Use of a Large-Aperture High-Energy Laser for Radiography of Z-Pinch Driven Hohlraums

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Abstract: A large-aperture high-energy laser has been constructed adjacent to a z-pinch accelerator for the purpose of providing radiographic images of high energy density conditions on the accelerator.

OCIS codes: (140.3530) Lasers, neodymium; (140.4480) Optical Amplifiers; (340.7440) X-ray imaging

Accelerators such as the Z-Machine at Sandia National Laboratories have historically lacked the radiography diagnostics available at laser-based high energy density physics (HEDP) facilities. In such diagnostics, a laser synchronized to the HEDP event impinges upon a foil target to create an x-ray point-source, which in turn illuminates the high density target (or "backlights" it) such that a radiograph can be recorded much like a dental x-ray. Radiographic backlighting in this fashion has been widely used in inertial confinement fusion (ICF) laboratories such as the NOVA laser facility at Lawrence Livermore National Laboratories (LLNL). Based on this experience, a backlighting laser system for the Z-Machine [1,2] has been constructed using the former Beamlet laser [3,4] from LLNL.

Originally developed as a prototype segment of LLNL's National Ignition Facility, this kilojoule-class Nd:Glass laser system (λ=1053 nm), now referred to as the Z-Beamlet laser (ZBL), has undergone a number of modifications in order to meet backlighting needs (see Fig. 1). The basic design uses a diode-pumped fiber-optic master oscillator to provide a stable seed pulse typically of 300 ps FWHM. The seed in turn goes through 3 successive amplifiers: a small ring regenerative amplifier (capable of mJ-level outputs), a 4-pass rod amplifier (capable of J-level outputs), and the main cavity 4-pass amplifier (capable of kJ-level outputs in a square-shaped flat-top beam profile of 31 cm diameter – see Fig.2). After amplification, a large aperture KDP crystal allows second harmonic generation with conversion efficiencies in the 50-60% range. When focused, ZBL operates at an on-target wavelength of 526.5 nm (2ω) with 500 J in a 300 ps pulse in spot sizes on the order of 100 μm or better, allowing target irradiances to exceed 10^{16} W/cm^2. At the foil target, such intensities yield hot plasmas capable of generating x-rays in the 4 to 12 keV range, depending upon target type. Backlighting tests and stand-alone studies can be performed in the optional calibration chamber. When performing radiography on Z-Machine shots, the 2ω beam is propagated over 70 m via a vacuum relay telescope before being folded down by a mirror and focused by an aspheric lens (f=3.2 m) onto the foil target in the accelerator.

This approach has yielded, for the first time, radiographic images of what the HEDP conditions in the Z-machine are capable of. The Z-machine is a z-pinch device, using pulsed power methods to implode wire arrays and create high density plasmas and consequent x-ray emission. Small cavities (holhraums) are used to symmetrically bathe capsules in this radiation, causing the capsules compress for ICF studies. Radiography performed during an accelerator shot shows implosion symmetry and a factor of 2 compression at 14 ns after peak accelerator radiation (see Fig. 3). The new radiography ability provided by ZBL allows this implosion symmetry to be studied and improved.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94-AL85000.

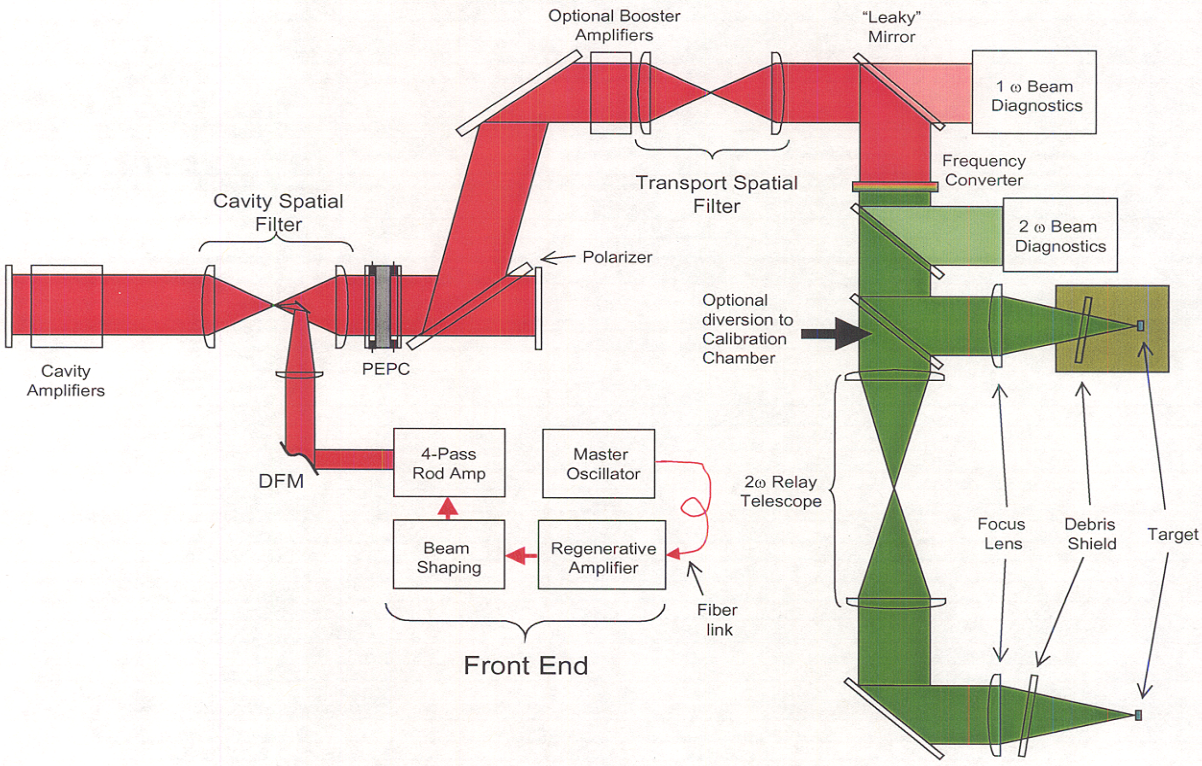

Fig. 1. Overall ZBL system schematic.

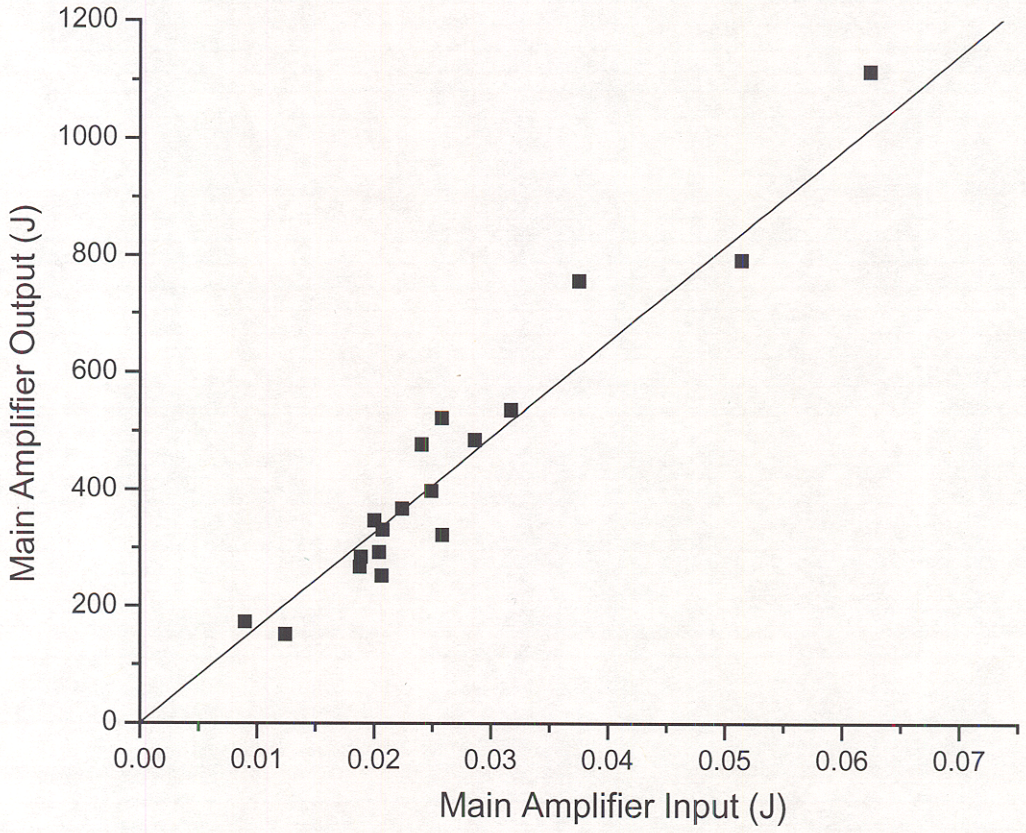

Fig. 2. Main cavity gain for initial activation series from April to June 2001. The total small signal gain indicated by the line slope is 16270±2590 for 300 ps FWHM pulses.

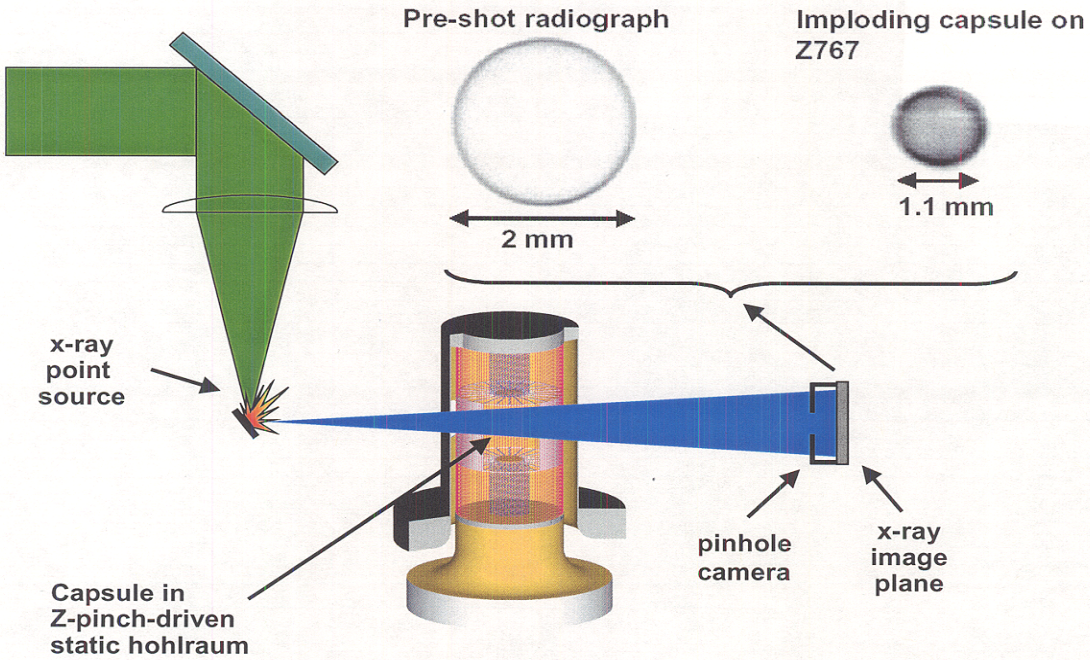

Fig. 3. Radiography schematic and radiographs of capsule before compression and during compression on a Z-machine system shot using a titanium target.

References

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