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SIMULATION OF PLANE FOCUSER FROM FRAGMENTS OF THE FAMILY OF SOFOCUS PARABOLS

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A computer graphic model for calculating a plane parabolic focuser is considered, the normal section of which consists of fragments of the family of confocal parabolas.

Keywords: flat focuser, parabolic focuser, sun concentrators, PlanarSun and Sun Simba.

Formulation of the problem. Well-known expediency of the use of concentrators of solar radiation [1]. French scientist Buffon in the mid-18th century first tested in practice the idea of concentration of solar energy. Until recently, the mirror systems that concentrate solar energy, are fundamentally different from the Buffon design. They consist of a set of individual mirrors (or one large mirror) that redirect the "sun bunny" into one common point. Libraries in the form of Fresnel lenses, which have the appearance of a quasi-planar relief structure of transparent light plastic materials, have received considerable popularity recently. Functionally, Fresnel lens solves the focus problem - similar to traditional glass lenses. Quasi-planar relief structures of the concentrators have a flat spatial shape, which in many cases is much more technological than the parabolic form. There are two types of planar concentrators of the sun - PlanarSun and Sun Simba [2, 3]. But their implementation in practice is associated with significant costs, which do not allow their widespread use in everyday life. Therefore, it will be advisable to develop flat concentrators focused on everyday use.

Analysis of recent research and publications. Two types of "solar crystals" are known for highly efficient transformation of light energy into electric (with an efficiency of more than 15%). Namely: monocrystalline silicon (mono-Si) and gallium arsenide-based heterostructures (GaAs). At the same time, the economics of the issue is closely linked with the specific value of cells of "solar crystals". The specific value of the cell of gallium arsenide is at the level of 3-15 $ / cm2, and the crystalline silicon is 0.01-0.02 $ / cm2. That is, the specific value of gallium arsenide per unit area is about three orders of magnitude larger. That is, to reach the price of a solar panel based on gallium arsenide, comparable to a conventional solar cell, its useful area can be reduced by five orders of magnitude. Therefore, it is advisable to use optical concentrators.

The creation of "solar crystals" allowed the development of a flat concentrator of minimum thickness, or a planar concentrator. At the same time, the degree of concentration was achieved sufficient for a serious economic effect. An elemental cell of the PlanarSun solar panel with a planar concentrator is a plate of plexiglas (glass) with a special surface and internal structure with attached photovoltaic converters (Fig. 1).

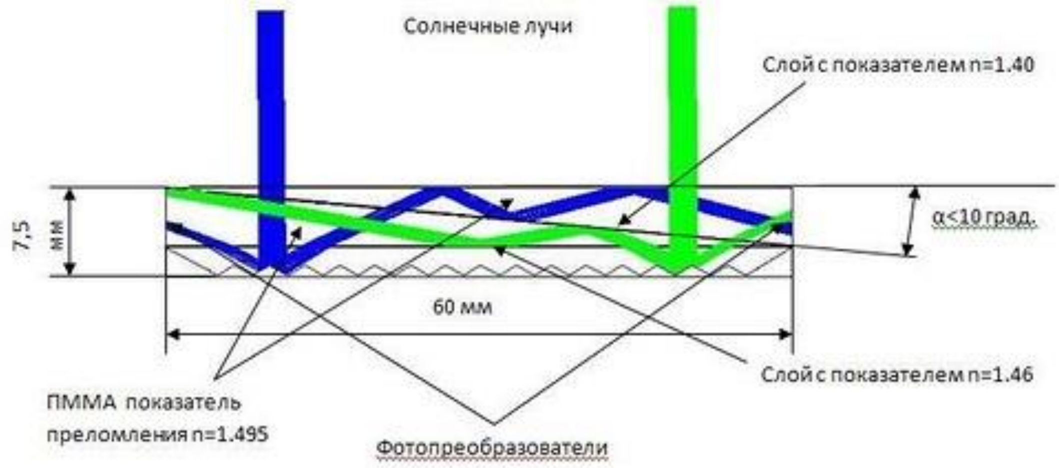

Fig. 1. Scheme of the concentrator PlanarSun (borrowed from work [2])

Falling near normal, the sun's rays with the entire plane surface of the planar concentrator are directed to two opposite ends, due to a single reflection from the back surface and multiple full internal reflections from the outer and inner surfaces. In the immediate proximity of the output radiation of the ends of the planar concentrator, there are photovoltaic converters that have a geometric dimension corresponding to the end face. This design of the planar concentrator allows you to create devices with a thickness 10-20 times smaller than its width of the surface from which solar energy is collected.

More promising and promising is considered by Sun Simba, a planetary solar hub (which, incidentally, tens of millions of dollars was invested [3]) proposed by Morgan Solar. Several options for focusing solar radiation using 1-3 aspherical surfaces have been developed. The simplest of them is clearly represented in rice. 2, which consists of aspherical grooves located in a circle. The principle of the Sun Simba concentrator is as follows.

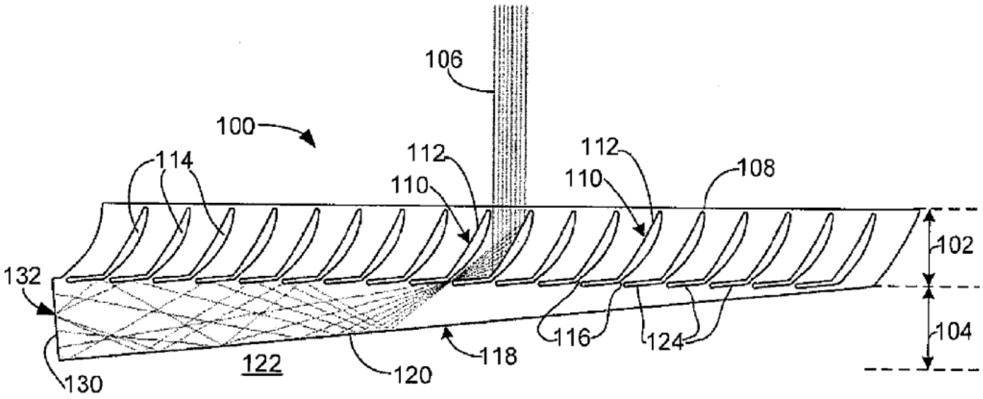

Fig. 2. The scheme of the Sun Simba concentrator (borrowed from work [3])

The barrels simultaneously focus on incident radiation in small "gaps" (Fig. 2). Further, the radiation enters the wedge, which can not escape, and extends to the "solar crystal".

Compared to PlanarSun, the Sun Simba system provides a higher concentration of radiation - practically to a point, not to two opposite planes. On the other hand, the PlanarSun has more corner field for one coordinate, which makes it easier to follow the direction of the sun. But their main advantage is the flat geometric form, which in many cases the introduction is much more technologically more convenient than the parabolic form.

Formulating the goals of the article. To develop a computer graphic model of the calculation of a flat concentrator in the form of a parabolic focal point, the normal section of which consists of fragments of the family of symphonic parabolas.

Main part. Consider the formation of a component of the surface of an optical element that focuses radiation with a plane front to a point. Let a beam of parallel rays, directed in the opposite direction relative to the axis, fall on the reflecting surface Oz [4]. It is necessary to focus this radiation on a coordinate point (0,0,f), moreover, the front of the reflected wave must be spherical. In this case, eikonal of the reflected field can be expressed by the formula [5]:

$$\Phi_1(x,y,z) = -\sqrt{x^2+y^2+(z-f)^2}\ .$$

Let's denote through λ the wavelength of the radiation and write the equation of the equivalent focusing surfaces of the rotation in the form:

$$z-\sqrt{x^2+y^2+(z-f)^2} = C+m\lambda,\ m=0,\pm1,\pm2,... \qquad (1)$$

Let's solve equation (1) relative z as a function x, y; then we get:

$$z = \frac{x^2 + y^2}{2(f - C - m\lambda)} + \frac{f + C + m\lambda}{2}. \tag{2}$$

All surfaces, which are described by expressions (2), are paraboloids of rotation with tricks at the point (0,0,f). Next we will be interested only in the fragments of the surface, which are located near the plane z = 0. So let's put it C = - f and we will investigate the family of surfaces

$$z_m(x,y) = \frac{1}{2}\left[\frac{x^2 + y^2}{2\left(f - \frac{m\lambda}{2}\right)} + m\lambda\right].$$

Each of these surfaces (in Fig. 3 shows their central intersection) creates an identical wave field that focuses at the point (0,0, f), where the cell of the "solar crystal" is located. The same the wave field will create a piecewise continuous mirror surface composed of fragments of surfaces that are located near the plane z = 0 (in Figure 3 the cross section of this surface is shown by a thick line). But the height of the crests of the component surface is uneven. When $\frac{m\lambda}{2} << f$, then the expressions for the surfaces are simplified $z_m(x,y) \approx \frac{1}{2}\left[\frac{x^2 + y^2}{2f} + m\lambda\right]$.

And then the equation of the component of the surface can be written in the form:

$$z(x,y) = \frac{\lambda}{2}\left[\frac{x^2 + y^2}{2f\lambda}\right]. \tag{3}$$

In this case, the height of each crest of the relief will be the same and will be half the wavelength λ.

In practice, the phase optical element, which acts on reflection, is constructively constructed in the form of a flat parabolic focus. The section by the central central plane of its active surface is shown in Fig. 4. Structurally, the focusator can be provided (Fig. 5, a, b) with a rectangular shape (with focal line), or the shape of the surface of the rotation (with a focal focus). Such molds are relatively easy to manufacture on milling or turning machines.

For the energy calculation of a flat parabolic focuser, it is necessary to determine the parameter p of the parabola with the equation $y = f + \frac{x^2}{2p} - \frac{p}{2}$, he is optically equivalent (here f - focal length) [6]. The software created in the environment of the mathematical processor Maple is created in the work.

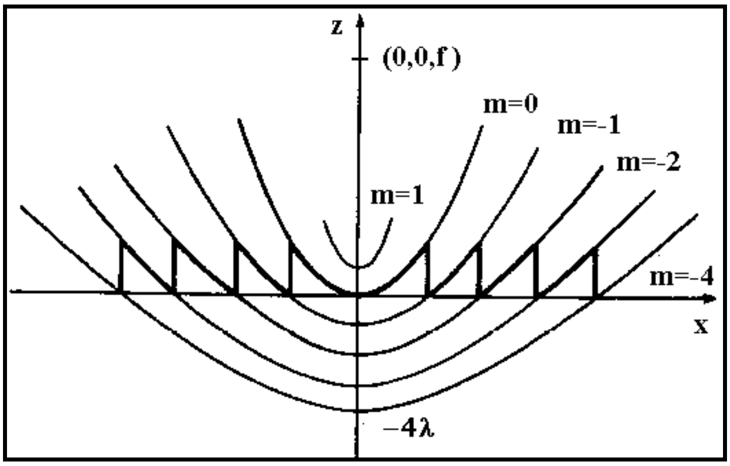

Fig. 3. Scheme of the formation of a flat optical element from a family of symphonic parabolas

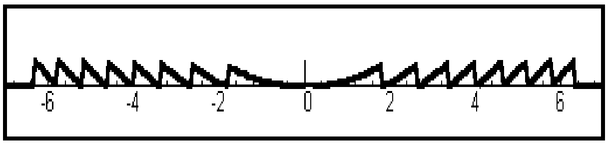

Fig. 4. Normal section of the flat focuser

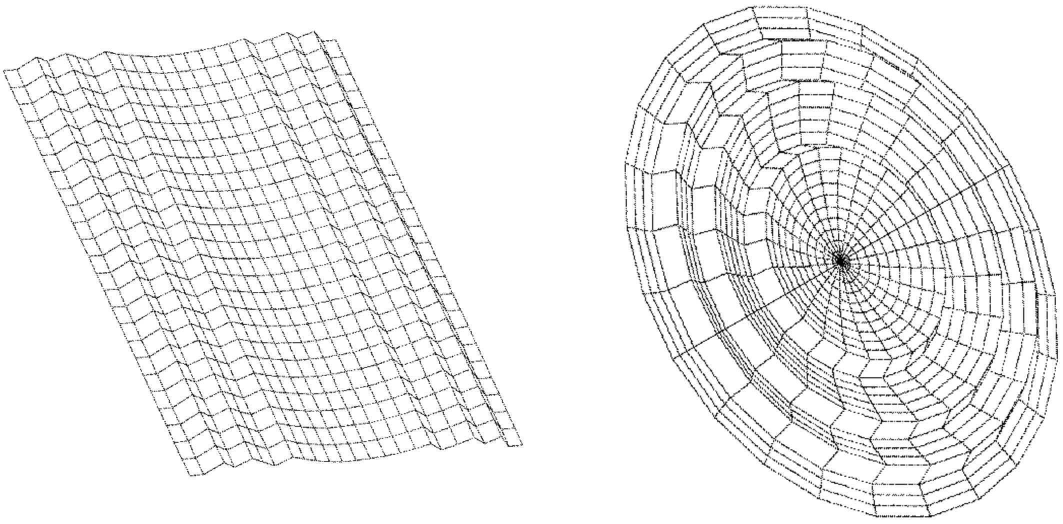

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Fig. 5. Schemes of structures of a flat parabolic focus

Conclusions. The developed graphical model of the calculation of a flat concentrator allows us to describe a parabolic focusor with a cross section in the form of family fragments of a symphonic parabola. Their implementation in practice is not associated with significant costs.

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МОДЕЛИРОВАНИЕ ПЛОСКОГО ФОКУСАТОРА ИЗ ФРАГМЕНТОВ СЕМЕЙСТВА СОФОКУСНЫХ ПАРАБОЛ

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Рассмотрено компьютерную графическую модель расчета плоского параболического фокусатора, нормальное сечение которого состоит из фрагментов семейства софокусных парабол.

Ключевые слова: плоский фокусатор, параболический фокусатор, концентраторы солнца, PlanarSun и Sun Simba.

МОДЕЛЮВАННЯ ПЛОСКОГО ФОКУСАТОРА ІЗ ФРАГМЕНТІВ СІМ’Ї СПІВФОКУСНИХ ПАРАБОЛ

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Розглянуто комп’ютерну графічну модель розрахунку плоского параболічного фокусатора, нормальний переріз якого складається з фрагментів сім’ї співфокусних парабол.

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