High-Temperature Distributed Measurements Based on Femtosecond Fiber Bragg Gratings

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1. Introduction

The operational efficiency of Concentrated Solar Thermal (CST/CSP) systems is intrinsically linked to the ability to perform precise thermal monitoring under extreme conditions [1]. Conventional high-temperature sensing methods, such as based on thermocouples, often encounter significant challenges regarding durability and integration complexity when deployed in solar receivers. In contrast, Femtosecond Fiber Bragg Gratings, fs-FBGs represent a more practical and robust alternative, offering the distinct advantage of providing consistent temperature measurements within a single-fiber architecture. This technology has proven particularly effective within the framework of the European project ASTERIx-CAESar, where volumetric absorbers are required to withstand temperatures reaching 1000 °C. In this demanding context, the implementation of fs-FBGs has demonstrated remarkable resilience and accuracy, establishing itself as a superior solution compared to traditional instrumentation for high-flux solar applications.

2. System description

The experimental configuration utilizes fs-FBGs provided by Engionic Femto Gratings (Goslar, Germany). These sensors were integrated onto a Incoloy 625/N06625 flat plate, coated by Pyromark 2500, where the optical fiber was precisely secured to the substrate surface through a series of mechanical clips and screw-based fasteners. A primary innovation identified in this work is the system's dual-mode measurement capability: the proposed architecture facilitates high-temperature sensing through both rear-side contact methods and direct front-side exposure to concentrated solar irradiance.

(a) (b)

Fig. 1: *(a) Frontside of the Incoloy 625 steel plate with the FBGs secured in its surface, surrounded by alumina; and (b) Backside of the Incoloy 625 steel plate equipped with the FBGs.*

This versatility allows for a comprehensive characterization of the thermal gradient within the receiver, whereas traditional methods are typically restricted to a single orientation. Consequently, the fs-FBG integration provides a robust and adaptable solution for monitoring extreme flux distributions, ensuring reliability even under the most demanding CST/CSP operational conditions.

3. Results

The experimental validation was conducted in the 42kW High Flux Solar Simulator RIRAN42 at IMDEA Energy (Móstoles, Spain). Under a peak flux of 360 kW/m² (calibrated via a Gardon radiometer), the testing protocol focused on the central Xe arc lamp to evaluate the fs-FBG performance. By modulating the orientation of the Incoloy 625 plate, the sensors were tested in both rear-side and front-side configurations. As illustrated in Fig. 2, the synchronized temperature profiles of the five fs-FBGs in the rear-side configuration demonstrated high stability, reaching values near 800 °C when the objective of the lamp focused on them. In contrast, the front-side configuration, subjected to direct irradiance, successfully monitored temperatures up to 1000 °C. These results are of paramount importance for the ASTERIx-CAESar project, as they confirm the feasibility of fiber-based sensing for volumetric receivers operating at extreme thermal thresholds. Future research will focus on the instrumentalization of the ASTERIx-CAESar volumetric receiver.

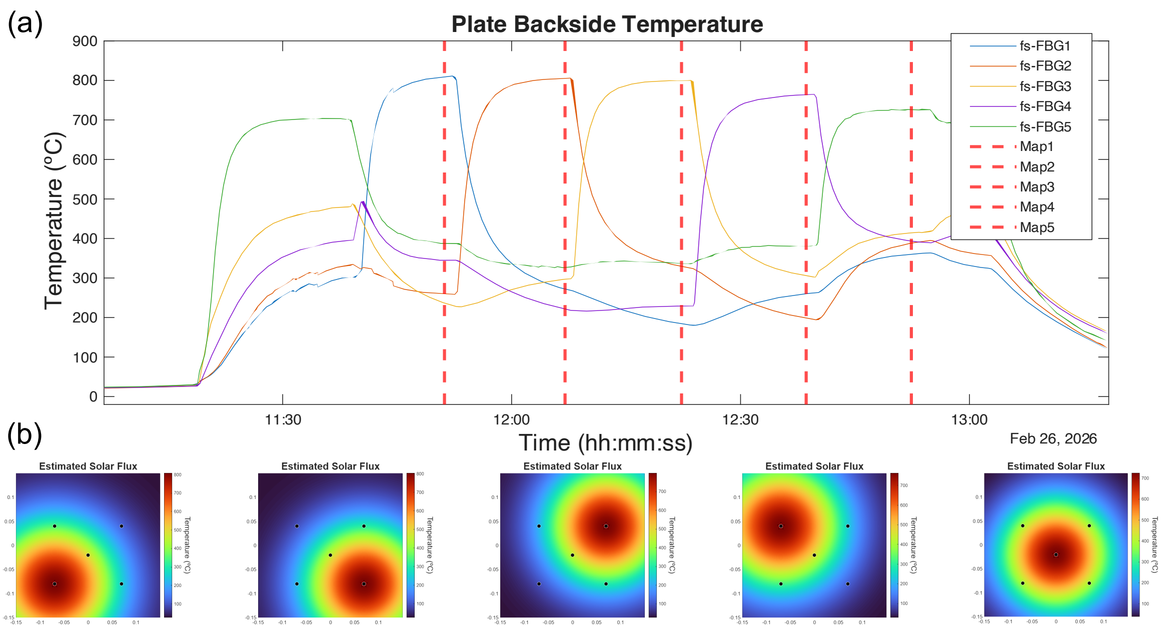

Fig. 2: *(a) Temperature measurements provided by the five femtosecond Fiber Bragg Gratings on the backside of the Incoloy steel plate; (b) Distributed-temperature maps for each focused point.*

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References

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