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Introduction to the Special Issue: “Optical Solutions for Solar Energy”

The importance of renewable sources in the construction of a resilient national energy portfolio and to reduce climate changing emissions, is widely recognized. Among those, PV technology is now mature, having developed since the 1970s, but resistance still remain to its spread on a large scale due to its relatively low conversion efficiency. Unfortunately, there are still Sun-rich countries that have invested little on this technology, despite significant system cost reductions in recent years.

For large scale installation, concentrating photovoltaics (CPV) is demonstrating significant advantages with respect to flat panel systems. With CPV modules the solar radiation is usually focused on multi-junction solar cells. The key success factor for this technology is the high efficiency of the multi-junction solar cell, which settles down around 40%, that must be complemented by efficient optical concentrators. One of the challenges for the CPV technology is to reduce the price of devices, maintaining their high performance at the same time. Several system designs have been proposed. One approach to classify the different system designs is the primary optics used. For example, when parabolic mirrors are applied, this optics is particularly suitable for very high concentrations of 1000x and more. Considering that the solar cell is still costly, increasing the concentration factor is one way to reduce the module costs. In addition, in comparison to lens optics, mirror optics show no chromatic aberration. Another aspect of the module design is how the thermal energy is distributed. There are actively and passively cooled systems. The way of thermal management is essential for the high performance of the system; active cooling is preferred for use in large primary optics systems.

The special issue we propose here, albeit limited for the number of papers, wants to bring attention to the importance of optics in the development of concentrating solar photovoltaics. While optics is certainly present in planar photovoltaics (PV), where it is aimed at enhancing the performance of solar receiver (the solar cell) in terms of design of anti-reflection coatings and trapping of light inside the semiconductor layers, in the case of concentrating solar power, however, it is an essential element of the system. While providing the high power flux necessary for the cell operation, it must satisfy stringent cost, reliability and efficiency constraints.

All the works of this special issue are dedicated to the optical projects applied to concentrating photovoltaics. We find both reflective-type (Parretta et al.) and refractive-type concentrators (Parretta et al., De Luca et al., Maragliano et al.). Among the latter, of particular importance is the work of Maragliano et al., which combines the solar concentration with spatial spectral separation. Spectral separation is already applied in CPV through the use of multi-junction cells (triple-junction generally) (the work of De Luca et al, for example, describes a solar concentrator suitable for this type of solar cells). However, in this case, the spectral separation takes place inside the multi-junction cell itself. When radiation passes through the PV device, the high-energy radiation is absorbed in the first layer, a lower energy radiation is absorbed in the second layer, and so on; in this way the individual junctions work "in series" with potential issues when the PV device receives a radiation that is significantly different from that for which it was optimised. In the work of Maragliano et al., spectral separation takes place before the concentrated radiation meets the solar cells. The result is that each solar cell can be optimised with the band of assigned radiation and the solar cells can be connected in parallel, thus avoiding the disadvantages concerning the radiation spectrum. More fundamentally, this approach allows for wider latitude of converters to be considered.

The two works by Parretta et al. are devoted mainly to optical characterization of solar concentrators and describe in detail two methods suitable for this purpose, the traditional "direct" and the innovative "inverse” method, applied both to reflective and refractive concentrators. It shows that the "inverse" method is by far preferable to obtain all information about optical transmission efficiency as a function of the misalignment respect to the Sun.

We must mention here that the optics plays a vital role also in concentrating solar power (CSP), another concentrating solar technology important for his high conversion efficiency, and, above all, for the energy availability on the 24 hours, due to the possibility of thermal storage. As this is a large subject by itself; we hope to discuss it specifically in the future.

In conclusion, this special issue is just a first approach to the theme of the optics applied to the solar concentration. We hope that other special issues will follow in the future, when the technology associated with CPV and CSP will have marked further progress.

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