Experimental Characterization of Micro-Optics for Integrated Tracking Included in HIPERION micro-CPV Modules

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1. Introduction

Concentrator photovoltaic (CPV) technology, because of the extremely high efficiencies achieved by CPV systems, is nowadays widespread all over the world. Recently, the strong development in the methods and processes used to manufacture both solar cells and optical systems for CPV opened the door to the new frontier of the micro-CPV, that are systems that employs solar cell with a surface aperture smaller than 1 mm^2 [1].

The reduction in size of the solar cell implies the proportional shrinking of all the other components, which in turn made possible the implementation of novel features such as the *integrated tracking*. This technology has been conceived to avoid the use of the external tracking system. Hence, the primary optical element (POE) is designed in order to maintain the shape of the light spot also when sunlight impinges the lens with high incident angles (*i.e.* ±60º). Obviously, the spot position with respect to the lens varies requiring that the solar cells inside the module *follow* the spot (see figure 1a).

Nowadays, several possible architectures for integrated tracking are being investigated around the world. However, the closest to industrialization is the concept developed by the Swiss company Insolight SA which is currently being developed within the framework of the European project HIPERION (https://hiperion-project.eu/) [2]. Along the project, the modules continuously evolved from the first generation (called GEN0 and developed before the beginning of the project) to the current configuration (GEN2) implementing a series of overall improvement based on the experience learned along the technology development. This work is mainly focused on the difference between GEN1 and GEN2, where the optical design drastically changed.

2. HIPERION Modules: From GEN1 to GEN2

HIPERION modules are composed of a parquet of plano-convex hexagonal lenses of polymethylmethacrylate (PMMA) having a circumscribed circumference equal to approximately 16.6 *mm*. For both GEN1 and GEN2 the whole module size is equal to about 0.6 m^2 for around 3000 cell-lens pairs (see figure 1b). From GEN1 to GEN2 there are several differences such as the technology of the backplane where the solar cells are glued, and how the actuators used to move the integrated tracking mechanism and the guiding elements used to force the backplane movements into a spherical trajectory are attacched either to the front glass and to the backplane (in GEN1 they were glued while in GEN2 they are screwed). However, the most significant difference between the two generations is the optical design. For GEN1 the two-surface lens was molded as a single part and then mated to a front window glass that serves both as a rigid support as well as protection from outside environment (figure 2a). This has two drawbacks: first, two additional air-glass interfaces lead to unnecessary Fresnel losses. Second, it is difficult to attach lenses to the glass at their apex while balancing reliability and efficiency, due to limited surface area. In GEN2, the lens has been broken apart into two PMMA pieces, which are laminated on either side of the front glass pane (figure 2b). The efficiency improvement derived by removing two optical interfaces was estimated to be appoximately equal to 5% [2]. Furthermore, in GEN1 modules the reduced bonding area requires high precision device to dispense the glue exclusively in the apex of the lenses. With the used automated dispensing system about 6% of losses due to glue spillage were estimated [2]. Preliminary results on-sun at Insolight show 8-15% higher power from GEN2 against GEN1 modules.

3. Characterization of the Primary Optical Element (POE)

In this work the authors present a complete optical characterization of both GEN1 and GEN2 optical assembly. The optical efficiency of the lens is measured using the method described in [3]. In addition, the small sizes involved in micro-CPV require high precision alignment between the lens and the solar cell used as light sensor, which is carried out prior to any measurement using an iterative method.

The optical characterization has been carried out varying the angle of incidence (AOI) from 0° to 60° for both generations. As showed in figure 3, from GEN1 to GEN2 the measured optical efficiency is ~6% higher for every AOI except 60°.

In order to confirm that the higher optical efficiency of GEN2 design is beneficial also for a full HIPERION module, at the conference, a comparison of the electrical performance of complete GEN1 and GEN2 modules measured outdoor will be presented and compared with the optical characterization results.

References

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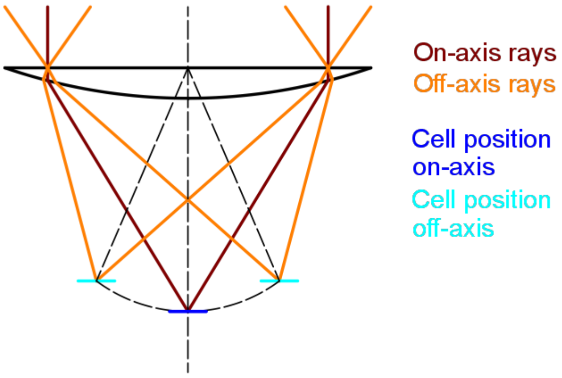
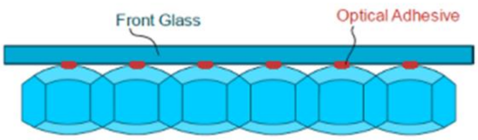


(a)

(b)

Figure 1. (a) Scheme of the internal tracking concept. Both on-axis and off-axis rays concentrate in a focus. Such focus moves as a function of the incident angle following a quasi-circular trajectory. (b) Photograph of GEN1 HIPERION module.



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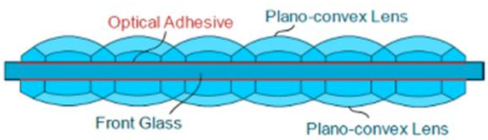

(b)

Figure 2. (a) GEN1 optical architecture (bi-convex lens mounted below glass. (b) GEN2 optical architecture (dual plano-convex lenses on either side of the front glass.

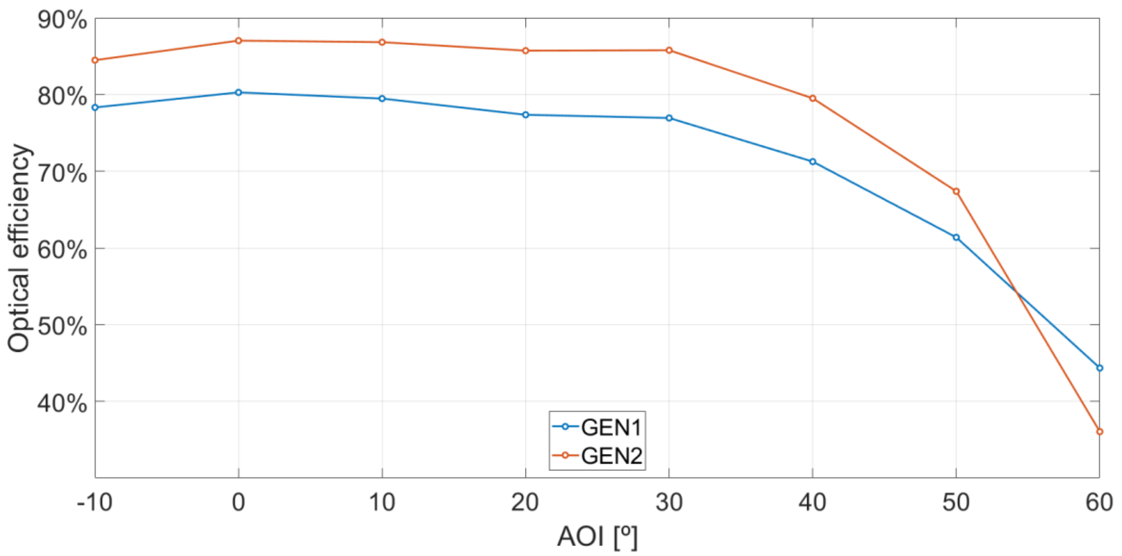

Figure 3. Graph respresenting a comparison of the measured optical efficiency of GEN1 and GEN2 HIPERION optical designs.

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