Measurement of concentrated solar radiation: the calorimeter ASTERIX

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Abstract:

The project ASTERIX (Advanced Solar Technology: Estimation of Radiation for Improved eXperiments) is held by CNRS-IMP in the French solar facilities of Odeillo. The objective is to provide the research groups with a reliable and easy-to-use device capable of measuring the flux densities delivered by the various solar furnaces of the institute. The main requirements are:

- A small area of measurement, in order to pick local values out of strongly non-uniform distributions.
- No calibration, since no reference device is available. One objective is to use this new device as reference gauge, in order to calibrate the other fluxmeters of the institute.
- Capability of withstanding elevated flux densities during indefinite time, for long-time flux evaluation.
- Easy handling and operating of the device.
- Wide angular acceptance, up to a half attack angle of 80°.
- And, of course, a very good accuracy of measurement (better than 1%) in the range 10-1000 W/cm^2, without any sensitivity to the variation of the spectral distribution of the solar source neither to the variation of the sunshape.

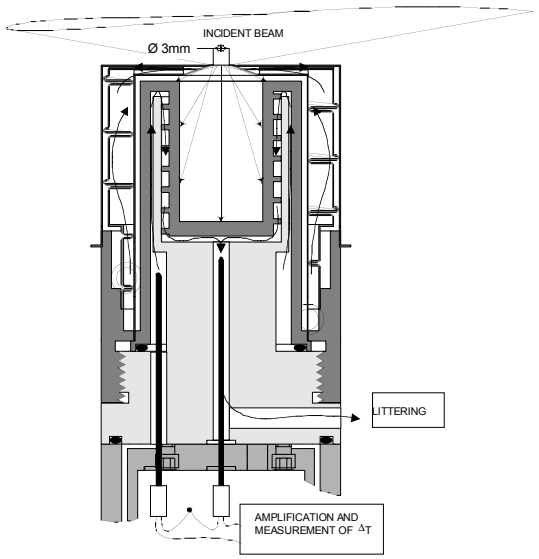

Fig.1: Basic schematic of ASTERIX

No commercial device can fulfill all these requirements. Therefore, the device ASTERIX has been designed and manufactured in the frame of an R&D program of CNRS-IMP in Odeillo. ASTERIX is a small water-cooled calorimeter, housed in a cylindrical body of 46 mm in diameter and 120 mm in length. The aperture of the cavity is 3 mm

in diameter, and the thin and sharp diaphragm results in an angular acceptance of 80° (half-attack angle). The cavity is protected against heat losses and undesirable inputs of heat with an active heat shield. This protection consists of a double water circulation: cold water is circulating near the external wall, and the inlet of the measurement circuit (cooling of the cavity) prevents temperature gradients in the wall surrounding the cavity before this water circulates around the cavity (see fig.1).

ASTERIX was operated for the first time in 1996, showing some major drawbacks in the electronics for the measurement of the temperature. Minor modifications were completed, and ASTERIX was successfully operated in 1997-98. The control of the water pressure and quality at the inlet still requires heavy equipment: 2 pressure controllers with a tank in-between, and a filter. The measurement of the low water flow-rate also remains uneasy: littering-weighting is the most accurate method. The recent development of ASTERIX consists of implementing a reliable checking system in order to assess the real accuracy of the measurements. No calibration is necessary for this kind of measurement device, but two comparison campaigns involving various calorimeters have shown that deviations of several percents are observed. The design of ASTERIX was therefore modified. Electrical power is directly supplied into the water through a resistance merged and brazed to the wall. The electrical power is measured with accuracy better than 1%. The procedure consists in comparing the power measured at the outlet (water flow-rate and increase of temperature) with the electrical power supplied, in the range 0.7 - 70 W, corresponding to the range of flux density 10 - 1000 W/cm^2. Hence the measurement circuit of the calorimeter is carefully checked.

The long-term development of ASTERIX will consist in the automatic control of the electrical power supplied into the cavity. The procedure for the measurement of the solar flux density will be simplified: starting from a given top value of electrical power (for example 100 W) when the device is not solar-irradiated, the electrical power will be decreased by the same quantity as the solar power received by the cavity when it is irradiated. For this purpose the water flow-rate should be stabilized, that is the major difficulty. The control loop then relies on the stability of the increase of temperature into the cavity. In this configuration, the measurement of solar flux density will not require the measurement of water flow-rate any longer. It will be replaced by the more reliable and much easier measurement of electrical power.