L.5 Development of single frame x-ray framing camera for pulsed plasma experiments

High speed gated x-ray imaging is required to obtain time resolved information in a variety of research investigations such as laser plasma interaction, capillary discharge plasma, plasma focus, tokamak devices etc. In principle, this can be accomplished by using an x-ray framing camera with multiframe recording facility. The latter necessitates use of a stripline microchannel plate (MCP) with an array of pinholes, where a high voltage gate pulse travels along the stripline, recording each pinhole image sequentially on a phosphor screen. Such stripline MCPs are very expensive and not easily available commercially. As a simpler alternative, one can use a regular MCP, with a single pin-hole and activate the same with a short duration gating pulse to record a single frame, and obtain x ray images in consecutive time frames. A single frame x-ray framing camera with a minimum gate duration of 5ns has been developed at the Laser Plasma Division and used for measurement of x-ray emission from laser produced plasmas.

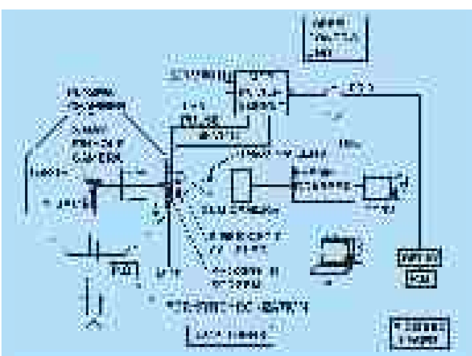

Fig. L.5.1 *Single frame x-ray framing camera setup.*

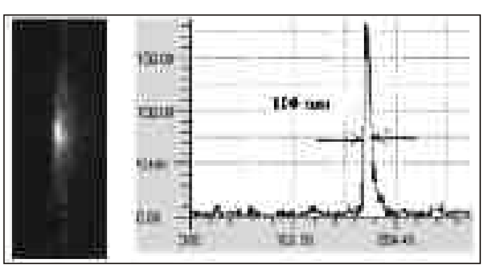

Fig L.5.2 *A typical x-ray frame for a laser produced copper plasma and corresponding intensity profile.*

The single frame x-ray framing camera consists of two parts, viz. an x ray pin-hole camera using an open ended MCP detector coupled to a CCD camera, and a variable high voltage short duration gate pulse for activating the MCP (fig. L.5.1). The camera uses a 10μm pin-hole aperture for imaging the x-ray source on the MCP detector with a magnification of 6X. Design of the high voltage pulser circuit is based on self-matched transmission line *[J. Upadhyay and C.P.Navathe, Measurement Science and Technology, 17, 25 (2006)]*. The pulser circuit can generate a pulse of variable duration from 5ns to 38ns with variable amplitude from 800V to 1.2kV. In addition, the system includes a variable delay for synchronizing high voltage pulse with the event.

The performance of the system was checked by recording x-ray emission from a laser produced copper plasma. For this purpose, high power Nd:glass laser beam (30J, 2ns FWHM) was focused on a planar solid target kept at the center of a plasma chamber evacuated to ~10^{-6}torr. A high density, high temperature plasma was produced having typical dimension of ~ 100μm diameter. X-rays generated from this plasma were imaged onto the MCP using the x-ray pin-hole camera. The MCP output on the phosphor screen was further imaged onto a CCD camera, which in turn was controlled by a frame grabber card, triggered by the laser control unit, about 400μs prior to the laser pulse. *[J.Upadhyay, J.A.Chakera, C.P.Navathe, P.A.Naik, A.S.Joshi, and P.D.Gupta, to appear in Sadhana, 2006].*

A typical image of the copper plasma x-ray source produced by a 13J, 2ns laser pulse, and filtered with aluminized polycarbonate foil is shown in fig.L.5.2. The MCP gating pulse was 1.1kV / 7ns duration. A corresponding intensity profile is also shown in fig.L.5.2. From this profile, a plasma expansion size of ~100μm (FWHM) was measured, which is in agreement with focal spot size of the laser used for producing the plasma source. Further, as the delay of the frame was scanned, it was observed that up to a delay of 5ns, the image continued to appear and by increasing it further, the image vanished. This shows that the x-ray emission lasts for ~5ns. A reduction factor of ~6.5 was seen in the dark current contribution as the MCP gate pulse was decreased from 250μs to 5ns duration.

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L.6 Generation of hollow conic beam using an axicon mirror

Generation and characterization of hollow beams has attracted considerable attention recently because of their applications in diverse areas such as atom guiding and trapping, optical tweezers, laser machining, and generation of beams with large depth of focus. Different methods have been employed to generate hollow beams. These include use of conical lenses, holograms and transverse mode selection.

We have developed a new reflecting element, all-metal axicon mirror, and demonstrated its use to generate hollow conic beam. The axicon mirror has a base angle of ~3 degree and is made of copper. It was fabricated in Laser Workshop of RRCAT, polished on a diamond turning machine in Machine Dynamics Division of BARC and gold coated in the Optical Workshop of RRCAT. Using this axicon mirror, a good quality hollow conic beam has been generated with a power conversion efficiency of ~ 85% for transformation of a Gaussian beam into a hollow conic beam. Focusing of the hollow beam by a lens was investigated and it was found that it is possible to have a region of length several cm over which the hollow beam diameter is few mm. This is suitable for guiding of cold atoms by using a suitably detuned laser beam.

Fig. L.6.1 *CCD image of the hollow beam generated by axicon mirror.*

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L.7 Development of near 100 watt kinetically enhanced copper vapor laser

Kinetically enhanced copper vapor lasers are the advanced CVL systems with high efficiency 1.2-1.5% and increased output power (2-3 times) as compared to standard CVLs, where efficiencies are normally less than 1%. The carefully optimized HCl component of the buffer gas controls the electron density in the discharge medium by the process of dissociative attachment (DA), thus ensuring most favorable excitation conditions in the CVL. We have recently demonstrated a high power KE-CVL which was capable of generating about 94watt output power at ~ 10 kHz repetition rate using special buffer gas mixture in the discharge medium. The KE-CVL was based on 58mm bore and 1450mm length discharge tube. Alumina bulk fibre was used as thermal insulation around the discharge tube. Two water-cooled electrode assemblies were supported at two ends of the discharge tube with suitable end mounting flanges. HCl component of the buffer gas was prepared online by using a carefully optimized quartz cell containing high purity zirconium cloride as the source material. The total input power required was about 7kW. The overall wall plug efficiency was about 1.4 % which is highest so far achieved in our laboratory and very close to maximum value of 1.49% reported so far in KE-CVLs in the literature. The laser require about one hour to reach maximum output power after threshold lasing. The laser pulse durations are typically of about 50ns FWHM. The near field pattern of the beam cross-section is Hat Top type with higher intensity at the center.

Fig. L.7.1 *94 watt CVL beam being coupled out from laser window.*

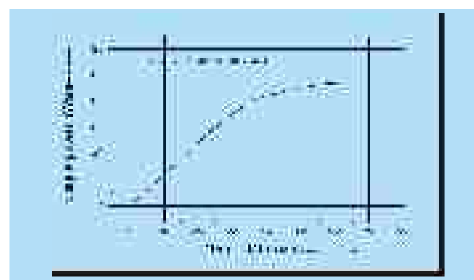

Fig. L.7.2 *Laser power buildup with time.*

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L.8 Generation of 120 watt CVL beam from single stage oscillator amplifier configuration

The kinetically enhanced (KE) CVLs offer high wall plug efficiency (1.2-1.5 %) and increased output power (2-3 times) capabilities as compared to standard CVLs by favorably enhancing the inter-pulse discharge kinetics using special buffer gas mixtures and other operating parameters [*B. Singh, V.V. Subramaniam, S.R. Daultabad, A. Chakraborty, Review of Scientific Instruments 126104, Dec 2005*]. These individual KE-CVL units can be grouped into oscillator amplifier configurations (fig. L.8.1) to generate single high power CVL beam. We have recently demonstrated a single stage oscillator-amplifier configuration using two KE-CVLs which was capable of