the light pipe and the ellipse is placed below the surface-**1**

DETAILED DESCRIPTION OF THE DRAWINGS

[0031] The present invention is directed to a thin solar concentrator.

[0032] FIG. **1** shows a line drawing of the first surface **<100>**. This is a flat transparent glass surface with an elliptical dimpled surface, **<110>** in the middle. The lower drawing shows the geometrical relation of the hypothetical ellipse to other surfaces of the concentrator. The ellipse has two foci. The first focus point lies in line with the cover glass window surface. Also this same focus point of the parabolic focusing surface-**2**. The focal point **2** **<130>** is the vertex of the parabolic reflector. This is where the concentrated light exits and the solar chip is located.

[0033] FIG. **2** shows a line drawing of the parabolic receiving and focusing mirror **<200>**. This surface is made of thin metal or plastic coated with thin metal. The inner surface **<210>** is polished and mirrored. The top plane of the parabola is the plane where the cover glass is attached.

[0034] FIG. **3** shows the preferred shapes of the light pipe. Either a truncated cone or truncated square pyramid is used. The solar chip is located at the narrow bottom end of the light pipe.

[0035] FIG. **4** shows the line schematic of the concentrator assembly with the solar cell. The Cover glass **<100>**, elliptical mirror **<110>**, parabolic mirror **<200>**, light pipe **<300>**, and the solar cell **<400>** are shown.

[0036] FIG. **5** shows a 3 dimensional rendition solar concentrator. It is a single concentrator after the top surface-S**1** and Surface S-**2** are attached and welded together. Surface S-**2** is shown separately in picture-**2**. The solar cell **<400>** can be any type used in the industry like the silicon rear illuminated, or front illuminated, compound semiconductor single junction or multi junction cells or multi-energy cells. Any commercially available cell can be placed at the concentrated light exiting the light pipe. a molded and metalized concentrator, the preferred method of making the concentrator is much like making an automobile head lamp, and can be made of glass or plastic. The entire concentrator, including the top entrance surface with elliptical mirror-**2**, bottom parabolic mirror surface-**2** and the light pipe and holding clips are all made of single piece. The space within the bulb is atmospheric pressure or partial vacuum-sealed bulb. Main criteria for optimal performance are that the solar cell is placed at the vertex of the parabola, and the elliptical mirrors focal plane and the focal plane of the parabola are coincidental. Alternate ways of making the concentrator: (1) the parabolic piece is made of metal and attached to the top planar entrance sheet with elliptic mirror; (2) the top entrance piece is made of two pieces, one plane glass and an elliptical mirror attached to it; (3) the attachment method can be varied by different mechanical designs like clips, snap on grooves, metal clips etc.

[0037] FIG. **6** shows the top view of a 3×3 array of concentrators. This illustrates the true array of squares when assembled. The receiving surface is fully illuminated by the suns radiation. There is no wasted space in between concentrators.

FIG. **7** shows a 3×3 array of concentrator and solar cell mounted. The array can be any size typically it is 8×16. This array is secured along the edges by rigid fasteners. The assembly is mounted onto a tracking device that points the receiving surface <**100**> at all times towards the sun. The receiving surface <**100**> is made of a transparent surface like glass or plastic. 90 to 95% of this surface is transparent and the rest is an elliptical mirror pointed away from a molded and metalized concentrator, the preferred method of making the concentrator is much like making an automobile head lamp, and can be made of glass or plastic. The entire concentrator, including the top entrance surface with elliptical mirror-**2**, bottom parabolic mirror surface-**2** and the light pipe and holding clips are all made of single piece. The space within the bulb is atmospheric pressure or partial vacuum-sealed bulb. Main criteria for optimal performance are that the solar cell is placed at the vertex of the parabola, and the elliptical mirrors focal plane and the focal plane of the parabola are coincidental. Alternate ways of making the concentrator: (1) the parabolic piece is made of metal and attached to the top planar entrance sheet with elliptic mirror; (2) the top entrance piece is made of two pieces, one plane glass and an elliptical mirror attached to it; (3) the attachment method can be varied by different mechanical designs like clips, snap on grooves, metal clips etc.

[0038] FIG. **8** shows a line schematic of the concentrator attached to the base plate <**500**> and the solar cell <**400**>.

[0039] FIG. **9** Illustrates the details of the base plate. The base plate has the electrical conductors <**510**> and <**540**> screen printed on them. Also alignment and securing holes <**530**> are present that will keep the concentrator aligned and secure. The solar cell <**520**> is flip chip mounted and connected to the anode and cathode. At the corners of the concentrator are securing fasteners that attaches the concentrator to the base plate.

[0040] FIG. **10** shows the focal points of the ellipse and the parabola. The focal point of the parabola is at the vertex where the solar cell surface is placed.

[0041] FIG. **11** shows the second focal point of the ellipse in the middle of the light pipe rather than the end.

[0042] FIG. **12** shows another variation. The ellipse is now placed under the receiving surface <**100**>. The focal point-**1** of the ellipse is non-coincidental with the focal point of the parabola. Also the focal point-**2** of the ellipse is not at the vertex of the parabola.

[0043] While the present invention has been described above in terms of specific embodiments, it is to be understood that the invention is not limited to these disclosed embodiments. Many modifications and other embodiments of the invention will come to mind of those skilled in the art to which this invention pertains, and which are intended to be and are covered by both this disclosure and the appended claims. It is indeed intended that the scope of the invention should be determined by proper interpretation and construction of the appended claims and their legal equivalents, as understood by those of skill in the art relying upon the disclosure in this specification and the attached drawings.

What is claimed is:

1. A solar concentrator comprising: a parabolic reflector having an edge, an opening and a focal point; a cover having a top and a bottom and further being made up of an first surface that allows light to pass through and an elliptical concentrator portion, with the elliptical concentrator having a first focal point in line with the cover glass and a second focal point, wherein the second focal point of the elliptical concentrator is in the same location as the focal point of the parabolic reflector; and a solar cell located below the opening of the parabolic reflector; wherein at least a portion of the bottom of the cover surface rests on the edge of the parabolic reflector; and wherein the parabolic reflector collects light and redirects the light to the first focal point of the elliptical concentrator and onto the elliptical concentrator, upon which the elliptical concentrator refocuses the light through the second focal point and onto the solar cell.

2. The solar concentrator of claim **1** further comprising a light pipe having a side wall, a top periphery and a bottom periphery, wherein the side wall of the light pipe is disposed within the opening of the parabolic reflector.

3. The solar concentrator of claim **2** wherein the second focal point lies within the light pipe.

4. The solar concentrator of claim **3** wherein the parabolic reflector is polished and mirrored.

5. The solar concentrator of claim **4** wherein the parabolic reflector is made of a thin metal.

6. The solar concentrator of claim **4** wherein the parabolic reflector is made of plastic and coated with a thin metal.

7. The solar concentrator of claim **5** wherein the metal the parabolic reflector is made of is aluminum.

8. The solar concentrator of claim **6** wherein the metal coating of the parabolic reflector is a chrome plating.

9. The solar concentrator of claim **6** wherein the metal coating of the parabolic reflector is selected from the group consisting of nickel, chromium and a nickel-chromium alloy.

10. The solar concentrator of claim **7** wherein the first surface of the cover is transparent.

11. The solar concentrator of claim **10** wherein the first surface of the cover is made of plain glass.

12. The solar concentrator of claim **10** wherein the first surface of the cover is made of plastic.

13. The solar concentrator of claim **11** wherein the depth of the solar concentrator from the top of the cover glass to the focal point of the parabola concentrator is in the range of between about 1 cm to about 20 cm.

14. The solar concentrator of claim **13** wherein the depth of the solar concentrator from the top of the cover glass to the focal point of the parabola concentrator is about 6.6 cm.

15. The solar concentrator of claim **14** wherein the depth of the parabolic reflector is 66 mm.

16. The solar concentrator of claim **15** wherein the aspect ratio of the solar concentrator is between 3:1 and 4:1.

17. The solar concentrator of claim **17** wherein the depth of the solar concentrator from the top of the cover glass to the focal point of the parabola concentrator is about 10 centimeters.

18. The solar concentrator of claim **17** wherein the depth of the solar concentrator from the top of the cover glass to the focal point of the parabola concentrator is about 15 centimeters.

19. The solar concentrator of claim **17** wherein the elliptical concentrator portion is between about 5 to about 10 percent of the surface area of the cover surface.

20. A solar concentrator array comprising: a plurality of connected solar concentrators, with each of the solar concentrators having a parabolic reflector having an edge, an opening and a focal point; a cover having a top and a bottom and further being made up of an first surface that allows light to pass through and an elliptical concentrator portion, with the elliptical concentrator having a first focal point in line with the cover glass and a second focal point, wherein the second focal point of the elliptical concentrator is in the same location as the focal point of the parabolic reflector; a light pipe having a side wall, a top periphery and a bottom periphery, wherein the side wall of the light pipe is disposed within the opening of the parabolic reflector, and a solar cell is located below the bottom periphery of the light pipe; wherein at least a portion of the bottom of the cover surface rests on the edge of the parabolic reflector; and wherein the parabolic reflector collects light and redirects the light to the first focal point of the elliptical concentrator and onto the elliptical concentrator, upon which the elliptical concentrator refocuses the light through the second focal point, which lies within the light pipe, and onto the solar cell located below the bottom periphery of the light pipe.

* * * * *