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BOLOMETRIC CALIBRATION FOR TCABR PERFORMED WITH A SYNCHROTRON LIGHT SOURCE

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Resumo

Uma nova calibração para o bolômetro a ser utilizado no TCABR (Tokamak Chauffage Alfvén in Brazil) foi efetuada, utilizando como fonte de luz uma das linhas de raios-x do LNLS.

Foi obtido um valor para a capacidade térmica menor que o resultante da calibração para uso no JET.

Abstract

A new bolometric calibration for the bolometer that will be used in TCABR (Tokamak Chauffage Alfvén in Brazil) was carried out using the synchrotron light source from LNLS x-ray line.

The value of thermal capacity obtained is smaller than that obtained for the same sensor, when calibrated for use in JET.

1. Introduction

One of the main targets of the TCABR project is the study of the global energy balance in the magnetically confined plasma, in order to search for scenarios with improved energy confinement. For this, the measurement of the total radiated power by bolometry is essential. A bolometric system based upon a resistive bolometer, originally developed for JET (Joint European Torus), is now being designed. The incident radiation heats the bolometer, rising its electrical resistivity. Measuring this change, one can calculate the amount of incident radiation on the sensor. A special camera allowing the view of a large region of the plasma has already been designed and constructed.

The bolometer was developed for use in a plasma with specific parameters of temperature and energy fluxes. A new calibration is therefore necessary, in order to adapt the sensor to the new environment of TCABR.

The calibration was performed using a x-ray line of LNLS, located in Campinas, SP (Fig. 1), which provided the light source. The synchrotron accelerator is able to furnish up to 1.37GeV to the confined electrons, operating up to a limit of 140mA of electrical current.

The central role of the calibration is to get the value of the bolometer thermal capacity, besides its cooling time constant.

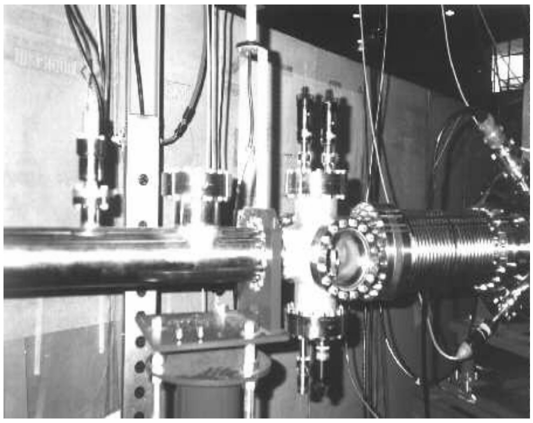


Fig.1 X-ray line at LNLS

2. The bolometer and bolometer signal

For a general overview about bolometer operation and calibration, see ref. 1-3. The bolometer to be used in TCABR has two identical sensors (Fig. 2), arranged in such a way that only one is directly exposed to the energetic flux[4]. Each one is connected to the arms of a resistive bridge, allowing differential detection and amplification of the electrical signal.

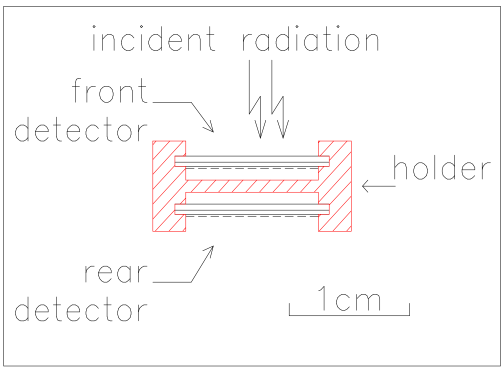


Fig. 2 Scheme of the resistive gold bolometer

The sensors are assembled in an aluminum case, with a square window (1.1x1.1cm^2) which allows the radiation flux to pass through. The assembly serves also as a heat sink, avoiding undesirable thermal signals, like those produced by long exposure of the bolometer to radiation.Each sensor is composed of a kapton foil (7.5 μm thick). Gold films are deposited on both faces of the foil.

The first deposition is 4 μm thick, serving as a heater to absorb the energetic flux. The second is a meander shape foil (0.1 μm thick), used as a electrical resistance (3.96 KΩ).

If a energetic flux of power *P* reaches the gold surface, the additional temperature rise *u* is given by the differential equation:

$$P = C \cdot (\frac{\partial}{\partial t} u + \frac{u}{\tau}), \qquad (1)$$

where *C* is the thermal capacity of the bolometer and τ is the cooling time constant. This rising in temperature will cause the electrical resistivity to change, according to the relation

$$R = R_0 \cdot (1 + \alpha \cdot u). \qquad (2)$$

Here, R_0 is the bolometric resistivity with no radiant energy falling on the sensor, and $\alpha = 2.7 \times 10^{-3}$/K.

3. Calibration

Once the physical parameters of the synchrotron accelerator are known, the incident energetic flux on the bolometer can be calculated during the calibration process. The flux can be altered by changing the electrical current in the accelerator.

The spectral power density for a 1.63mA current in the accelerator, at the center of the bolometer is shown in Fig. 3. The peak value observed decreases to 33nW/mm^2/eV for radiation incident at the top and bottom of the absorbing gold surface. Integrating over the photon energy range and foil surface area, we obtain the total power on the sensor.

Other values of electrical current in the accelerator do not change the spectral shape, but they do alter the total flux furnished to the sensor.

The light spectrum can well simulate the emission of a 700eV thermonuclear plasma. The power at the sensor surface is a linear function of the electrical current and amounts to 44mW, in the situation shown in Fig. 3. During the experiment, an intensity range from 20 to 1109mW was produced.

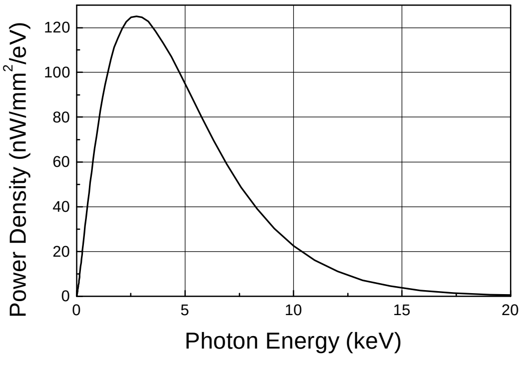


Fig. 3 Synchrotron light source spectrum, simulating a 700eV thermonuclear plasma

The bolometer was located 7.2m away from the light source, in a x-ray line with a base pressure of 5x10^{-8}mbar. The incident light on the bolometer could be turned off by means of a shutter controlled by an electrical system. Electrical connections with the outside were made through electrical contacts mounted on a flange specially designed for the experiment. The flange serves also as a holder to the sensor, during calibration process.

An operational amplifier configured for a 20dB gain was used to acquire the desired signal. The time interval for data acquisition was determined by opening and closing a shutter. The procedure was repeated for different values of the incident radiative flux.

Special care with the collimating of light over the gold foil was necessary, avoiding exposure of the entire aluminum case. This was achieved with internal collimators, already assembled inside x-ray line.

4. Results and conclusions

Fig. 4 shows the amplifier output signal when a 44mW square pulse is applied to the sensor. This data is a measure of departures from the original electrical resistivity of the sensor R_0, and is inserted in equation 2 to obtain the additional temperature rise *u(t)* .

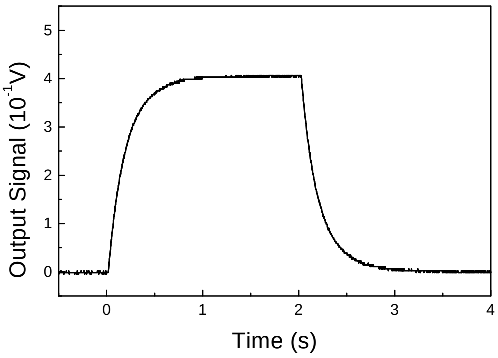


Fig. 4 Amplifier output, for a 44mW incident radiative power

The calculation furnishes a 6K temperature increase in the steady-state phase of Fig. 4.

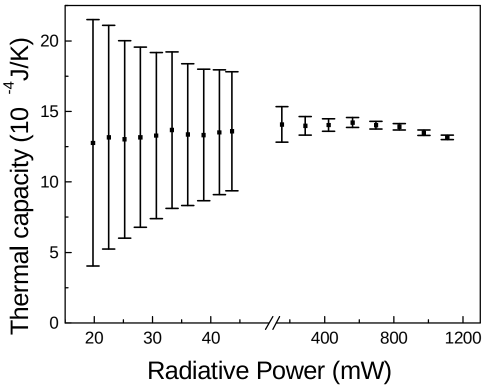
The solution of equation 1, for a power square pulse and initial condition *u(0) = 0* is given by:

$$u(t) = \frac{P \cdot \tau}{C} \cdot (1 - e^{-\frac{t}{\tau}}), \qquad (3)$$

Adjusting the temperature temporal evolution to equation 3, the constants *C* and τ are obtained. Repeating the procedure for different values of incident energetic flux, one can get several couples (*C*, τ). Calculating the average values of these parameters (Fig. 5) gives finally:

$$C = (1.360 \pm 0.009)\ \mathrm{mJ/K}$$
$$\tau = (206.08 \pm 0.07)\ \mathrm{ms}$$

This cooling time constant is almost twice that obtained earlier, using another procedure for calibration, i.e., the bolometer was ohmically heated, applying a well known electrical current to the sensor[5].



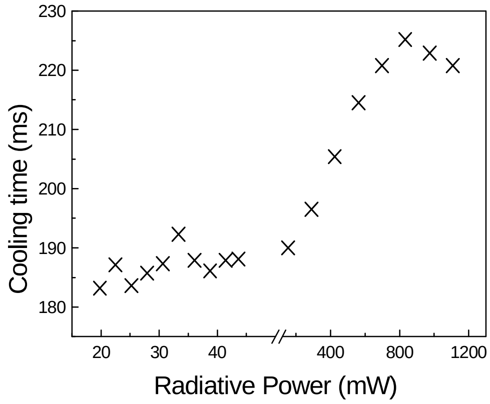


Fig. 5 Bolometer thermal capacity and cooling time values for the intensity range used in the experiment

The value of the thermal capacity is almost the same as that calculated for a gold foil with the dimensions already described ($1.1x1.1cm^2x4\mu m$). This calculation gives C=1.20mJ/K.

Nevertheless, the first calibration performed for the same bolometer , when used in JET, gave C=2.2 mJ/K and τ=200 ms[4].

Now the bolometer is being set up on TCABR, to perform the first acquirements.

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