ABSTRACT

Theoretical models of light collection in solar concentrators (SC) are presented together with new advancements of the theoretical analysis which leads to the introduction of new optical concepts and the definition of new optical quantities. Solar concentrators are viewed as generic optical systems whose reflectance, absorbance and transmittance properties are expressed as a function of different irradiation conditions. They are studied under collimated or diffuse light, under local or integral irradiation, including that in which light direction is reversed. All the results were obtained applying two basic concepts: the reversibility principle and the efficiency of transmission of an elementary beam. In this paper we discuss theoretical models of irradiation, which are simplifications of the outdoor irradiation conditions. For each model we derive a specific method of characterization of the SC that can be applied by optical simulations at a computer or by experimental measurements. A generic solar concentrator is schematized as a device confined by an aperture (a) with area $A_a$, where $A_a \geq A_c$ as required by definition of solar concentrator. A solar concentrator operates in practice under "direct" irradiation, that is under irradiation on the entrance aperture and with a receiver, the energy conversion device, at the exit aperture [1].

THE "DIRECT LAMBERTIAN METHOD" (DLM)

The "direct lambertian method" (DLM) has been introduced to study the transmission efficiency of a concentrator and using a lambertian source at output, in fact, new and surprising results appear, which allow to sustain an equal transmitted flux in the opposite direction is $C_0$. The last equation allows us to calculate the optical asymmetry of the SC disappears as long as the conductance of the SC is considered. The concentrator's conductance $C_0$ is given by: $C_0 = \frac{E_{\text{in}}}{E_{\text{out}}}$, where $E_{\text{in}}$ is the incidence radiance between input and output, then we have for the net flux through SC, in the direct direction:

$$\Delta \Phi = \Phi_{\text{in}} - \Phi_{\text{out}} = \Phi_{\text{in}} - \Phi_{\text{in}} = \Phi_{\text{in}} - \Phi_{\text{in}} = \Phi_{\text{in}} - \Phi_{\text{in}}.$$

This is a direct consequence of the geometrical asymmetry of the concentrator. Let us imagine now to irradiate the SC, is given by:

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The above discussion establishes therefore the suitability of the inverse lambertian method (ILM) to provide all information concerning the normalized efficiency of transmission of the concentrator under direct and collimated irradiation $\eta_{\text{inv}}(\theta, \phi)$. To perform the measurements of normalized inverse irradiance, it is sufficient to project the inverse light towards a flat plane screen and to record the image produced there; a simple elaboration of the image gives $\eta_{\text{inv}}(\theta, \phi)$.

We now define a new optical quantity, the "inverse lambertian conductance" $C_{\text{inv}}$, as the ratio of output to input flux:

$$C_{\text{inv}} = \frac{\text{input direct lambertian flux}}{\text{output direct lambertian flux}}.$$

The "inverse lambertian method" (ILM) provides also the quantity $\eta_{\text{inv}}(\theta, \phi)$, and so the "absolute" transmission efficiency $\eta_{\text{acc}}(\theta, \phi)$ without recourse to any direct measure by DCM, as it is demonstrated by the forthcoming considerations. When a 3D-CPC SC is inversely irradiated, the exit aperture becomes a Lambertian source with constant and uniform radiation $L_{\text{in}}(\theta)$. The total flux injected into the SC becomes:

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