TIME DEPENDENT IMAGING OF CYLINDRICAL SHOCKS AT THE PEGASUS FACILITY

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ABSTRACT

The pulsed power Pegasus facility at Los Alamos National Laboratory has been configured to drive cylindrically symmetric shocks into a load region containing multiple density regions. A series of experiments are being performed to permit the development of diagnostic techniquest o characterize the spatial distribution and temporal dependence of the cylindrical shocks generated in a 4.5cm diameter X 2cm thick "target" region. The loads utilized in the preliminary experiments contain multiple regions. Optically transmissive regions are being diagnosed with long pulse, 694nm laser backlighting. Framing cameras and fast optically shuttered cameras are being developed for high resolution image capture. Pulsed x-ray sources permit characterization of material boundary regions through differential x-ray absorption in a radiographic geometry. The desire for multiple visible and x-ray images requires fast time response, electronic imaging techniques.

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Typical shock pressures and velocities of 300Kbar and 5mm/us coupled with a desired spatial resolution of better than 5lp/mm dictate temporal resolution requirements on the order of 50ns. The current status of the diagnostic development will be described as well as possible directions for future improvements.

Introduction

The PEGASUS pulsed power facility at Los Alamos National Laboratory is currently being utilized to generate cylindrical shocks in a target region of dimensions 2.5cm in diameter and 2cm thick. This region is internal to and forms the central region of the PEGASUS "load" which is experiment specific. Initial experiments involve typical shock pressures of 300Kbar with propagation velocities near 5mm per microsecond. These shocks are routinely generated in an optically transmissive medium such as PMMA or Polystyrene and interact with different materials which need not be optically transmissive. This then provides a test bed for studying shock physics phenomena. Measurement techniques for characterizing shock velocities and interactions are currently under development and include time dependent visible and X-ray backlighter imaging.

Visible Light Imaging of Shock Generation via a Liner Driver

The impact of a 0.4mm thick, cylindrical "liner" onto the target region containing PMMA or Polystyrene in its outer region generates a cylindrical shock of very high circular symmetry into the target region. Visible light imaging of the outer surface of the liner driver with 50 to 100ns "snapshots" permits evaluation of the vertical (along the 2cm dimension) symmetry of the liner during acceleration as well as a determination of its radius vs time prior to impact with the target. Accurate relative timing of these images gives a radius vs time profile for detailed comparison with computer simulations. The absolute timing of the snapshots relative to the PEGASUS trigger pulse gives detailed insight into modeling of the pulsed power facility itself. An overview of the experimental geometry is shown in Figure 1.

Three independent camera systems view the outer surface of the liner/target region through a side port and an optical relay system. They are microchannel plate image intensified(MCPII), Focus Projection Scan (FPS) electron TV tube cameras capable of being externally triggered for optical shuttering and asychronous operation for viewing single transient events. Image data is relayedover fiber optic links to a screen room containing a PC based, 8-bit video digitising system. The MCPII can be gated to provide the necessary optical shuttering to prevent blurring of the image due do the liner motion. The resolution of the imaging system is dominated by the MCPII and results in about 2lp/mm at 5% modulation over the 7cm field of view (FOV). Trigger diagnostics permit accurate determination of both relative and absolute timing of the optical shutters to within a few nanoseconds.

Visible Laser Light Backlighting of Target Region

The concept of utilizing an optically transmissive medium which changes its index of refraction under pressure provides a means of observing a shock front as it moves in the medium. The present experiments are using a ruby laser pulse of duration longer than the time interval over which we wish to record data. The 694.3nm wavelength laser light can readily be diffused and

transmitted through the experimental region of interest and then imaged via telescopes onto the photocathodes of electronic framing cameras and optically shuttered snapshot cameras. Wavelength filtering of the image is used to improve the scene contrast by only allowing images to be formed by the transmitted laser light. Scattered light from electrical discharges near the load region can be reduced in the recorded data. A large format framing camera(IMCO) with an 18mm photocathode provides a series of eight, 50ns wide snapshots with better than 10lp/mm resolution in the source plane. The interframe time is programmable and can vary with the minimum being 40ns. Typical interframe times of 200 to 500ns are used. A cooled CCD provides immediate setup and readout capability. The 2.5mm FOV is focussed onto the photocathode with a Celestron telescope and teleconverter system. The framing camera is housed in a screen room located in the PEGASUS experimental hall and at a distance of over 10m from the load region. A beam splitter system permits using an additional framing camera (IMACON) with 12 frames to provide more detailed temporal coverage.
One MCPII gated camera is also used to provide maximum spatial resolution. The images from these cameras clearly show the shock wave leading edge propagating into the center of the axially symmetric target region. Recovery of the optically transmissive material to permit reflected shock characterization from the center propagating radially outwards is currently not possible and other materials are under investigation. The PMMA and Polystyrene do not recover quickly enough or are permanently altered so that optical transmission of the laser light does not occur at late times.

Pulsed X-Ray Backlighter for the Target Region

The imaging characterization of shock interactions in non-optically transmissive media requires the use of X-rays with differential absorbtion to provide scene contrast. Our initial experiments have embedded more dense materials in the PMMA or Polystyrene to permit both optical measurements as well as the development of a multi-pulse X-ray capability to examine material flow as well as the possibility for jetting studies from textured surfaces. The current X-ray machines are stacked vertically and triggered independently to provide multiple snapshots. End point energies are less than 200KeV with W targets and pulse widths of 20ns. Integrated doses are about 5mR @ 70cm (the target location). The X-ray to light converters are thin NaI xtals located 14cm above the target region resulting in a magnification of 1.2. The doses and light emission require a fast optical relay lense system to permit obtaining adequate statistics in the gated images. The decay time of the NaI (250ns) precludes multiple X-ray shot time intervals less than 300ns. The measured, composite resolution in the X-ray images is about 5 lp/mm with 30% modulation over a 1 cm region on axis with the X-ray sources. This includes the X-ray source spot size, the target region scatter, NaI resolution, and the optical relay and intensified camera systems. This data was obtained with a 2cm thick sample of plastic/brass sandwiched layers of different spacing. The image and a profile through lines 169 to 189 are shown in Figures 2 and 3, respectively. The group of three lines centered on line 300 in Figure 3 are approximately 5 lp/mm.

A variety of camera systems are being used to optimize sensitivity and resolution. A wavelength matched (to NaI emission), 18mm photocathode MCPII, fiber optically coupled FPS camera has been used for most of the initial experiments. More recently, wavelength matched, MCPIIs have been coupled to fiber optic CCD cameras as well as lens coupled, to cooled CCDs. Optical shutter times of 700ns have been used due to the interframe time of the X-ray pulses as well as to permit maximum light collection from the NaI and best gated resolution of the MCPII.

To provide improved resolution and greater dynamic range X-ray images, higher dose X-ray machines are being investigated as well as the possibility of using 40mm MCPII for enhanced resolution.

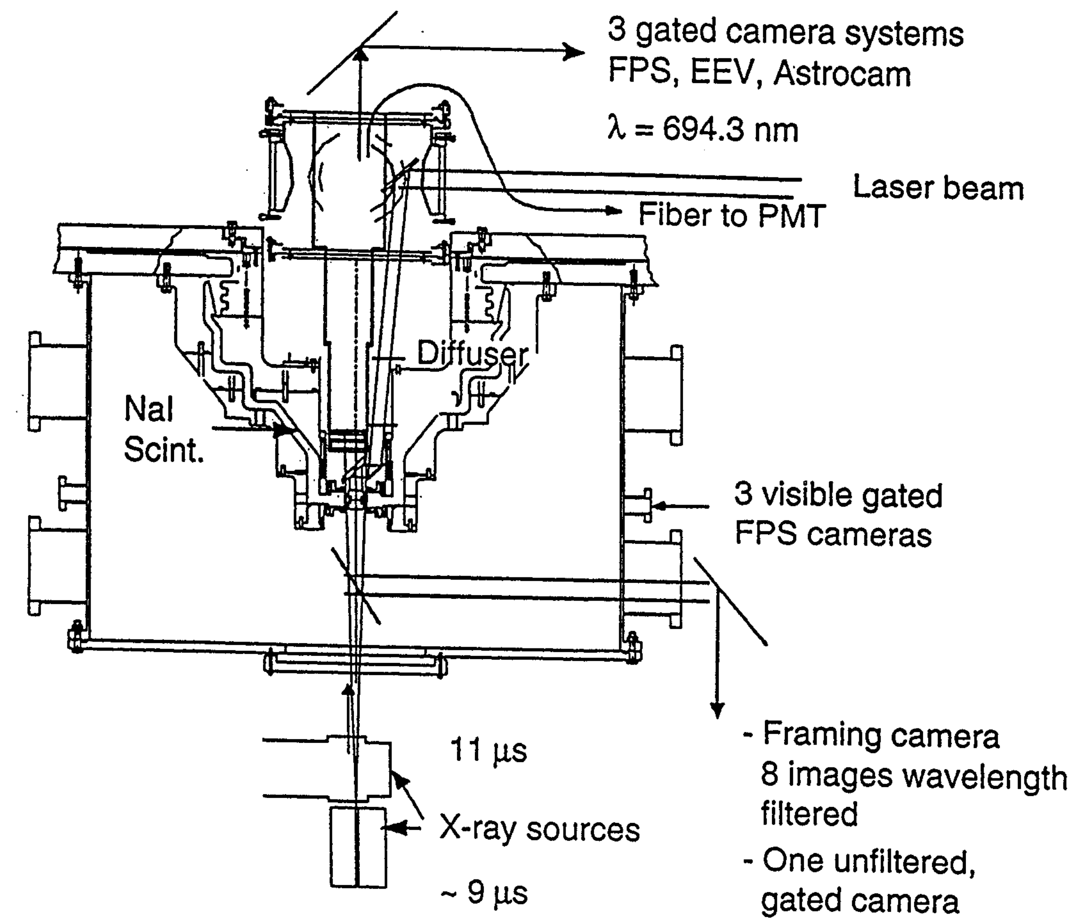

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Fig. 1 Overview of experimental setup

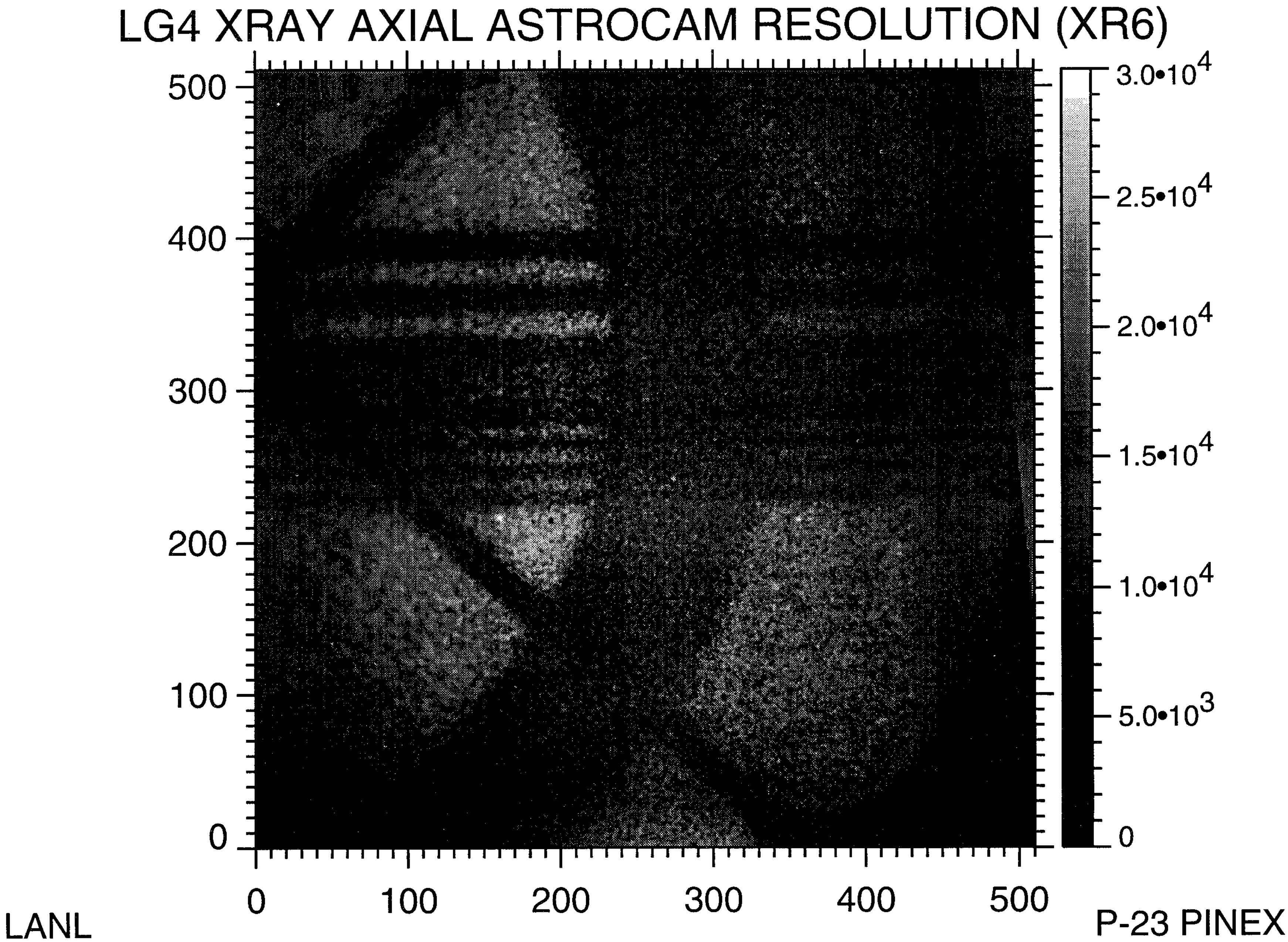

Fig. 2 X-ray image of brass/plastic resolution block

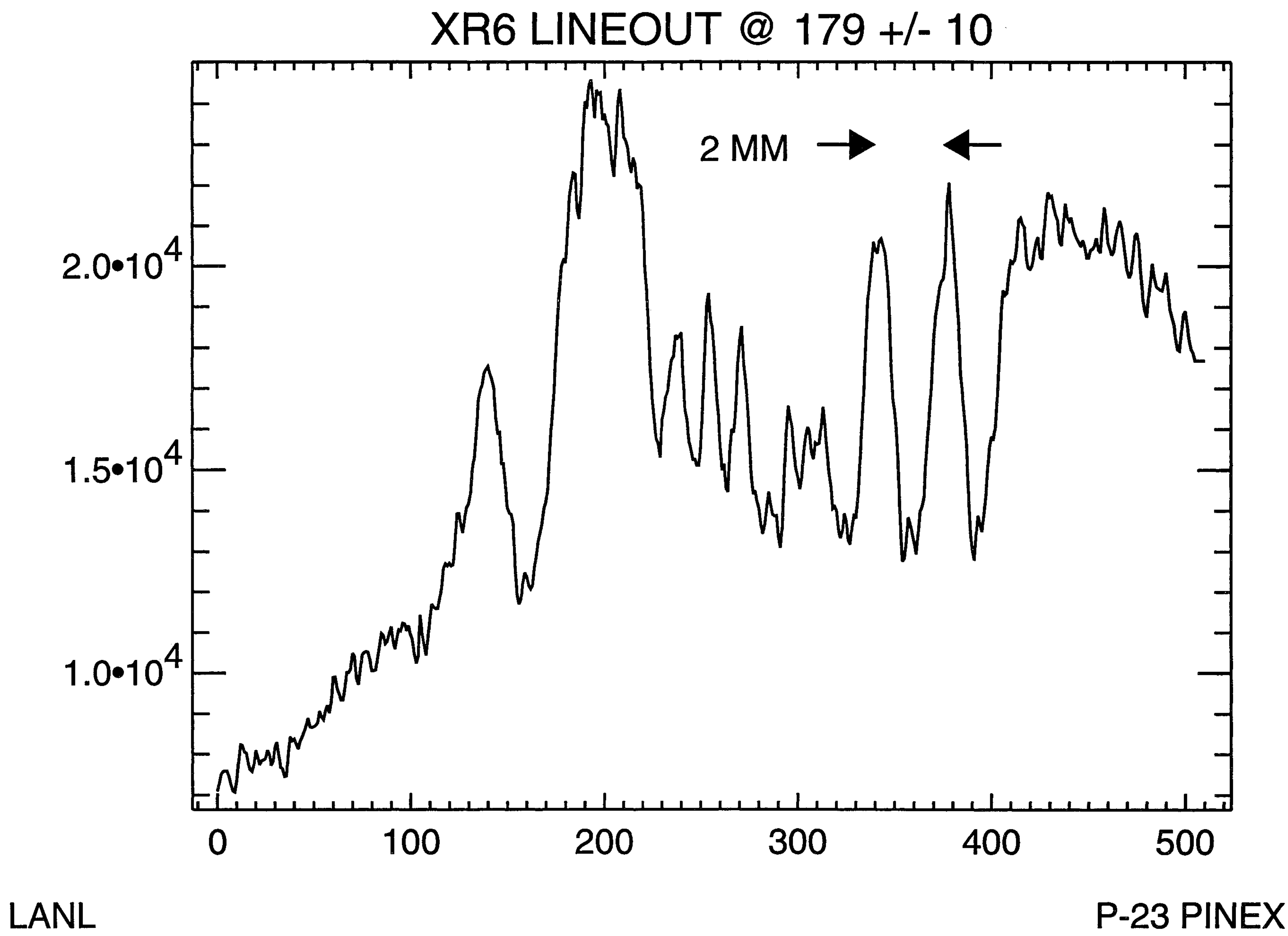

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Fig. 3 Line profile of x-ray image resolution pattern