Concentrated Solar Flux Measurements Based on Optical Fibers and Multiple Photodetectors

SolarPACES

Javier García-Borja[1], Alejandro Carballar[1], Ricardo Conceição[2], José González-Aguilar[2] and Alexander Thies[3]

[1] Electronic Engineering Department – E.T.S. de Ingeniería – Universidad de Sevilla, Spain

[2] High Temperature Processes Unit, IMDEA Energy, Spain

[3] Engionic Femto Gratings GmbH, Goslar, Germany

*Correspondence: Javier García-Borja, javiergb@us.es

1. Introduction

Profitability of Concentrated Solar Thermal (CST/CSP) systems based on solar towers can be improved when accurate and efficient monitoring of the solar flux distribution is achieved. State-of-the-art solutions such as radiometers and camera-based techniques have proven usability under a fixed set of complex and strict requirements. Nonetheless, their necessity of recurrent maintenance entails an undesirable dependence. Therefore, a more flexible and practical alternative is needed. This work presents a novel approach for the measurement of concentrated solar flux using optical fibers as radiation collectors and different photodetectors as optical power meters. The combination of all these components demonstrates the feasibility to measure concentrated solar flux with a passive, compact, robust, minimum-invasive and efficient sensor, which is essential for advancing the challenges of the CST/CSP technologies [1].

2. System description

In CST/CSP applications, the inclusion of components adapted to high temperatures is key to withstanding extreme conditions. Here, special “ad hoc” optical fibers were designed and manufactured (Engionic Femto Gratings, Goslar, Germany) consisting of temperature-resistant gold coatings inside a stainless-steel capillary. An Incoloy 625/N06625 flat plate, coated by Pyromark 2500, served as support of the fibers tips and coordinates mapping reference, as illustrated in Fig. 1 (left), (center). Experiments were performed in the High Flux Solar Simulator KIRAN42 (IMDEA Energy, Móstoles, Spain) (see Fig.1 right) with input fluxes up to 1 MW/m^2.

***Fig. 1**: (Left) Frontside of the Inconel steel plate, with one fiber tip sticking out of the plate; (center) Backside of the Incoloy steel plate, with two optical fibers embedded in the lower part; (right) High Flux Solar Simulator KIRAN-42 (IMDEA Energy, Móstoles, Spain) with the central lamp on.*

Two different photodetectors were used to measure the optical power transmitted by the optical fibers. One photodetector belongs to the integrating sphere photodiode category (model S140C, Thorlabs), while the other one is referred to as a thermal power sensor (model S401C, Thorlabs). This slight distinction between photodiodes and thermal power sensors leads to intrinsic characteristics that alter the power measurement results.

3. Results

The designed testbench focused on verifying two concepts. Initially, the two types of photodetectors were compared in the same scenario to analyze quantitatively their impact on the measurements. The data collected has shown that both photodetectors, in combination with the gold-coating fiber, when correctly calibrated, have measured up to 220 kW/m^2, with a Gardon reference of 312 kW/m^2 (see Fig.2 a,b). Nevertheless, their behaviour was decisively unalike. While the thermal power sensor presented a slower time response, it manifested flat stability in the long term. From a different perspective, photodiodes have an immediate response in combination with a pronounced rippling. Secondly, lateral lamps were powered to provide non direct irradiance to the optical fibers. In that manner, it could be checked how the limited angle of acceptance of the optical fibers could alter the measurements. Not only was it proven that the maximum measured solar flux was notably less than the prior case, but besides the results showed a degradation of the measured flux. Apparently, the tip of the optical fiber, when exposed to high side irradiance is vulnerable to thermal damage.

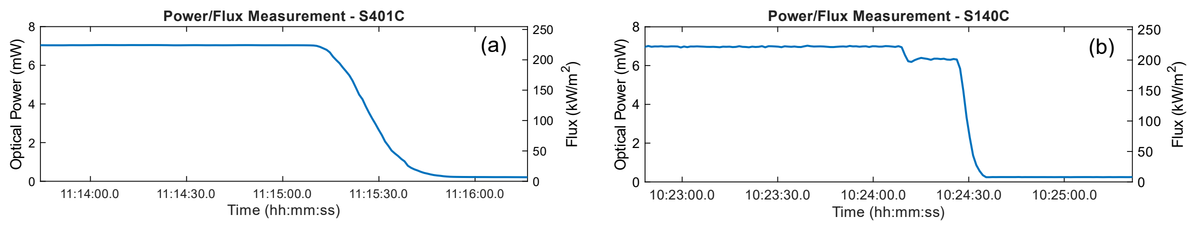

Fig. 2: *(a) Optical Power Measurement for a 312 kW/m^2 flux reference, using theS401C photodetector; and (b) Optical Power Measurement for a 312k W/m^2 flux reference, using te S140C photodiode.*

4. Conclusions

Photodiodes have better power sensitivity, enabling their use in DNI measurements [2] and CST/CSP applications where solar flux might present high variability. Photodiodes, however, present a restricted wavelength responsivity, creating the need for a calibration algorithm if the complete light spectrum wants to be considered [2]. Conversely, thermal power sensors are compatible for CST/CSP applications due to their low sensitivity and high flux requirements. Their wide wavelength responsivity range captures almost the totality of incoming light, removing the necessity of mathematical treatment. Current work is focused on widening the field of view, as well as reducing the temperature influence and dependence on the measurement.

Acknowledgements

This research was developed within CHLOE project, Grant PID2021-125786OB-C22 funded by MCIN/AEI/10.130339/501100011033. Lastly, funded by the European Union (ASTERIx-CAESar, id. 101122231). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

References

[1] M. Abdullah et al., “Advancements, challenges, and opportunities in the measurement of high heat flux for concentrated solar thermal systems”, Solar Energy, vol. 287, pp. 13252, 2025, doi: https://doi.org/10.1016/j.solener.2025.113252

[2] A. Carballar et al., “Measuring DNI With a New Radiometer Based on an Optical Fiber and Photodiode”, Sensors, vol. 2024, pp. 3674, June 2024, doi: https://doi.org/10.3390/s24113674