NATURAL CRITERION FOR DEFINING THE 3D FOCUS OF A PARABOLIC SOLAR COOKER COMPOSED OF FLAT LAMELLAE

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Abstract

Although a large number of models of parabolic solar cookers have appeared on the market in the recent years, still lacks a three-dimensional understanding for this type of appliance. The aim of the study is to build up a clear three-dimensional picture of the reflected light beam compression and to determine the spatial boundaries of what we call "focus" in the case of flat lamellae reflector.

A method is developed for deriving the 3D-focal area of a parabolic solar cooker composed of flat lamellae. The 3D-study revealed that a finite number of 3D light-layers can be identified, representing the successively increasing compression of the reflected light beam. The last and uppermost light-layer has the highest compression and naturally represents what we call "focus".

For better understanding of the essence, the new method is illustrated by a parabolic of equal depth and focal length. A concrete reflector of 80cm diameter was studied, consisting of 12 equal flat lamellae, focal length = depth = 20cm, bottom opening 12cm.

A 3D-body of the light, reflected from a single lamella, is first constructed and then multiplicated by Circular pattern around Y-axis. Finally, the intersections of the single 3D light-bodies are derived as separate 3D-bodies. The 3D focus layer thus obtained is symmetrical, with definite thickness and volume – 14mm and 120ml respectively by the concrete parabolic reflector.

The method could be applied for 3D modeling of all types of parabolic solar cookers with even number of flat lamellae. Also for other types solar appliances where compression of light takes place. Required input parameters to obtain the parabolic 3D-focus layer, are only three: diameter and depth of the reflector, number of lamellae. Additional parameters could be established, as for example bottom opening and distance between the lamellae.

Autodesk Inventor is a software created for machine design. By introducing the conception of "the body of light", the present work demonstrates how this software could be applied in the study of the light structure of solar appliances. In terms of Autodesk Inventor, the light structure components are treated as "parts".

Software used: Autodesk Inventor Professional 2018, Excel.

Keywords: 3D-Focus, Parabolic, Body of Light, Thermal

METHOD

Fig.1 shows the reflector and the corresponding lamella being subject of the present study. The single lamella in working condition (LWC) is curved, following the chosen parabola. The reflector is constructed by Circular pattern of LWC around Y-axis.

Three steps could be distinguished in the process of building the 3D focus layer of a parabolic reflector.

Step 1. Building up the lamella-light-body (LLB) –Fig. 1.

One could observe that the reflecting surface of LWC consists of parallel parabolae of the same focal length. As a result, the corresponding focal points form a straight line – line AB in Fig.1. So, what we have by the flat lamella is a focus line instead of focus point. This important property is being utilized for the construction of LLB. The special Sculpt-command of the Inventor for filling with stuff a closed 3D-area, is also being used.

Step 2. Building up the body of light(BL) of the parabolic reflector by Circular pattern of LLB around Y-axis – Fig.2.

The intersection of LLBs results in a net of lines on the surface. The decoding of that net leads to identifying of six different 2D intersection area-types:

Type 1 – single area of nonintersected light;
Type 2 – single area of intersection of two lamella light bodies;
Type 3 – single area of intersection of three lamella light bodies;
Type 4 – single area of intersection of four lamella light bodies;
Type 5 – single area of intersection of five lamella light bodies;
Type 6 – single area of intersection of six lamella light bodies.

Each 2D single area intersection type(2D-SAIT) on the surface corresponds to a single 3D-body, i.e. 3D-SAIT, of a specific rib-form, under the surface.

Twelve 2D-areas of a given intersection type form the corresponding 2D ring on the surface. Each 2D ring type corresponds to a 3D ring type under the surface, consisting of 3D-SAITs. The 3D ring type №6 being the 3D focus layer we are looking for.

We have a 2D-net on the surface of BL, corresponding to a 3D body-“net” under the surface. We start from the 2D-net to reveal the 3D-net, having in mind, that 3D-bodies implicate 2D-surfaces, 3D-SAITs implicate 2D-SAITS, 3D-rings implicate 2D-rings.

Step 3. Deriving the 3D-rings as separate 3D-bodies.

At this step the instruments of Inventor software for intersecting and combining bodies are utilized, to derive the common parts between the lamella-light-bodies.

Each 3D-ring is actually an intermediate focus layer. The layer with the highest number is what we actually call “focus”. As the layer number grows up, decreases the volume and resp. increases the concentration of light and of thermal energy(Fig.3). The sequence of layers corresponds to consecutive states of the light beam. Layer №6 being actually what we call “focus” in the practical case. Note, that the sum of layer volumes equals the volume of BL.

Fig.4 reveals details of the most compressed light layer №6.

Fig.5 demonstrates the mechanism of adjusting between layers №6 and №5 – the last and the most compressed two layers. The underside ribs of layer №6 lie in the upperside beds of layer №5, and vice versa: the upperside ribs of layer №5 lie in the underside beds of layer №6. The same mechanism of mutual penetration is valid for all other consecutive layer couples: (1, 2), (2, 3), (3, 4), (4, 5). Layer №6 is the only one, whose upper side is made of no ribs, being a plane.

3D FACTOR OF COMPRESSION

The 3D-representation of the parabolic light structure allows new parameter to be introduced for describing the light beam compression: the ratio between the volume of nonintersected light layer and the volume of the most compressed focus layer, as parts of the whole body of light of the parabolic. In the practical case that ratio equals 258. (see Fig.3)

GEOMETRIC FOCUS AND THERMAL FOCUS

What has been said so far allows the conception and the term of "thermal focus"(TF) to be introduced. The thermal focus should be distinguished from the geometrical focus.
The geometrical focus(GF) of the studied light structure is represented by layer №6: 3D-details of GF as the most compressed light layer are represented in figures 3, 4, 5.
The presence of light-components in the 3D-outline of GF is considered in this study the criterion for their belonging to the thermal focus. TF in the practical case comprises the following components:

- the whole layer №6;
- the upper side ribs of layer №5;
- the four conical light forms in the centre of the GF-outline, belonging to layers 1-4, each of 14mm height, equal to the GF-thickness. (see Fig.3, Fig.6)

Generally, the vessel in a flat lamellae parabolic cooker is affected thermally by all degrees of light compression, incl. the lowest degree of nonintersected light - through its conical form in the centre. Fig.6 clears up the adjustment of the thermal focus components, originating from low-concentration layers 1-4.

In order to construct the final thermal focus, an important property is utilized – namely, the mirroring of the body of light of the parabolic with respect to the focal plane. Layer №6, being the uppermost focus layer of the concrete structure, is mirrored to its 3D-image, so that both layers – the “original” and the mirrored “copy” - form the complete thermal focus - Fig.7.
GF consists of the prime compression of the last layer, before intersecting the focal plane. TF comprises the doubled by mirroring GF plus the “filling” of lower compression layers.

APPLICATION TO DEEP PARABOLIC

The natural focus method could be applied to all types parabolics consisting of even number of lamellae. For illustration, a parabolic of 80cm diameter, 32 cm depth, 12.5cm focal length and 12 flat lamellae by bottom opening 12cm is considered.

The deep parabola is considered as consisting of two components. The final light structure is built up as superposition of the corresponding two light-components – see Fig. 8, Fig.9.

CONCLUSIONS

The 3D-compression of light and resp. of thermal energy by the parabolic cooker is a superposition of two independent mechanisms: parabolic compression within the lamella-light-body in XY-plane and compression in XZ-plane, resulting from the intersection between the light bodies of the different lamellae.

A method is developed for deriving the 3D-focus of a parabolic solar cooker, based on constructing lamella-light-bodies. The intersection of LLBs suggests a natural criterion for defining the 3D focus of the parabolic – namely, that is the 3D-layer obtained as common part from intersection of the greatest number of lamella-light-bodies. The number of compressed 3D light-layers is equal to half the number of the lamellae.

”Focus” turns out to be a 3D light-heater consisting of radiating “ribs”, with the number of ribs being equal to the number of the lamellae. The focus diameter is equal to the lamella width. What we call “focus” appears to be the “hat” of a sequence of intermediate prefocuses, i.e. intermediate 3D-layers of compressed light, corresponding to the intersection of increasing number of lamellae light bodies.

Difference should be made between the geometrical and the thermal focus**.** TF contains GF. The 3D-outline of the thermal focus follows the 3D-outline of the geometrical focus. GF consists of the prime compression of the most compressed layer. TF comprises light-components of all grades of compression that are being closed in the GF-outline from both sides of the focal plane.

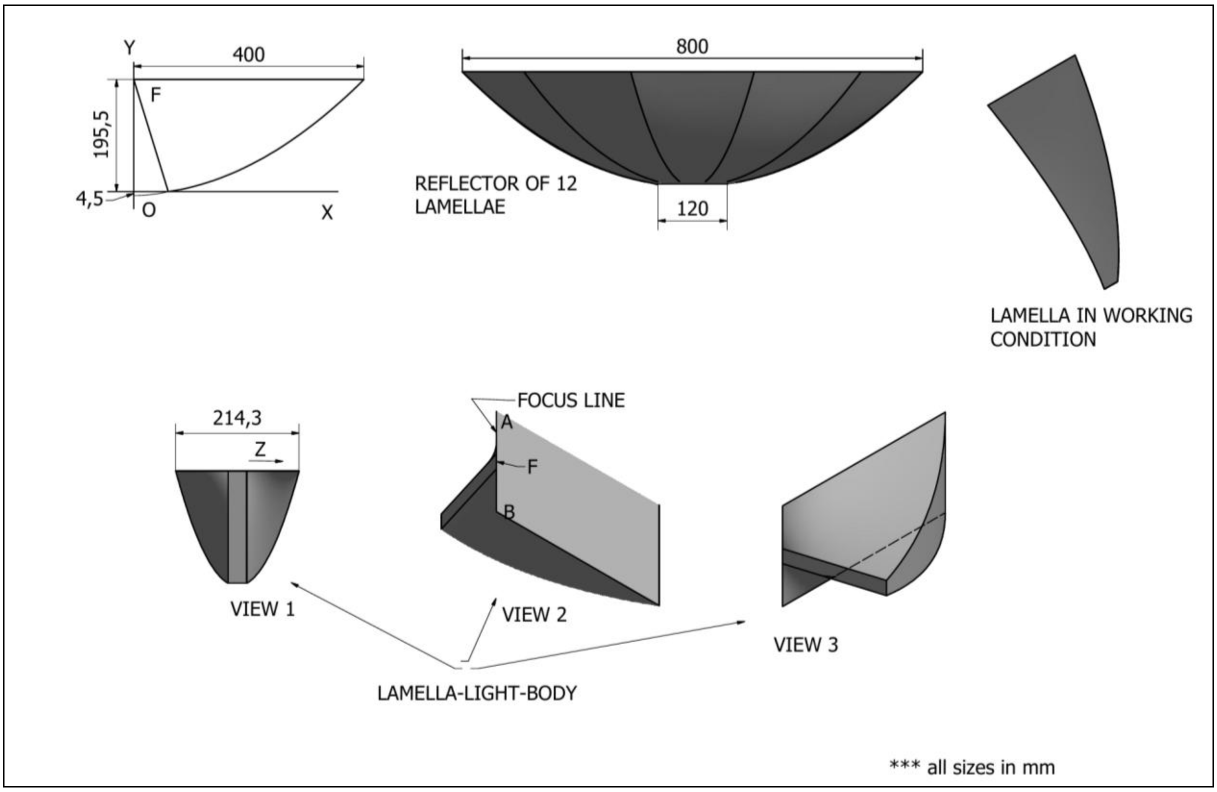

Figure 1. Parabolic d=800mm, f=200mm, 12 lamellae: lamella-light-body

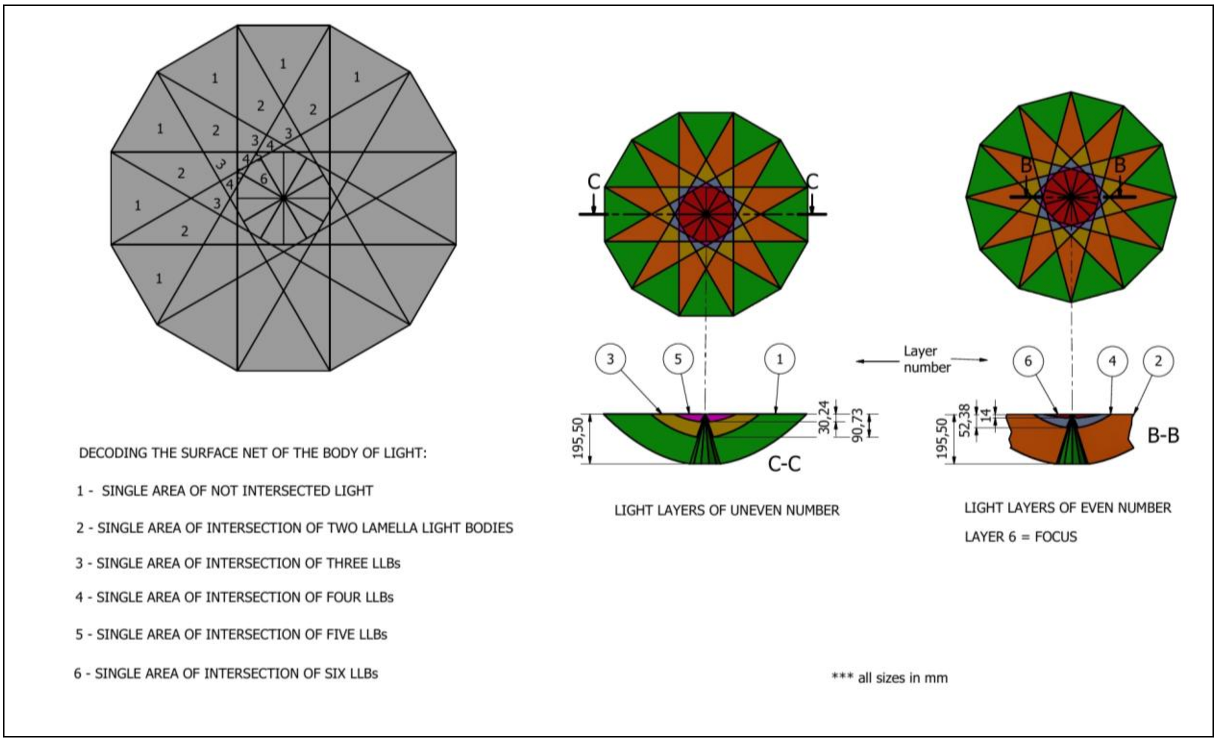

Figure 2. Parabolic d=800mm, f=200mm, 12 lamellae: Body of light of the parabolic solar cooker

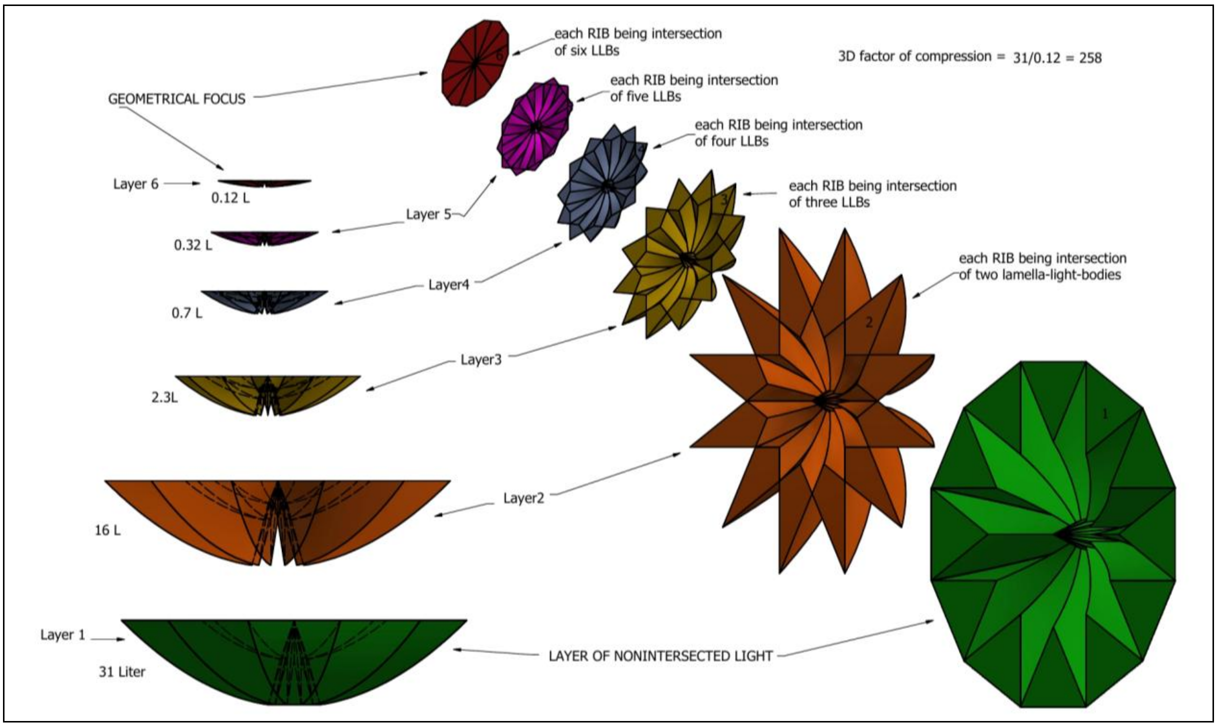

Figure 3. Parabolic d=800mm, f=200mm, 12 lamellae: Layers of increasing light compression

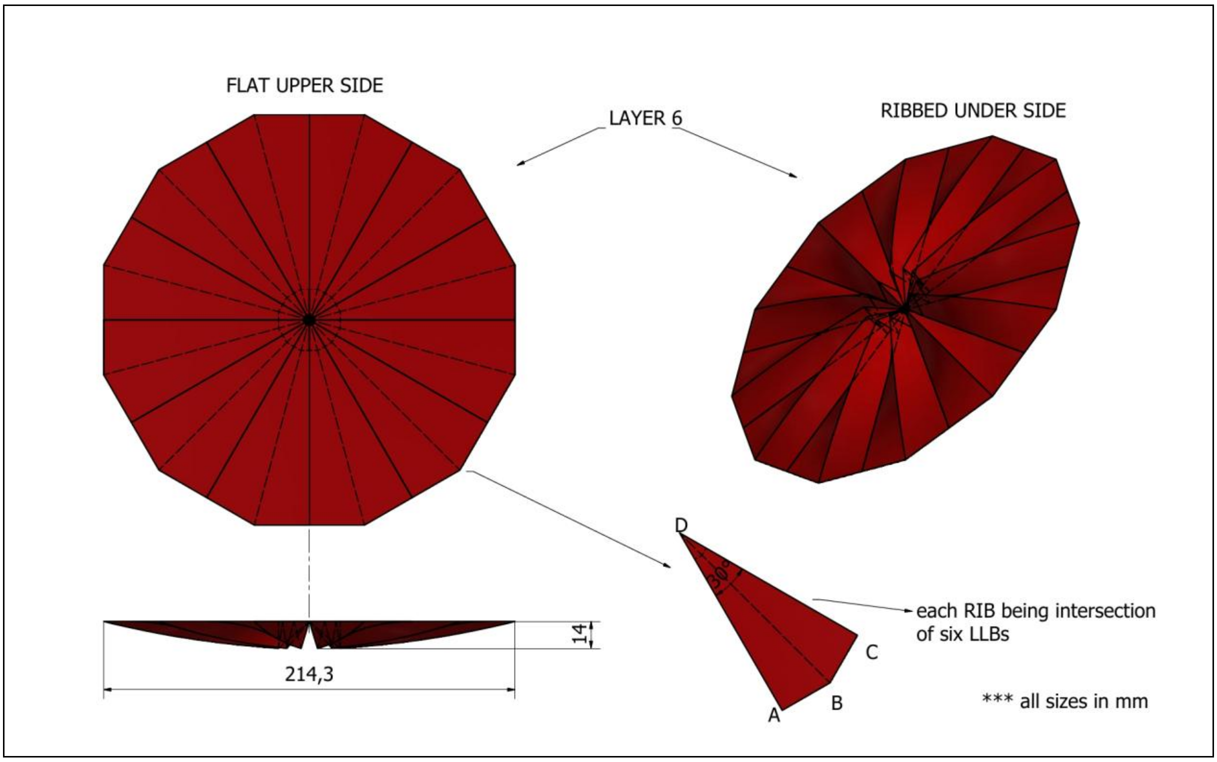

Figure 4. Parabolic d=800mm, f=200mm, 12 lamellae: 3D focus

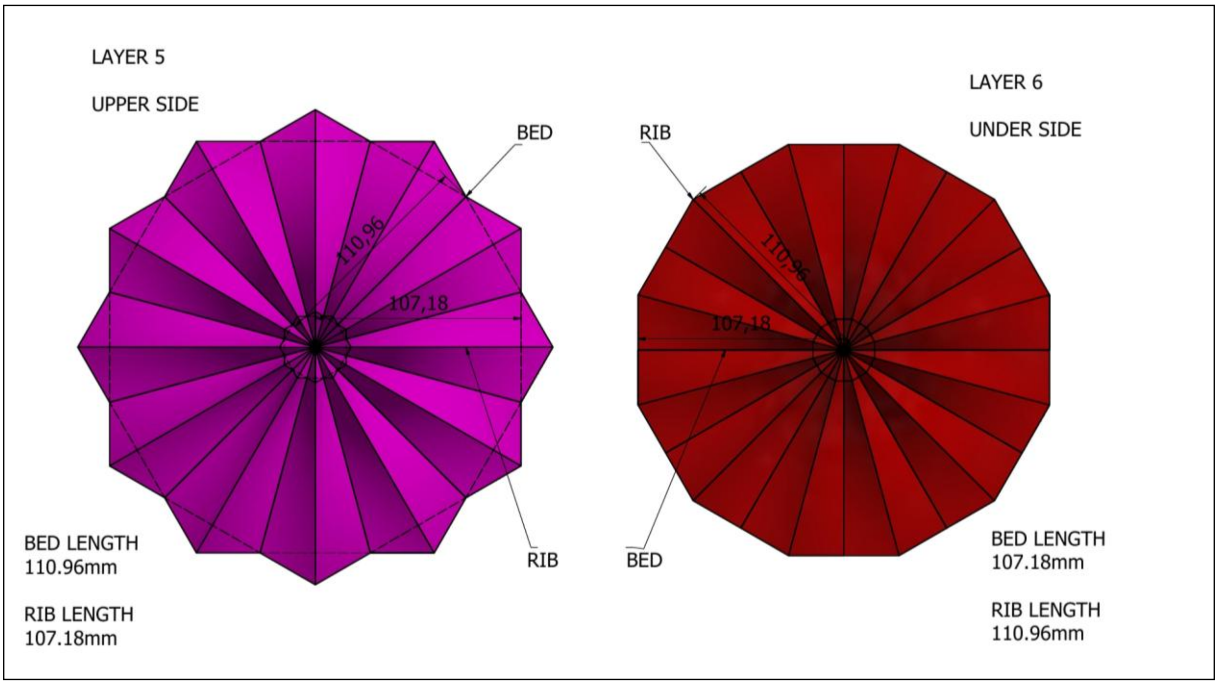

Figure 5. Parabolic d=800mm, f=200mm, 12 lamellae: Adjusting between the most compressed light-layers

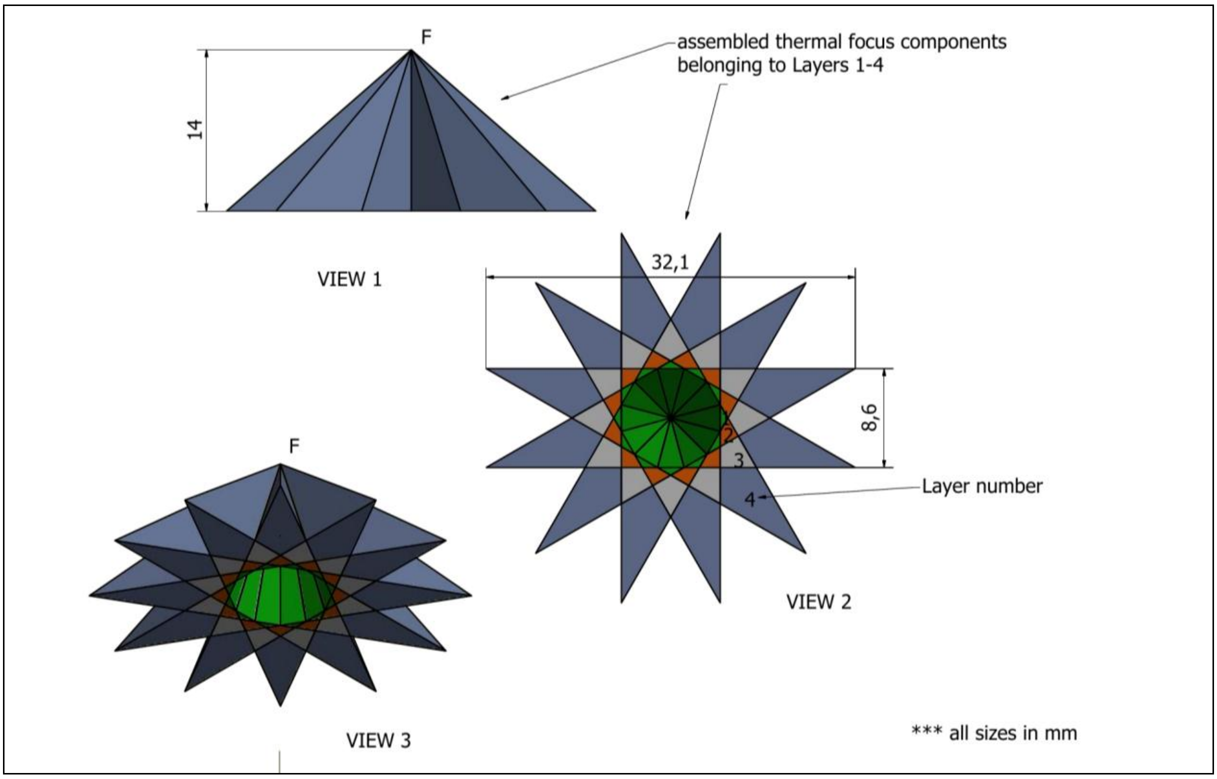

Figure 6. Parabolic d=800mm, f=200mm, 12 lamellae: Thermal focus components of lower compression

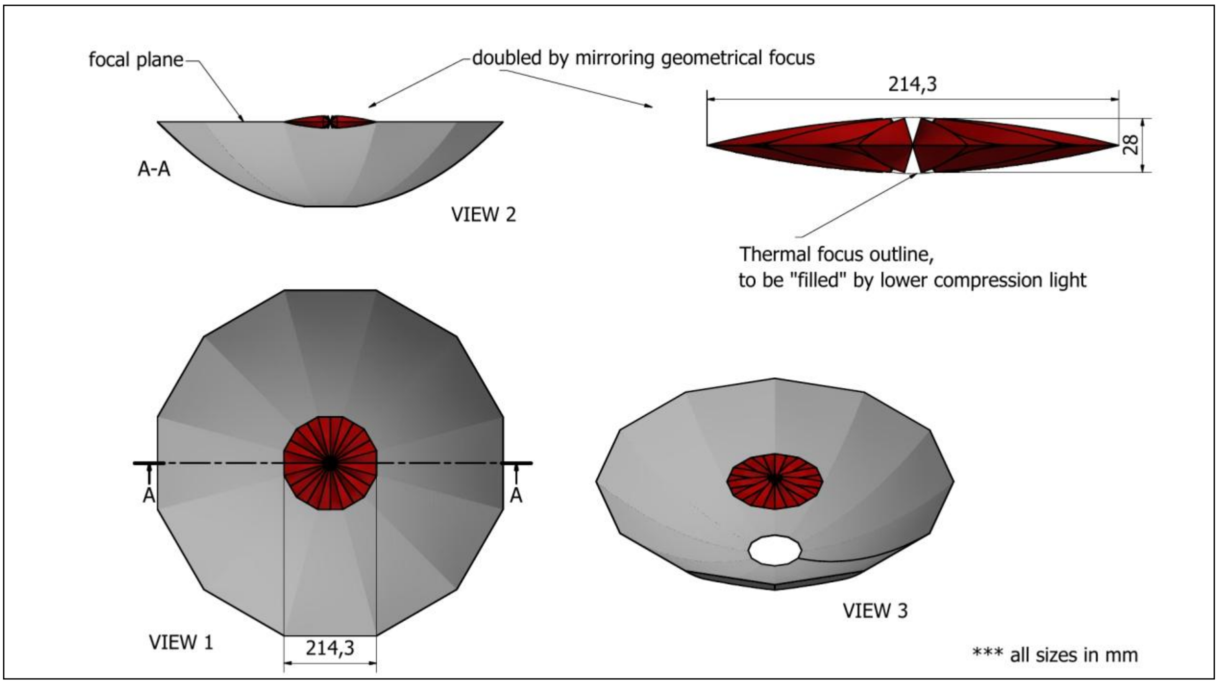

Figure 7. Parabolic d=800mm, f=200mm, 12 lamellae: Thermal focus

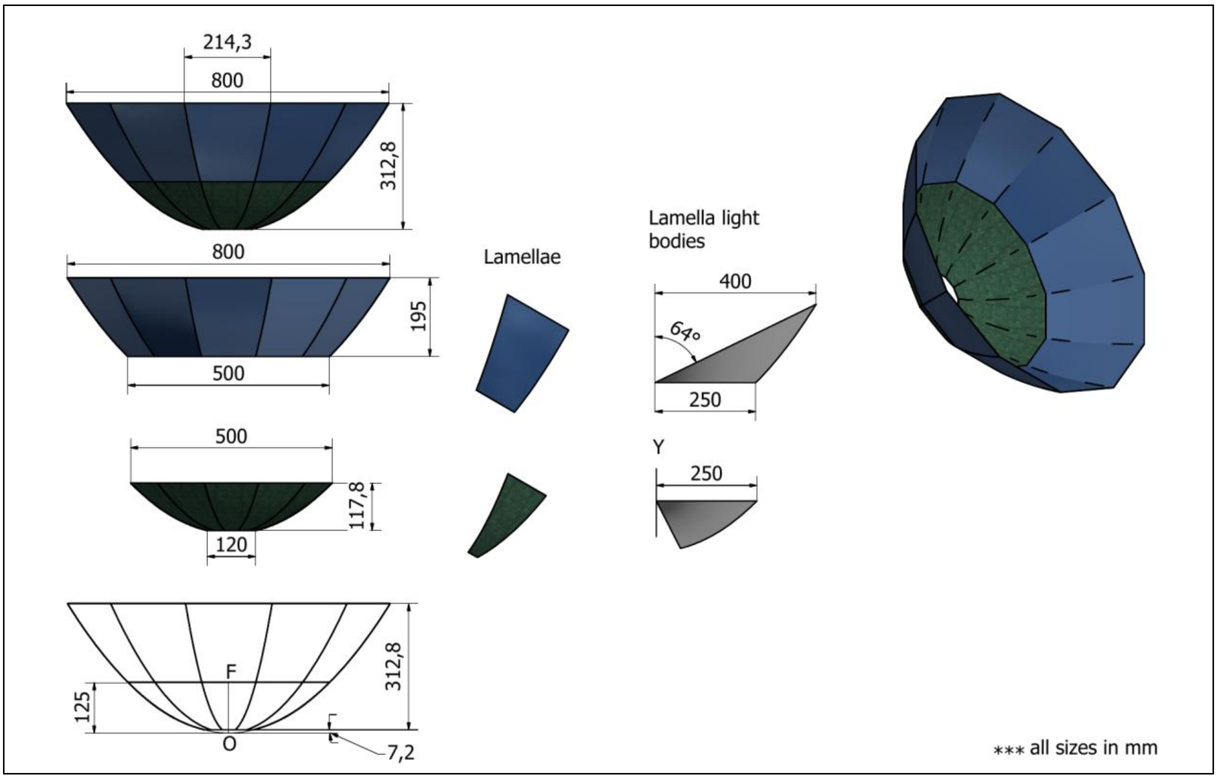

Figure 8. Deep parabolic d=800mm, f=125mm, 12 lamellae: Lamellae and Reflector

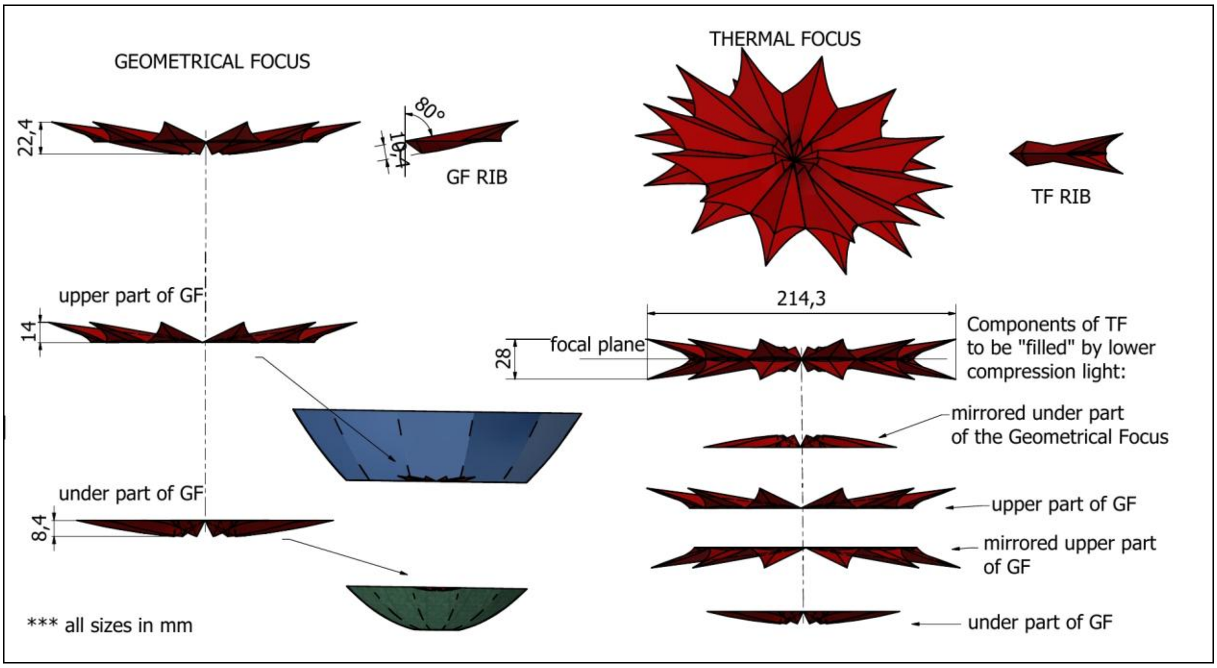

Figure 9. Deep parabolic d=800mm, f=125mm, 12 lamellae: Geometrical and Thermal focus