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 exploits the change of electrical resistance of a metallic microstructure due to rise in temperature caused 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.

Bolometer basically consists of three elements: 1) radiation absorber, 2) microstructure, and 3) balanced bridge circuit. A schematic of the detector element is shown in fig.L.4.1. The absorber layer and the microstructure are created on the opposite sides of a 8μm thick Kapton foil (25mm 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 50μm of a total length of ~ 38cm, 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 5mm^2 was achieved with a resistance value of 6.68kΩ. Next, the thickness of the gold absorber layer on the front side of the Kapton foil was increased to ~ 4μm 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 (overall size 40 x 80 x 100mm^3) enclosing the bolometer structure (fig.4.L.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).

The bolometer was characterized using X-rays (hν > 0.8keV) 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.

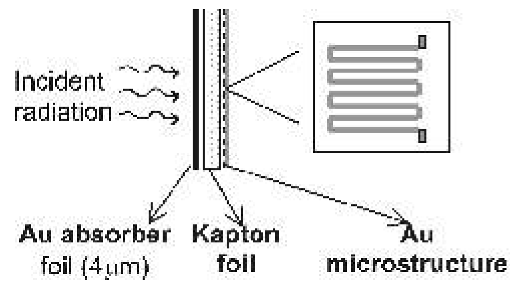

Fig. L.4.1 *Schematic of X-ray bolometer detector*

Fig L.4.2 *Bolometer detector assembled in the metallic housing*

The response of the bolometer was found to be 1.23mV/mJ and is linear over a wide range of incident X-ray flux. The bolometer is suitable for broadband x-ray flux measurement from 10eV to 5keV energy range, and is being used for studies of laser-produced plasmas.

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L.5 Intense x-ray emission from moderate-current low-energy laser-triggered vacuum discharge

Low inductance vacuum spark discharge initiated by laser pulses or electrical trigger is an attractive X-ray source of energy ranging from a few keV to few hundred keV. Hard X-ray emission from these devices (which typically involve discharging a capacitor of 20-30μF, charged to 10-20kV with stored energy of $\geq$ 1kJ, and peak discharge current of $\geq$ 100kA) comes due to micro-pinching of the plasma in the discharge gap to a high temperature of 1-10keV and at high density ~ 10^{22} – $10^{23}cm^{-3}$. It will be interesting if such a hard X-ray source operates as a low energy compact device. Recent experiments performed at CAT in collaboration with P. N. Lebedev Physical Institute, Moscow, have shown intense multi-keV X-ray generation in a low-energy ($\leq$ 20J, electrical) moderate-current (~ 10kA) vacuum discharge initiated by short duration (multi-picosecond) laser pulses.

A schematic of the experimental set-up is shown in fig. L.5.1. The vacuum diode consists of a planar titanium plate as a cathode and a conical point-tip titanium anode, kept at a separation of ~ 3mm. The anode was biased to a voltage up to +20kV using a dc power supply and a low inductance 100nF capacitor. The inductance of the discharge circuit was ~ 0.15μH. The whole set-up was kept inside a chamber evacuated to a pressure of ~ 5 x 10^{-5} torr. The discharge was triggered by producing a plasma on the cathode using laser pulses of ~ 5mJ energy, 27ps full-width at half-maximum duration from an Nd:glass laser (wavelength: 1.054 μm). The laser beam was incident on the cathode at an angle of 45^0 to the cathode normal.

Intense K-shell ($K\alpha$: $h\nu \approx$ 4.51keV) X-ray emission was observed from the titanium anode tip due to its bombardment by the accelerated electrons extracted from the expanding cathode plasma. This X-ray emission occurs in the form of two or three pulses, each of 20-30 ns duration, occurring up to ~ 100ns from the time of triggering. The number of $K\alpha$ photons is estimated to be $\approx$ 6 x 10^{10} photons per shot, comparable to that for the nanosecond pulse laser-driven vacuum diode X-ray source [A. Moorti et al. Pramana - J. Phys. 63, 1031, 2004]. An evidence of a much harder X-ray component ($h\nu$ > 100keV) was also seen from the flooding of

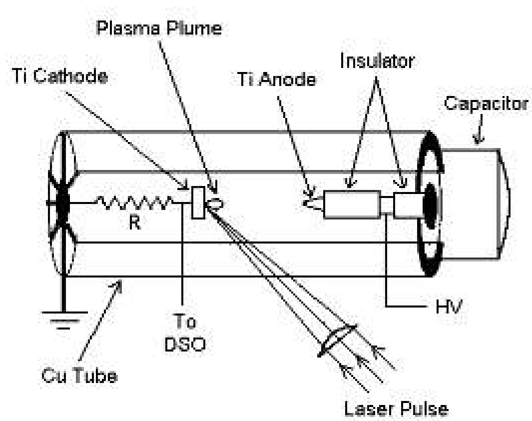

Fig L.5.1 *Schematic of the experimental set-up.*

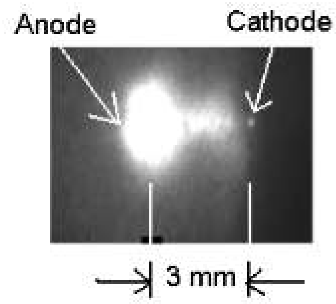

Fig L.5.2 *Pin-hole image of the discharge gap.*

micro channel plate detector filtered through 10mm thick copper disc. Hence the discharge gap was imaged at a lower anode voltage of ~ 5kV using an X-ray pin-hole camera filtered with a formvar filter of 0.3μm thickness (photon energy for 1/e transmission ~ 100eV). The image of the discharge gap (fig. L.5.2) clearly shows pinching of the plasma near the cathode [A. Moorti et al. J. Appl. Phys. to appear in February1, 2005 issue]. This pinching effect occurring in the cathode plasma jet expanding with a free boundary is different from the high-current discharges in which the pinching occurs in the plasma column bound by the electrode surfaces. Detailed measurements of hard X-ray emission will be carried out.

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L.6 Development of fiber optic based optical coherence tomography setup for in-vitro and in-vivo imaging of biological tissues

Optical coherence tomography (OCT) is a very attractive technique for real time depth resolved cross-sectional imaging of biological tissues and can provide micrometer-scale resolutions. OCT relies on the principle of low coherence interferometry, wherein light from a broadband source backscattered from a sample is mixed with the reference light using Michelson interferometer geometry. Interference takes place only when the sample arm path length matches exactly the reference arm path within the coherence length of the source. This allows probing different layers of the sample. Two-dimensional cross sectional imaging is achieved by performing successive axial measurements at different transverse positions. Heterodyne detection is used to detect the weak interference signal that has the signatures of the sample layer being investigated. OCT is being increasingly used in various clinical areas like ophthalmology, gastroenterology, dermatology, etc. A single mode fiber optic based optical coherence tomography system has been developed and used for in-vitro and in-vivo imaging of