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Title: Dual Microchannel Plate Module For A Gated Monochromatic X-Ray Imager.

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Dual Microchannel Plate Module for a Gated Monochromatic X-ray Imager

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Development and testing of a dual microchannel plate (MCP) module to be used in the national Inertial Confinement Fusion (ICF) program has recently been completed. The MCP module is a key component of a new monochromatic x-ray imaging diagnostic which is designed around a 4 channel Kirkpatrick-Baez microscope and diffraction crystals which is located at University of Rochester's Omega laser system. The MCP module has two separate MCP regions with centers spaced 53 mm apart. Each region contains a 25 mm MCP proximity focused to a P-11 phosphor coated fiberoptic faceplate. The two L/D = 40, MCPs have a 10.2 mm wide, 8 ohm stripline constructed of 500 nm Copper overcoated with 100 nm Gold. A 4 kV, 150 ps electrical pulse provides an optical gatewidth of 80 ps and spatial resolution has been measured at 20 lp/mm.

I. INTRODUCTION

Some of the most important diagnostics used in the ICF program are gated x-ray imagers.[1,2] These imagers can resolve broadband x-rays (1 - 5 keV), both temporally (80 ps) and spatially (20 lp/mm). What sets this new diagnostic apart from current technology is the ability to maintain resolution, temporally and spatially, while observing a very narrow band of x-rays on the order of 10 to 20 eV. The diagnostic is also designed to easily change between different energy ranges of interest by simply rotating a Bragg crystal. This technique isolates line emission from a single element and thus rejects continuum or background radiation. Observation of gated monochromatic images has important applications which include the measurement of the targets's core size, areal density, and implosion symetery.

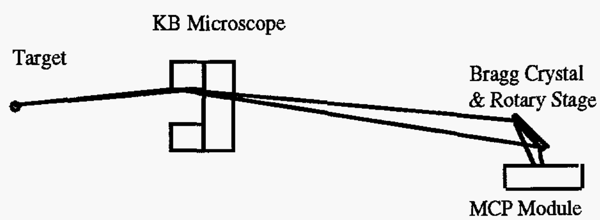

FIG. 1. Top view of the gated monochrome imaging system.

Figure 1 shows the gated monochrome system consisting of a grazing incidence KB microscope which is arranged to form 4 images. Near the focal point, the 4 beams illuminate 4 separate Bragg crystals. The crystals are mounted upon two crystal turrets (left and right), which can rotate through >45° (θ) on computer controlled rotary stages. The diffracted image finally falls upon a pair of gated microchannel plates (MCP) modules which rotate through 90° (2θ). The KB mirrors are designed to sit on the target-chamber-center side of a vacuum flight tube protected by a Beryllium debris shield. On the other end of the vacuum tube is a 12" diameter vacuum tank which houses the crystals, rotary stages, and MCP modules. The tank was designed to be easily removed, leaving just the base plate, for instrument calibration and maintenance. For normal operations the tank remains in place and has two 10" vacuum doors (top and rear) for removal of film and minor adjustments. Descriptions of the KB microscope, dispersive elements, rotary stages and the gating system are described below.

II. Imaging Optics

The KB microscope design [3] is operated at grazing incidence angles (<1°) where focusing occurs in a single plane. This requires an additional surface to produce two-dimensional information. The microscope consists of two pair of cylinderical mirrors arranged perpendicularly to each other as to produce four images. Typical parameters of the KB microscope are: mirror radius = 28 m, angle of incidence = 0.7°, magnification = 11.7, and solid angle = 4×10^{-7} sr. Tests performed at LANL's Trident laser facility and with DC x-ray sources have shown the best resolution to be ~ 5 μm with a depth to field in excess of 1 mm. To enhance reflectivity of the KB mirrors we have tested various metallic coatings. Previous KB mirrors have been Au-coated with reflectivity measured using a DC x-ray source as described in Dhez *et al.*[4] Present KB mirrors are Ir-coated, resulting in relatively increased reflectivity for higher photon energies (8 kV) as compared to Au.

III. Dispersive Elements and Rotary Stages

The light from the KB microscope is made monochromatic by placing a Bragg crystal just before the focal plane of the KB. Typical crystals for this application are LiF (2d = 4.027 A) and Highly Oriented Pyrolytic Graphite (HPOG) (2d = 6.708 A). The crystal is placed at an angle θ relative to the incident x-rays and the gating module is placed at an angle of 2θ. The wavelength (λ) of the diffracted x-rays is given by the Bragg equation, $2d\sin\theta = n\lambda$, where d is the crystal plane spacing and n is the diffraction order. Since the crystal has a finite angular response to wavelength λ, this yields a finite field of view Δx given by $\Delta x = d\Delta\theta$, where Δθ is the width of the crystal rocking curve and d is the distance from source to mirror. Typical values for Δx = 700 um with crystal rocking curves of $\Delta\theta = 0.2^{\circ}$ (LiF). For an x-ray source emitting broadband radiation, the effective energy band ΔE is given by $\Delta E = E\cos\theta\Delta\theta$. Crystal reflectivity's (Rp) have been measured at Rp = 0.15 for LiF and Rp = 0.27 for HPOG.

The crystal turrets sit upon 2 separate computer controlled commercial rotary stages with 1 arc second resolution.[5] The rotary stages drive a pair of vertical shafts which are 2θ out of phase of one another. This enables the crystal to be at an angle of θ, relative to the incident radiation, while the MCP module is always at an angle of 2θ. The usable range of crystal angle is between $\theta = 0^{\circ}$ to 50°. Table 1 shows a list of crystal angles vs energy for LiF and HPOG. Monochromatic images of resolution grid targets have been captured using LANL's Trident laser with DEF film as shown in Figure 2. The grid targets had a wire size of 10 μm and spacing of 40 μm.

LiF		HPOG	
Angle (θ)	Energy (KeV)	Angle (θ)	Energy (KeV)
23.25	8	13.72	8
25	7.47	15	7.33
30	6.31	20	5.55
35	5.5	25	4.49
40	4.9	30	3.79
45	4.45	35	3.3
50	4.1	40	2.94
55	3.83	45	2.67

TABLE I. Usable crystal angles vs. energy for LiF and HPOG.

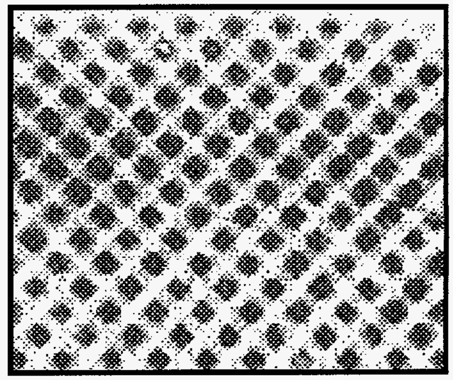

FIG. 2. Monochromatic DC image taken on LANL's Trident laser. Target was a wire grid with 10 μm diameter wire spaced 40 μm apart.

IV. Gating and Image Recording System

The 4 monochromatic images formed by the microscope and crystals are arranged in a square pattern with 53 mm sides at the image plane. Each image falls on its own 25 mm diameter MCP, which is proximity focused to a fiberoptic faceplate coated with P-11 phosphor. Light from the phosphor is recorded by Kodak 2484 film loaded into a film cassette that is compressed against the fiberoptic faceplate. As shown in Figure 3, each module contains a pair of 25 mm MCPs, with centers separated by 53 mm. Each MCP has an 8 ohm microstrip which acts as the electrical conduit for the gating pulse and the photocathode. The microstrip is constructed of 500 nm Cu overlaid by 100 nm of Au. The MCPs are feed by microstrip ohmic tapers which efficiently transfer the voltage pulse from 50 ohms to 8 ohms and back out again for a pulse monitor and DC biasing. To gate or shutter the x-rays, a short duration, high voltage pulse travels across the MCP stripline with a propagation velocity of 0.5c. Photo-electrons from the Au photocathode are amplified only during the pulse duration at a given point along the microstrip. The LANL built gating pulsers have an amplitude of 4 kV and an electrical width of 150 ps FWHM. See Figure 4. These avalanche transistor based pulsers give us an ~80 ps optical gate with MCPs having micropore length over diameters of 40 (L/D = 40). There is however, a noticeable gain reduction due to ohmic losses between the two MCPs because they are feed by the same continuous strip. MCP #1 has an ~ factor of 4 more gain than MCP #2. For our first run of experiments this is acceptable, though subsequent designs will allow the MCPs to be gated and DC biased separately for increased flexibility.

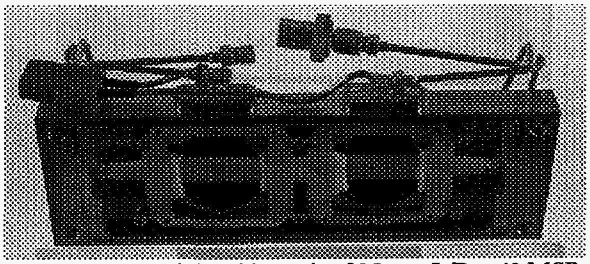

FIG 3. MCP module with a pair of 25 mm L/D = 40 MCPs.

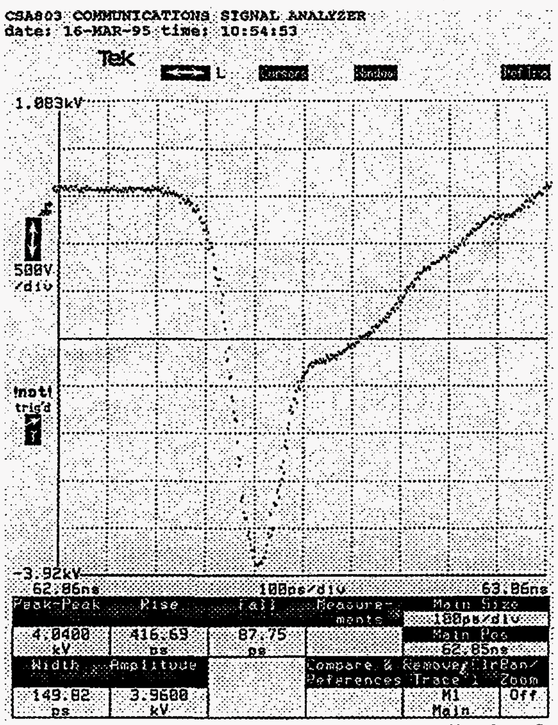

FIG. 4. LANL gating pulser with amplitude of 4 kV and FWHM = 150 ps.

V. CONCLUSIONS

This new gated monochromatic imaging system is a product of a sucessful collaboration between University of Rochester's Laboratory for Laser Engerics and Los Alamos National Laboratory. We collectively have designed, developed, and tested the imaging system at both LANL's Trident laser[6] and LLE's Omega Upgrade[7]. This new imaging system will be an important diagnostic for Omega yielding critical information concerning target symetery, size and density of ICF implosions.

VI. ACKNOWLEDGMENTS

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4 P. Dhez, H. Duval, and J.C. MaLaurent, J. X-ray Sci. Tech. 3, 176 (1992)

5 Rotary stages model ART50N were manufactored by Areotech.

6 Information on the Trident laser system can be found at http://harry.lanl.gov/PlasmaPhysics/trident.html.

7 Information on the Omega laser system can be found at http://www.lle.rochester.edu/.