

RADIATION TEMPERATURE MEASUREMENTS
IN LASER-HEATED HOHLRAUMS

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Abstract

Two x-ray spectrographs have been used on the Trident laser at LANL to monitor the radiation temperature of small Au hohlraums. The cylindrical targets are smaller than 1 mm. The x radiation produced by ~400 J of 0.53- μ m laser light is detected with a 7-channel VNIIEF soft-x-ray spectrometer. Each channel employs a multi-layer mirror and a filter to limit the channel bandwidth to 1 - 3 % of the channel energy. X rays are detected with calibrated Al x-ray diodes. A second spectrometer is based on a free-standing Au transmission grating for spectral dispersion and a multi-channel diamond photo-conductive device detector. The small hohlraum results are consistent with radiation temperatures exceeding 100 eV. Simple computer modeling shows that late in the plasma discharge, radiation of this temperature is emitted from the target.

Characterization of radiation drive in hohlraums is an important task for many scientific endeavors including indirect inertial confinement fusion, laser-plasma instability physics, shock physics, and material science [1]. We have employed two separate x-ray spectrometers to accomplish this characterization of hohlraums at the Trident laser facility in Los Alamos. The spectroscopic determination of radiation drive in hohlraums is an alternate to the measurement of shock breakout and changes in reflectivity [2]. By selecting the appropriate spectroscopic energy and by using fast

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response electronic detectors, the researcher may determine a time-dependent spectrum of the drive and thus the energy content over a large spectral range. The other options are time-integrating determinations of the drive. Their interpretation requires model-dependent analysis of the witness plate rather than the calibration of sensitivities of the spectroscopic channels.

Trident [3] is a glass laser with two main beams of frequency doubled light at 527 nm. Each beam, depending on pulse length, may focus up to 250 J of energy onto the target. The best focus spot size is 120 μm . For the present hohlraum experimental series, we used flat-top pulses from 0.5 to 1.0 ns duration.

The Au hohlraum target is shown in Fig. 1. It is a modification of the labyrinth hohlraum [4]. In order to raise the radiation temperature, we designed the target to be smaller with no regard for symmetry of

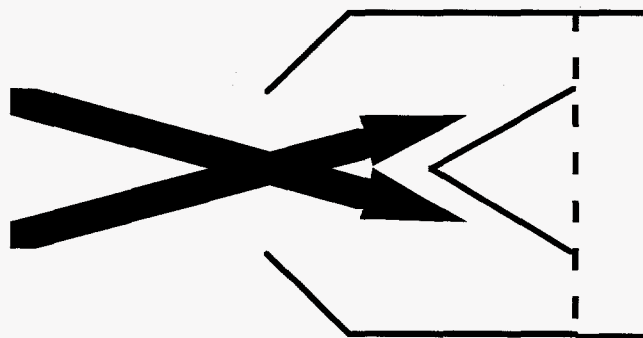


Figure 1. Two beams enter the hohlraum from the left. The diagnostic hole is on the right.

illumination. The cylindrical target is 600 μm in diameter and 700 μm in length. A hollow Au cone is supported on a plastic ($\sim 0.5 \mu\text{m}$ thick) web. The laser entrance hole is 300 μm while the diagnostic hole behind the cone is 250 μm in diameter. Best focus of the beams was at the laser entrance hole.

Typical energy input was 320 - 400 J. Backscattered radiation was monitored with a calorimeter and found to be < 10% of the laser drive. X-ray pinhole photography showed that the laser energy passed through the entrance hole into the target.

The hohlraum was modeled with 2-D LASNEX, a hydrodynamics code [5]. The density profiles within the target are shown in Fig. 2. The heavy lines show the position of the fastest ions moving out from the wall as it is filled with plasma. The gray scale indicates the logarithm of the electron density. As seen below, the critical density region [$\log(n_e) = 21.6$]

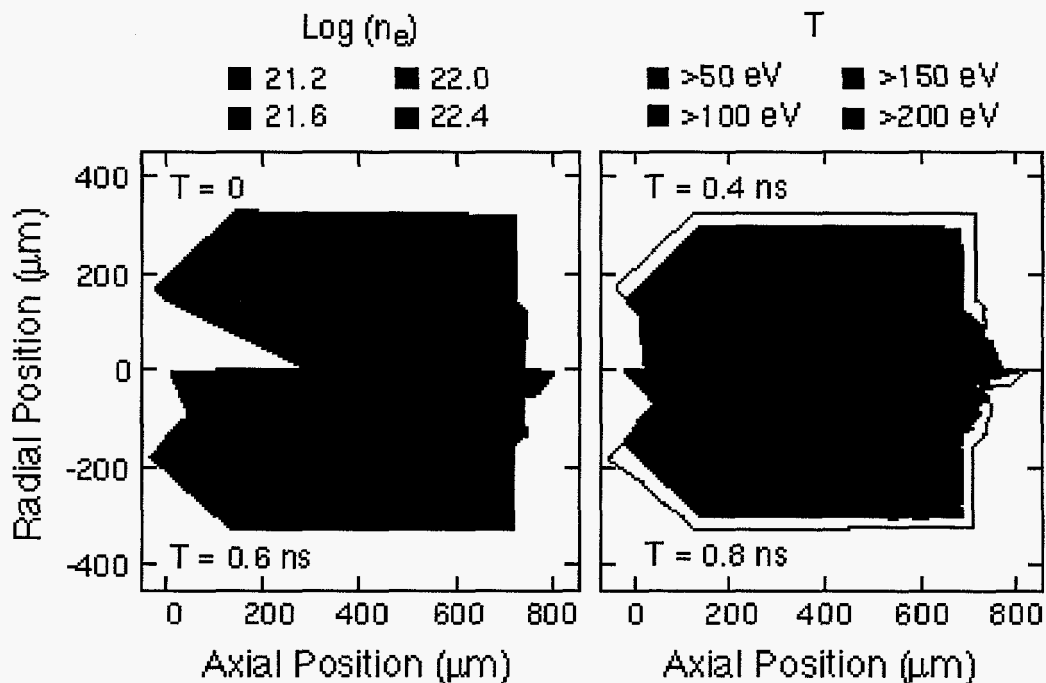


Figure 2. Plot of the hohlraum density initially and at 0.6 ns on the left; radiation temperature and values are on the right.

is moving at 0.6 ns such that the right side of the target is nearly sealed off to the laser drive. However, the x rays converted at the wall are still free to

flow throughout the volume. Figure 2 also shows the computer model of the radiation temperature. On this low resolution figure, it is possible to see regions exceeding 100 eV in the back of the hohlraum while at the tip of the cone, temperatures approach 200 eV. The heavy lines have the same meaning regarding density as in Fig. 2. Note that plasma is moving into the diagnostic hole at the rear of the target. The opacity of this plasma may become an issue for this design to drive packages of interest efficiently.

Of the two spectrometers employed, one is a Russian-built soft x-ray spectrometer [6] consisting of 7 filtered x-ray diode (XRD) channels. The second, which is still undergoing refinement, is a 6-channel transmission grating device with a diamond photoconductive array [7]. Reference 8 describes the single channel version of a photoconductive device (PCD), which is the key element in the array.

The typical channel of the Russian spectrometer is shown in Fig. 3. The channel energies used in the Trident experiment were 0.27, 0.40, 0.52,

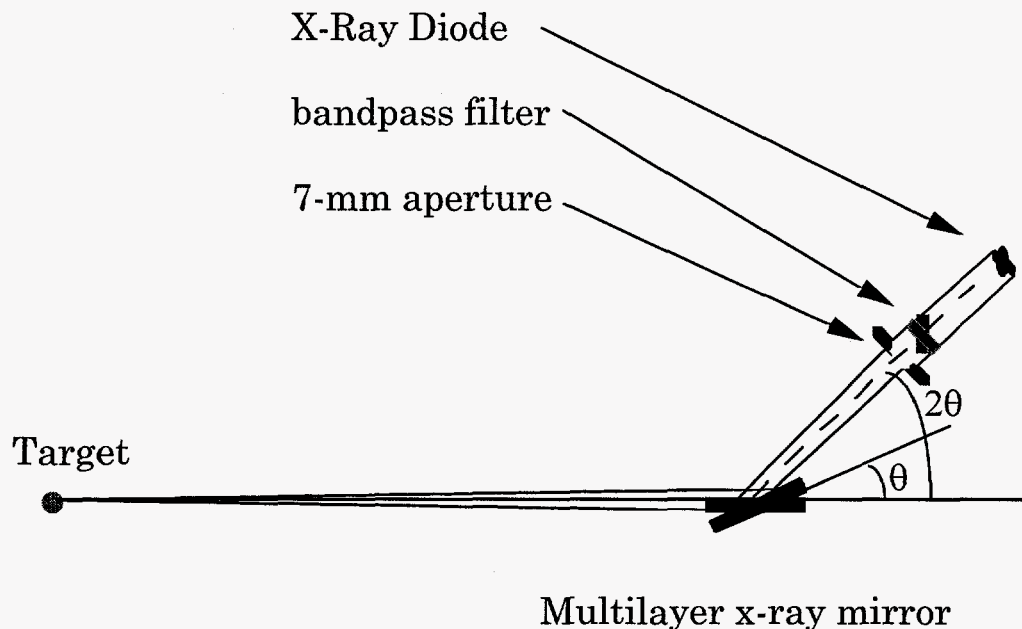


Figure 3. Schematic of a channel in the XRD spectrometer

0.70, 0.93, 1.25, and 1.47 keV. (It is optimized for a radiation temperature range near 0.2 keV.) The most important innovation in its design is the use of multi-layer mirrors, which in combination with the x-ray filters provide extremely narrow bandwidths for detection of x rays. The usual E/dE of the channels is of order 30. The detectors are standard Al photocathodes. Figure 4 shows data from three hohlraum targets shot at Trident.

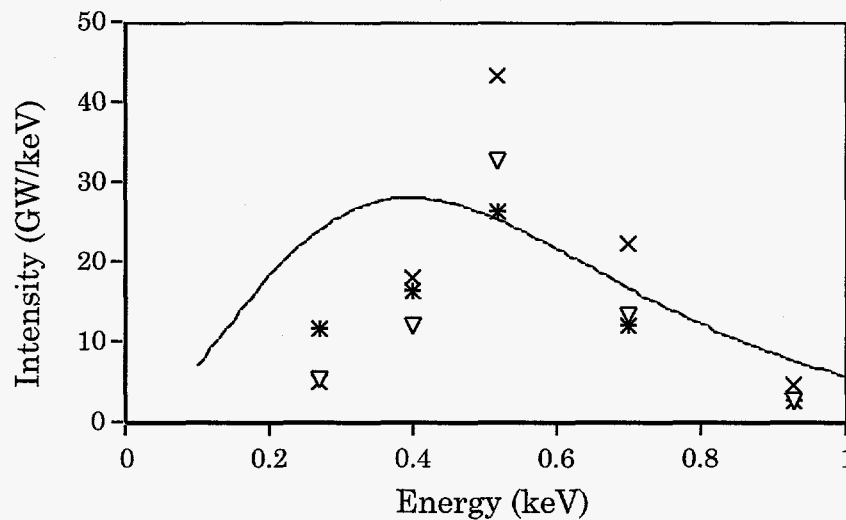


Figure 4. 0.14-keV blackbody curve with data from three hohlraums

The solid curve is for a 0.14-keV blackbody emission taking into account the diagnostic hole size. We find it significant that even with only 400 J of input laser energy, the hohlraum radiation is still recorded by the first 5 channels of the spectrometer. Signal amplitudes ranged from 20 to 300 mV.

It is noted that the first two channels lie below the 0.14-keV curve. This may be attributed to any of several factors. First, the emission may not be representative of blackbody radiation. Second, there may be some Au opacity effect since the diagnostic hole is closing as plasma fills the hohlraum.

Finally, small amounts of surface contamination and changes in the oxidation state of the Al can change the response in the region below 0.5 keV [9]. This because the photocathode becomes something other than Al, i. e., Al₂O₃ or C. This last effect never serves to improve the sensitivity.

The second spectrometer uses a free-standing Au transmission grating to disperse the hohlraum radiation across a diamond PCD array. The grating period is 200 nm. The PCD array is shown in Fig. 5. Its dimensions are 3 x 10 mm. The multi-channel (6 in this case) array is

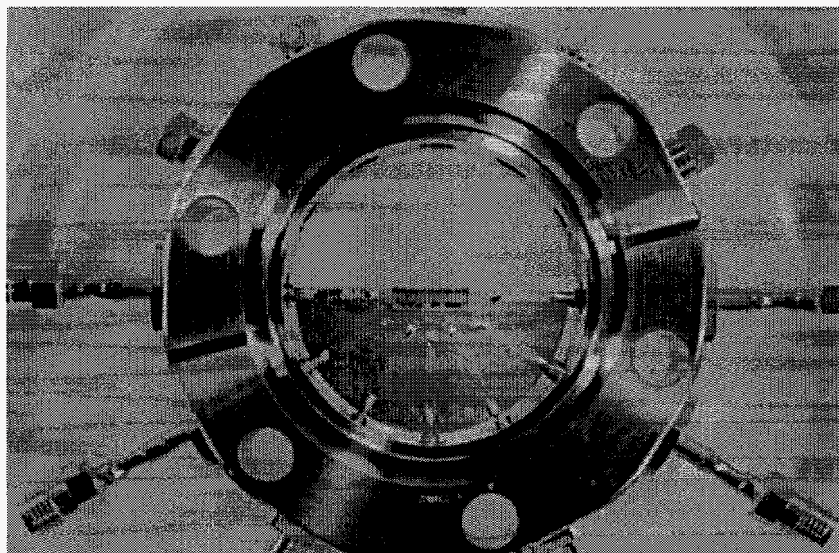


Figure 5. Diamond PCD array, center, with 50-Ω strip lines.

illuminated by the dispersed x-ray spectrum as in Fig. 6. An x-ray CCD (charge-coupled-device) camera is used behind the open area for wavelength calibrations, alignment, and time-integrated measurements. There are several advantages of this spectrometer. First, the dispersion may be varied by changing the grating-PCD array spacing to fit the expected emission spectrum of the source. Second, the diamond, which is blind to laser radiation, has a higher sensitivity to x rays than Al XRDs, and third, the

inherent speed of the PCD is extremely high by virtue of interdigitated electrodes with 10- μm spacing. At 10 VDC bias, the effective electric field is 10 kV/cm for collecting electron-hole pairs. Finally, the PCD is immune to the sort of surface contamination which hinders Al XRDs. For the PCD, being a volume detector rather than a surface detector, the surface film becomes only a thin filter -- not the virtual photocathode as with an XRD. Sensitivity calibrations should be more stable than for Al XRDs. The time response of either spectrometer is limited by the digitizer speed.

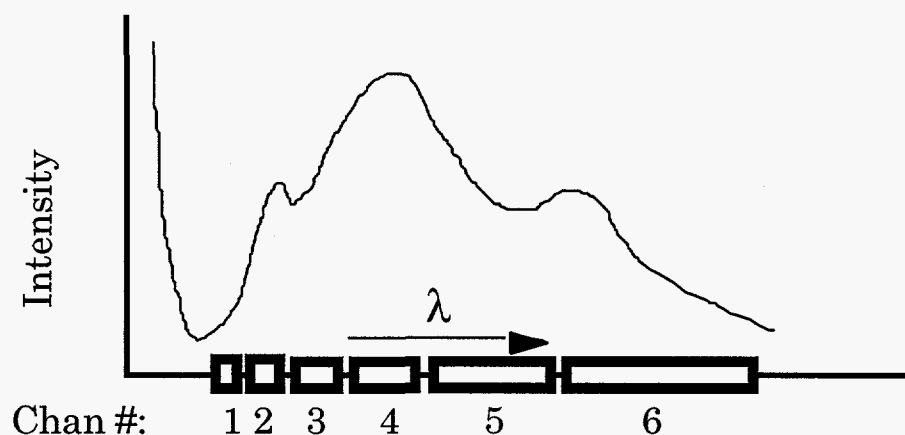


Figure 6. Schematic of 6-channel PCD array superimposed on an x-ray spectrum. The zeroth order of the grating spectrum rises to the left.

In summary, we plan to use these two spectrometers for hohlraum characterization. Further calibration efforts will have a high priority. The development of the transmission grating spectrometer will continue. We look forward to further collaborations between our institutions.

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