A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although portions of this report are not reproducible, it is being made available in microfiche to facilitate the availability of those parts of the document which are legible.

LA-UR -85-3002

CONF-850887 --33

Received by CIA

SEP 10 1985

85017339

DR-1390-0

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--85-3002

DE85 017339

TITLE: THE FORGE: A SHORT PULSE X-RAY DIAGNOSTIC DEVELOPMENT FACILITY

AUTHOR(S): G. L. Stradling
T. R. Hurry
E. R. Denbow
M. M. Selph
F. P. Ameduri

SUBMITTED TO: SPIE's 29th Annual Technical Symposium
Town & Country Hotel
San Diego, California

August 19-25, 1985

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

By acceptance of this article, the publisher recognizes that the U S Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U S Government purposes

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U S Department of Energy

Los Alamos

MASTER

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

The Forge: a short pulse x-ray diagnostic development facility

G. L. Stradling, T. R. Hurry, E. R. Denbow, M. M. Selph and F. P. Ameduri

Physics Division, Los Alamos National Laboratory
Mail Stop D410, P. O. Box 1663, Los Alamos, New Mexico 87545

Abstract:

A new short pulse x-ray calibration facility has been brought on line at Los Alamos. This facility is being used for the development, testing and calibration of fast x-ray diagnostic systems. The x-ray source consists of a moderate size, sub-nanosecond laser focused at high intensity on an appropriate target material to generate short pulses of x-ray emission from the resulting plasma. Dynamic performance parameters of fast x-ray diagnostic instruments, such as x-ray streak cameras, can be conveniently measured using this facility.

System design objectives

We created this experimental facility to provide the means to efficiently and conveniently perform dynamic characterizations of fast x-ray detectors. Static sources are generally inadequate for evaluating the dynamic performance of streak cameras, framing cameras and other fast detectors. Important dynamic streak camera parameters to be determined include sweep linearity, dynamic spatial resolution, temporal resolution, dynamic range, dynamic distortion, and spectral sensitivity.

The Forge facility is to be used to characterize and improve x-ray streak camera designs, to develop and test fast framing camera concepts and to provide first order calibrations of the spectral sensitivity of x-ray detectors. Forge will also serve as a test bed for testing diagnostic systems consisting of x-ray optic elements coupled to x-ray detectors.

Optimum utility will be obtained from this x-ray source if the x-ray pulses are stable in amplitude, pulse width and spectral shape and are intense enough for low sensitivity applications. Additional requirements include a short cycle time (a few minutes) to allow rapid iteration, selectable pulse widths, and a high level of system reliability.

To have real time image recording and analysis capability is highly desirable for efficiently performing iterative measurements at this type of facility.

The laser system

We have met these requirements with a 1.06 micron wavelength solid state laser which irradiates a target at very high intensity in a short pulse. This creates a hot x-ray emitting plasma of a duration similar to the laser pulse.

The laser consists of a commercial AML 2000 Nd:YAG oscillator/preamplifier system* followed by three stages of amplification (Figure 1).

The laser oscillator is of an actively modelocked and Q-switched design^{1,2} which results in very stable, reliable operation which has low jitter (8 ns) with respect to an external trigger.

The AML 2000 laser typically generates pulses at up to 10 Hz with better than 90 percent energy stability and better than 95 percent reliability, shot to shot. The pulse width may be adjusted between the limits of 100 ps and 1 ns by changing the RF power to the acousto-optic modelocker and by tuning the oscillator cavity. A preamplifier and two Pockels cell single pulse selector units follow the oscillator in the AML 2000 system to produce a single laser pulse of up to 7 mJ with a pulse to background contrast ratio of 1000:1. A pulse train of adjustable separation may be obtained by directing the oscillator pulse through a variable spacing etalon (Figure 2).

For x-ray generation, the oscillator output is passed through the main amplifier chain and is then focused onto a target. Alternatively, the pulse at the output of the preamplifier may be harmonically converted to 532 nm, 355 nm or 266 nm. This visible or UV signal may be diverted directly to shorter wavelength detectors. The UV pulse is particularly useful as some x-ray detectors have UV sensitivity.

*This AML 2000 laser is manufactured by JK Lasers, Rugby, England.

Figure 1. The Forge laser schematic layout showing the oscillator/preamp unit which feeds an optical signal into an amplification chain. The chain of three glass rod amplifiers, Pockels cell switches, and spatial filters increase in aperture to maximum of 50 mm diameter. The amplified laser pulse is focused onto a target in the vacuum chamber. An x-ray pulse is produced by focusing the amplified laser pulse onto a target in the vacuum chamber. X-ray detectors directly view the x-ray emitting plasma.

The main amplifier chain of the laser (Figure 1) consists of three ND:glass rod amplifiers.** Two amplifiers have rod diameters of 25 mm. The final amplifier has a 50 mm aperture.

Figure 2. A 1.06 micron pulse train with 300 ps pulse spacing is recorded using a Hamamatsu S-1 streak camera. The pulse train is generated by passing the output of the AML 2000 system through a variable spacing etalon.

**These components are from the dismantled Shiva laser and were provided by the LLNL laser fusion program.

A hard aperture at the beginning of the amplifier constrains the laser beam to a super gaussian spatial profile. This aperture is optically relayed through the system by a series of three beam expanding spatial filters.** The spatial filters also smooth diffraction ripples in the beam spatial profile, Figure 3, allowing higher average power density in the glass and a tighter diffraction limited focus on the target.

Figure 3. A burn pattern of the amplified laser pulse on a Polaroid burn card. The beam diameter is 40 mm with a relatively smooth spatial profile.

The output energy of the laser is limited by the surface damage threshold of the target or by the target. Conservative limits are 1.5 J at 100 ps pulse width and 15 J at 1 ns pulse width.

Isolation between amplification stages and between the last amplifier and the target is accomplished using shutters** consisting of Pockels cells positioned between crossed polarizers. These electro-optical shutters are synchronized to open with the arrival of the laser pulse and are open for 20 ns. In their normally closed state they prevent amplified stimulated emission (ASE) from depleting the amplifiers or generating a spark at the target. In addition they prevent amplified reflections from traveling in the reverse direction and damaging the smaller optics.

Consistent with our objective of a low maintenance, reliable system, we have drawn on the extensive solid state laser engineering and design experience accumulated in our fusion program. We have followed the drive power conditioning technique used in our rod amplifier power conditioning system. Our amplifier drive consists of a thyristor-ignitron-switched capacitor bank which are charged to 20 kV. About 100 capacitors (12 kJ) are required to fire our amplifier system.

When repetitive operation is required, a control system with automatic synchronization through its charge and fire sequence, typically with a five minute period.

We have given particular attention to engineering the optical system for handling the laser with minimum of maintenance. The entire laser system is positioned on a specially designed optical table† 30 ft. long by 4 ft. wide by 2 ft. thick. (See Figure 4). The optical system is on highly stable positioners† for optics and for beam fiducials, induces alignment signals for periods of weeks. When misalignments do occur, the use of fixed, IR sensitive video cameras for viewing the beam fiducials allows us to align the entire system in less than an hour.

The laser table is enclosed and back protected with HEPA filtered blower to maintain clean, dust-free optics.

†These items were supplied by Newport Corporation, Mountain View, California.

Figure 6. Dynamic resolution data from a Hadland X-chron 340 streak camera. Resolution is observed in 13 lp/mm and 10 lp/mm blocks. Sweep speed is 100 ps/mm.

Data analysis

Data recording of streak camera type images is often done on photographic film. Polaroid films allow a fairly rapid turn around albeit with very limited resolution and dynamic range. A compelling replacement for photographic film in iterative measurements is an active readout with real time image analysis. We currently use a SIT camera readout with an image processor. We will soon implement a cooled, slow scan CCD with fiber optic coupling to the streak camera for high fidelity recording. Digital images will pass directly to the data analysis system for real time analysis.

Conclusion

We have fulfilled our initial design objectives of building a stable, reliable system producing generous levels of x-ray flux in time scales relevant to ultra fast x-ray diagnostic instrumentation. The Forge pulsed x-ray source has operated consistently for several months and will continue to fill a critical role in x-ray diagnostic development.

Acknowledgments

We wish to acknowledge the generous support and encouragement given to the development of this facility by Peter B. Lyons and Robert A. Day, P-14 Group Leaders, at Los Alamos. We also gratefully acknowledge the advice and assistance of numerous laser program participants at LLNL, including John Holzerich, Howard Patton, Don Hughes, Jeff Biele, Bernice Marshall, Ralph Speck, Tim Wieland, Don Browning and Rich Coombs.

References

1. D. J. Kuizenga, "Short-Pulse Oscillator Development for the Nd:Glass Laser-Fusion Systems", IEEE Journal of Quantum Electronics, Vol. QE-17, No. 9, Sept. 1981.
2. M. S. White, A. D. Damerell, E. M. Hodgson, I. N. Ross, P. W. Wyatt, and D. L. M. Ireland, "An Ultra Low Jitter Synchronized Laser Pulse Generator", Opt. Comm. 21, 1, 51-53, 1 Sept. 1982.
3. G. L. Stradling, D. T. Atwood and R. L. Kauffman, "A Soft X-Ray Streak Camera", IEEE Journal of Quantum Electronics, Vol. QE-19, No. 4, April 1983.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.