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Effect of spatial resolution of heliostat surface characterization on its concentrated heat flux distribution

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ABSTRACT

The optical characteristics of solar concentrators are key factors influencing the overall efficiency of solar power plants. For instance, heliostats need to be evaluated prior to installation and during its operation lifetime. This guarantees that the optical and thermal performance of these systems is close to design. One methodology that has gained importance due to its potential capabilities has been the Fringe Reflection Technique. This technique uses the reflection of a series of regular stripes to obtain the local slope deviations from a specular surface. Coupled to a ray tracing analysis, these slopes can be used to identify the distortion in concentrated solar spots. The enormous amount of data needed to carry out this analysis difficult its implementation at large scale. In this work, a study for determining the optimal number of sample points for heliostat surface characterization is realized. It has been found that, depending on the level of errors, the number SPFS required to reach convergence in the flux distribution profiles and intercept factors is variable. However, for the wide range of parameters considered in all cases 48 SPFS where enough to reach convergences to 1%. This is equivalent to one point per every 2.5 cm of facet side length. For values of slope and canting errors up to 2 mrad, half this density is sufficient.

1. Introduction

The Fringe Reflection Technique (FRT, also known as deflectometry) has been used with good success as a non-invasive profilometry technique for the characterization of irregular specular surfaces in several fields like the automotive industry (Kammel and Puente León, 2005; Kammel and Puente León, 2008). One of the first introductions of structured light reflection for solar mirrors was made by Fontani et al. (2005), by the Reflection Grating Moiré (RGM) method, which compares reflection of a projected pattern with a reference image. This method allowed the determination of the local slope map of the surface with high resolution. Later the Heimsath et al. (2008) introduced the FRT for the evaluation of the facets of a linear Fresnel collector. This method is based on projecting regular sinusoidal patterns one a screen, whose images are reflected by the mirror under evaluation and recorded by a camera. The distortion of the reflected fringe pattern is used to obtain a map of the local slopes of the mirror. This method has been used to evaluate different type of collectors: linear Fresnel collectors (Heimsath et al., 2008), heliostats (Ulmer et al., 2011; März et al., 2011), parabolic dishes (Andraka et al., 2013; Finch and Andraka, 2013; Andraka et al., 2009, 2011), and parabolic trough mirrors (Peña-Cruz et al., 2014).

The success of this methodology lies in the possibility to obtain the local slope deviations from the reflective surface of the concentrator with very high accuracy. Ulmer et al. (2011) reported a local error below 0.2 mrad, for parabolic trough concentrators, with typical uncertainties values are around 0.4–0.5 mrad (März et al., 2011). For parabolic dish facets (Finch and Andraka, 2013) a sensitivity of 0.05 mrad in slope deviations has been reported. Furthermore, the technique is also capable to provide very high spatial resolution (in the order of 1–100 data points per square centimeter). This allows for very detailed ray tracing simulations, where the large amount of information provides closer matching against experimental results.

In spite of the above, acquiring high data density with accuracy for far heliostats may be challenging. Also, the amount of information can be excessive for the simulation purposes; i.e., having a central receiver power plant with thousands of heliostats and consequently, having millions of data points per heliostat, which leads to the need of very

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Fig. 1. Hermosillo's Solar Platform (PSH) – National Laboratory of CSP and Solar Chemistry Systems (LACYQS).

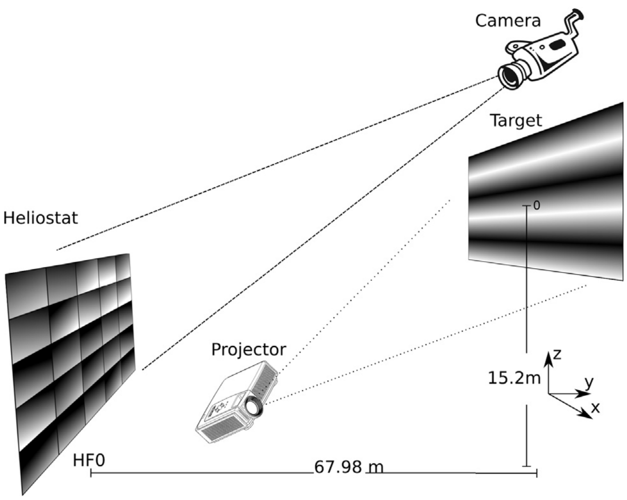

Fig. 2. Fringe reflection technique scheme.

Fig. 3. Sample of HF0 under fringe reflection analysis.

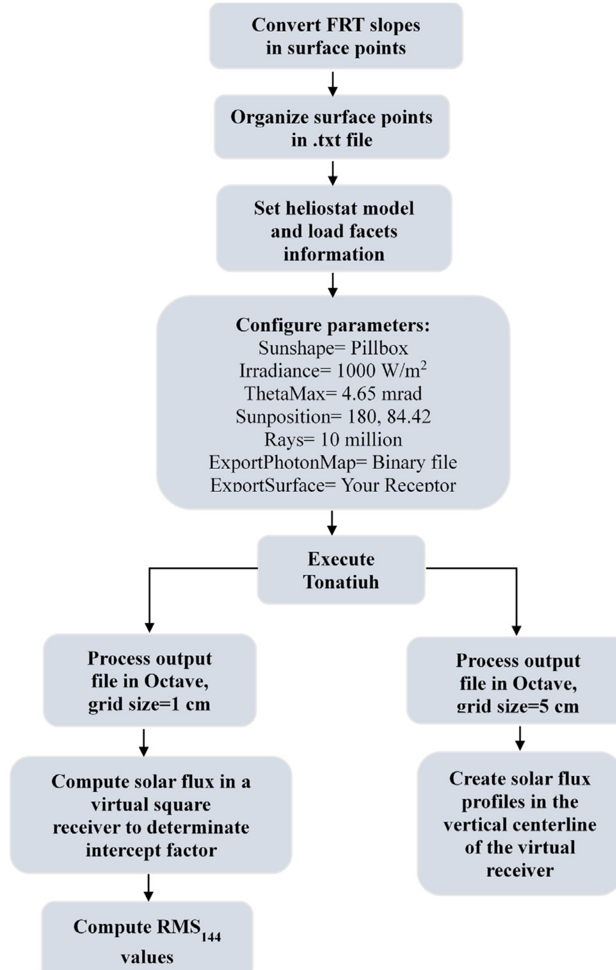

Fig. 4. Flow diagram of ray tracing simulations in Tonatiuh.

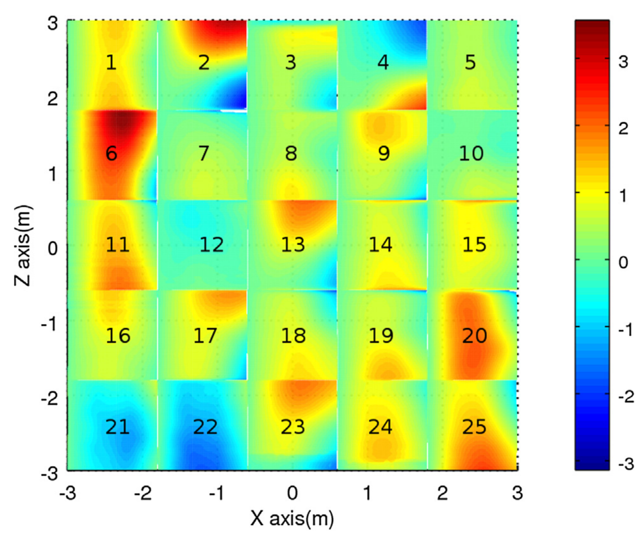

Fig. 5. Reconstructed surface of HF0 heliostat from FRT data (without the canting information).

extensive computing power and high processing time.

This work focuses on discussing the effect of the number of sample points on the evaluation of a heliostat facet, from the point of view of producing accurate flux distribution simulation results. The FRT is used for the surface characterization of three different heliostats, each one with 25 facets. The surfaces information is processed and introduced in a ray tracing software to compute the concentrated solar flux distribution. Different data densities are employed, and the results of the simulation are compared with experimental information. Additionally,