X-ray bolometer for studies of laser produced plasmas

Absolute quantitative measurements of broad band (10 eV < $h\nu$ < 5 keV) x-ray fluence from pulsed plasma sources such as laser produced plasmas, Z-pinch plasmas etc. play an important role in using intense x-ray emission from these plasmas for applications in the indirect inertial confinement fusion scheme, development of soft x-ray lasers, soft x-ray imaging of live biological specimen, and x-ray lithography. X-ray bolometer is one such device widely used for absolute flux measurements from pulsed x-ray sources. It is essentially a radiation detector which works as a temperature transducer based on the change of electrical resistance of a metallic microstructure due to rise of temperature by x-ray absorption. Broadly there are two types of bolometers depending on whether the microstructure is directly exposed to the incident radiation or otherwise. While the directly exposed bolometers have a higher sensitivity, they suffer from the noise generated by resistance shunting due to secondary electron emission by the incident radiation and exposure of the microstructure to the plasma debris. Hence indirect type of bolometers, in which the microstructure resistance receives heat from the absorber element through an insulating foil, are more suitable for pulsed plasma sources. We have developed this type of x-ray bolometer in collaboration with Space Application Centre, Ahmedabad, and used it for measurements of intense x-ray radiation emitted from laser produced plasmas.

The bolometer basically consist of three elements:1) Radiation absorber, 2) microstructure, and 3) balanced bridge circuit. A schematic of the detector element is shown in figure 1. The absorber layer and the microstructure are created on the opposite sides of a 8 μm thick Kapton foil (25 mm x 25mm) which serves as the insulator layer. The production of gold microstructure, comprising of a meander pattern of 15 μm line width spaced at 50 μm of a total length of ~ 38 cm, involved several critical steps. After cleaning the foil by glow discharge, a thin layer of chromium of 100 nm thickness was coated on a central area of 7mm x 7mm. This was followed by deposition of 0.2 μm thick gold layer on both the sides of the foil using an RF sputtering system. Then, using standard photo-lithography technique, a meander resistor pattern of a line width of 15 μm spaced at 50 μm was transferred onto the positive resist coated Kapton foil on one side through a corresponding glass mask. Since wet processes were not suitable for handling such thin foils, the pattern delineation was carried out using a dry etching process viz. ion beam milling, which provides almost zero undercut profiles of the pattern.. A meander pattern area of 5 x 5 mm^2 was achieved with a resistance value of 6.68 kΩ. Next, the thickness of the gold absorber layer on the front side of the kapton foil was increased to ~ 4 μm by standard pulsed electroplating technique. Finally, the resistance pattern connecting pads were glued using conducting epoxy with two thin copper wires for electrical connections. These wires were then soldered to a BNC connector mounted on a metallic housing (over all size 40 x 80 x 100 mm^3) enclosing the bolometer structure (Fig. 2). The absorber layer at the front of the bolometer was thermally shielded from the metallic housing. This prevents any lateral heat conduction from the gold absorber foil to the housing, and therefore results in error-free measurement of the x-ray flux. Further, since there is no loss of heat due to lateral heat conduction from the foil, the cooling time constant of the bolometer is high (~ 5 seconds).

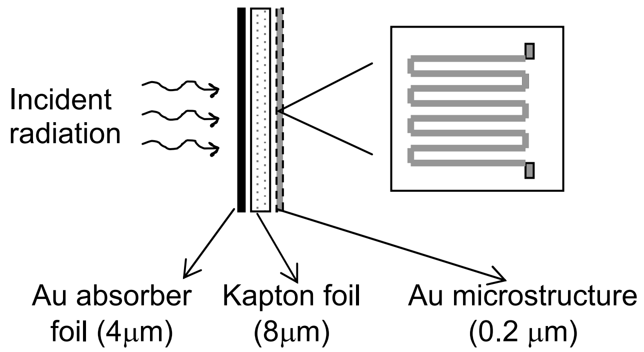

Fig. 1: Schematic of X-ray bolometer detector

Fig. 2: Bolometer detector assembled in the metallic housing

The bolometer was characterized using x-rays (hν > 0.8 keV) from laser produced copper plasma and calibrated with the help of standard XUV p-i-n diodes of known response. The change in the microstructure resistance was detected by a simple balanced bridge circuit followed by a low drift, low offset and high stable gain commercial differential amplifier with a gain of 1000. The response of the bolometer was found to be 1.23 mV/mJ and is linear over a wide range of incident x-ray flux. The bolometer is suitable for broad-band x-ray flux measurement from 10 eV to 5 keV energy range, and is being used for studies of laser produced plasmas.

Reference :

1) Design, fabrication and characterization of an x-ray bolometer for pulsed plasma x-ray source
S.Mahadevan*, J.A.Chakera, P.P.Vaidya*, D.Balasubramanian*, O.P.Kaushik*, P.A.Naik, L.M.Rangarajan*, and P.D.Gupta
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* : Our collaborators