TECHNICAL CONCEPT AND SOME POSSIBLE APPLICATIONS FOR HIGH-TEMPERATURE PARABOLIC BLIND-REFLECTING SOLAR CONCENTRATORS

VIKTOR VASYLYEV

Solar-Environmental Res. Center, Institute for Electromagnetic Researches,
P.O. Box 30, Kharkiv, 310052, Ukraine
Fax.: +38 0572 43 59 52, E-mail: vvs@land.kharkov.ua

ABSTRACT. There is a steady prejudice that the mirrors reflecting the light flux towards the source are necessary when the maximum possible one-stage concentration of solar radiation is required. The well-known parabolic dish collector is a most effective optical system among such mirrors. An alternative approach for creating the better-concentrating solar collectors is proposed and discussed in this paper. The optical design of the proposed type solar concentrator is based on the multi-imaging approach, which suggests shaping and superpositioning of multiple source images/caustics in the common focal zone by a set of parabolic rings or bands. Such a technical concept possesses the two main advantages: very high concentration level, which can reach half of the thermodynamical limit, and rear disposition of the focal zone relatively far away from the reflecting elements. These advantages allow to apply parabolic blind-reflecting concentrators as a more promising solar optics for Stirling or photovoltaic power systems, as well as for various "immediate" thermal technologies and solar architecture of small individual cottages and social buildings.

1. TECHNICAL CONCEPT

The technical concept of parabolic blind-reflecting solar concentrator is based on the so-called multi-imaging approach [1-3], which suggests shaping and superpositioning of multiple source images/caustics in the common focal zone by coaxial set of reflecting elements. To attain maximum concentrating ability the elements are rings with the inner reflecting parabolic surfaces and disposed in the "Russian matreshka" style above the common focal plane (see Fig.1).

As Fig.1 shows the discussed optics design transforms the quasi-parallel solar radiation flux similar to Fresnel lens, being nevertheless a purely reflecting system. These properties of the parabolic blind-reflecting solar concentrator are achieved at the expense of transition to multi-element zoned mirror, whose each element is a grazing incidence reflector screening neither of the rest of elements both in the incident and in the convergent light beams.

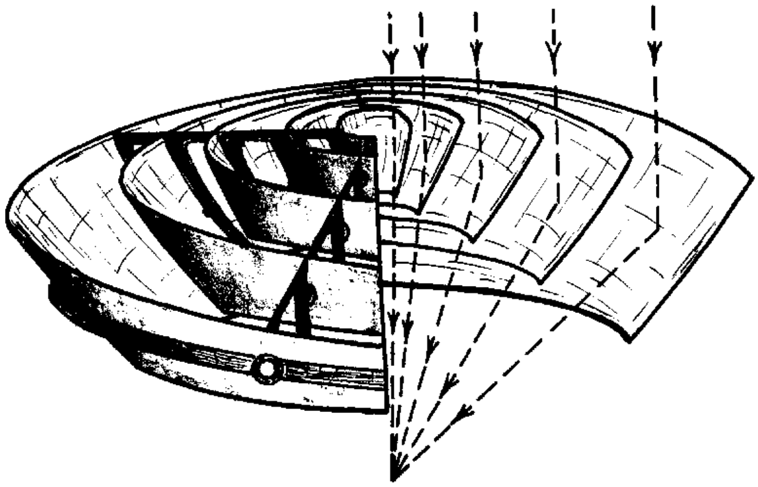

Figure 1. Schematic view of the multi-imaging blind-reflecting concentrator

The multi-imaging version of a blind-reflecting concentrator permits the concentration degree reaching half of the thermodynamical limit [3] with the optimum-selected parameters, number and mutual disposition of parabolic reflecting rings. The linear version of a blind-reflecting concentrator is the set of concave bands with parabolic reflecting profiles, which are disposed confocally in accordance with the venetian blind scheme. Employing this version a linear caustics, where the solar-ray concentration level reaches 200 to 300, has been formed. In the both versions the reflecting concentrator elements are fastened on the open-work (web-type) frame (see Fig. 1), which practically does not screen the solar radiation.

2. POSSIBLE APPLICATIONS

The discussed optical design possesses the two main advantages over the well-known one-stage reflectors: a very high concentration level, and a rear disposition of the focal zone being relatively far away from the reflecting elements. These advantages allow to apply the blind-reflecting concentrator as a more promising alternative to the dish-Stirling system, since, in addition, it can be optimized and designed in accordance with the absorber dome shape for any of sizes and avoiding rigid mechanical connection with the tracking concentrator. Moreover, the properties and specific features of this type concentrators allow to effectively use them in the various immediate high-temperature techniques. Further we will touch some of the trends for such applications.

The estimates show that for the target/absorber efficiency being more than 50% its equilibrium temperature in the focal zone may exceed $3{\cdot}10^3$ K. Thus, the multi-imaging blind-reflecting concentrator allows to provide the direct water thermolysis for the hydrogen production. Attaining the super-high temperatures in the focal zone of the discussed concentrator means that it can create a "surface burn" and even ensure evaporation of any chemical element/composition. Therefore, it may be used for obtaining the diamond-like thin films as well as for surface treatment and hardening of metals and alloys. It is worth-while mentioning that our approach to creating a one-stage high-temperature light-transfer allows to expand the solar thermal technique over a wide new application area, for instance under natural conditions, when positioning the target/absorber (soil or sea) above the reflector is impossible in essence. Thus, the opportunity appears for possible super-high temperature treatment of soil and water aiming to destroy the dangerous objects, e.g. landmines, and industrial waste. It seams also promising to employ the blind-reflecting technical concept in developing a new type of secondary concentrators in the double-stage non-imaging solar optics, since the approach allows to apart the resulting caustics from the back face plane of the secondary reflector, which is impossible, for instance, in CPS [4] and TERC [5].

Among the linear-version blind-reflecting concentrator applications we may also belong the devices for water purification, PV systems and solar architecture. Nowadays the solar-energy active buildings of various functional designations are gradually growing popular. There are some solar-active approaches utilized in these buildings: photocells/photovoltaic converters, heated collectors and collectors with solar flux concentrating devices. Traditional solar concentrators require disposing a heated target/absorber above the reflecting elements in order to achieve the maximum concentration level. This forms the stereotypes for the architectural R&D, since, e.g. large buildings need high and separate constructions or towers.

Our approach can permit more compact architecture compositions as well as highly efficient solar-heat/electricity conversion. Depending on the building purpose the concentrator reflecting band can be either straight or bent and composed of either symmetric or asymmetric systems. The concave-plate inner surface reflects and focuses the solar radiation on the water-heating tank, heat tube or any other energy-converter, which is located in the common caustic of all plates.

The diagrammatic sketches for some solar-architecture solutions based on the blind-mirror collectors are shown on Fig. 2-6. Locating the focal zone under the reflecting elements provides natural enrolling of the collector into the general architecture composition, as well as the target/absorber positioning inside the building. Besides, at least hundreds of concentration degrees [3] and easy adaptivity of the collector design are attainable. For small individual cottages the blind collectors can be mounted in the partially/fully transpired roof, whose southern and northern slopes are lightcollecting (see Fig. 2, where the depths of reflecting elements are shown enlarged for clearness). Social buildings can be equipped with the blind collectors acting as tents and walls (see Fig. 3-6) or as details of interior design, if necessary. In all cases the lightness and tracery of the collector design leave much freedom for the architecture's fantasy and can be adapted to local climatic and architectural styles.

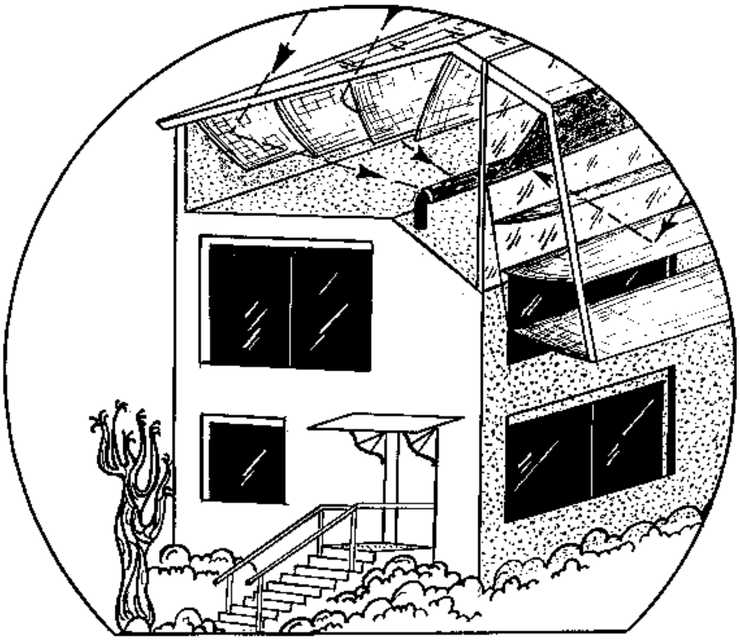

Figure 2. Individual small house with the roof arranged blind collector

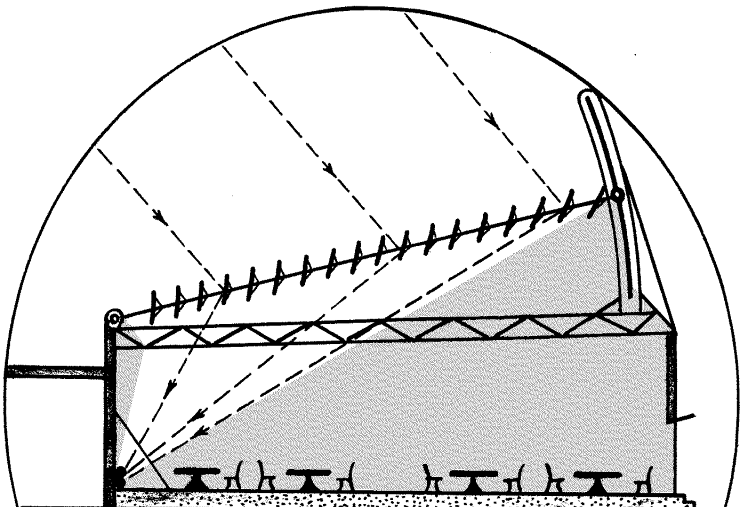

Figure 3. Blind collector with controlled declivity as a tent over the summer cafe

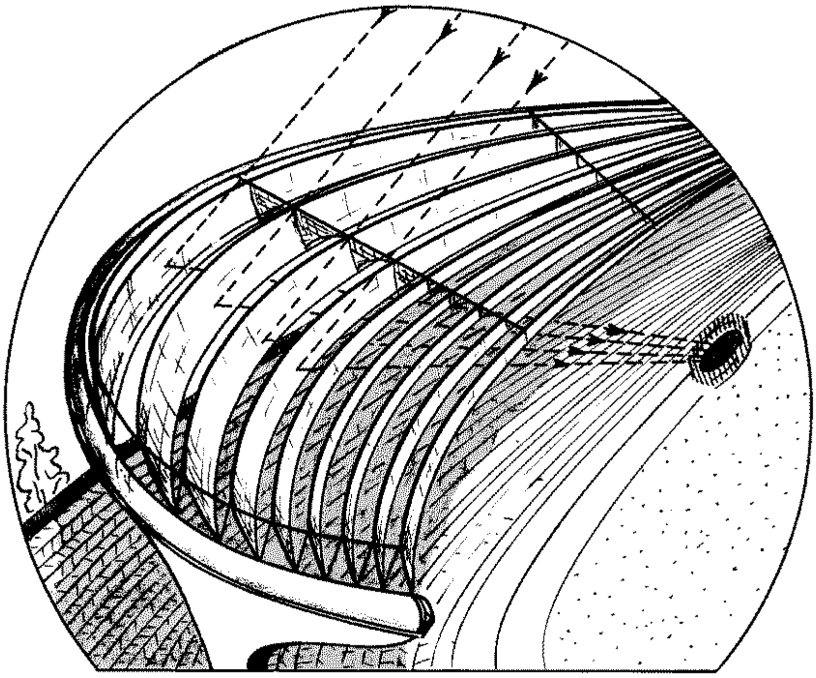

Figure 4. Blind collector as a tent over the stadium

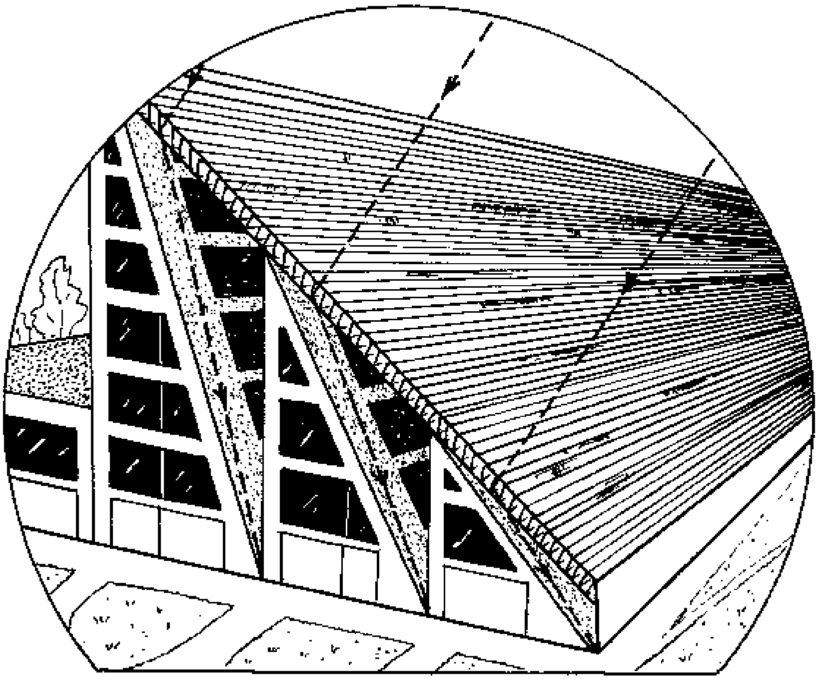

Figure 5. Blind collector as a pooling tent

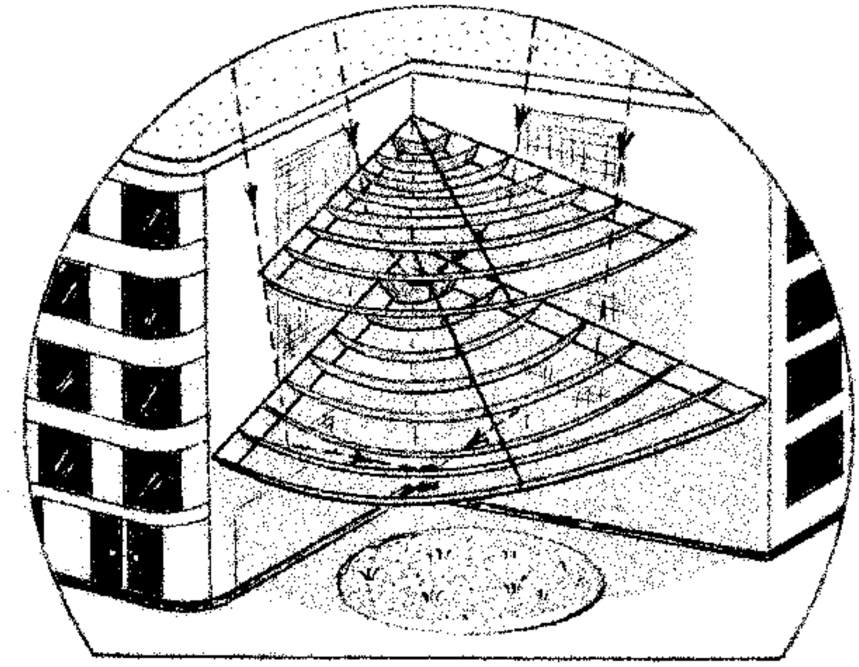

Figure 6. Sector blind collector on the building walls

REFERENCES

[1] Vasilyev, V.P. (1978), USSR Patent # 712251.
[2] Vasilyev, V.P. (1995), SPIE Proc., Vol. 2478, p. 301.
[3] Vasilyev, V.P. (1996), SPIE Proc., Vol. 2855, p. 313.
[4] Welford, W.T., Winston R. (1989), High Collection Nonimaging Optics, Academic Press, San Diego.
[5] Gordon, I.M., Reis H. (1993), Appl. Optics, Vol. 32, p. 2243.