

LA-UR-94-3182

Jmj 9409225-

Title:

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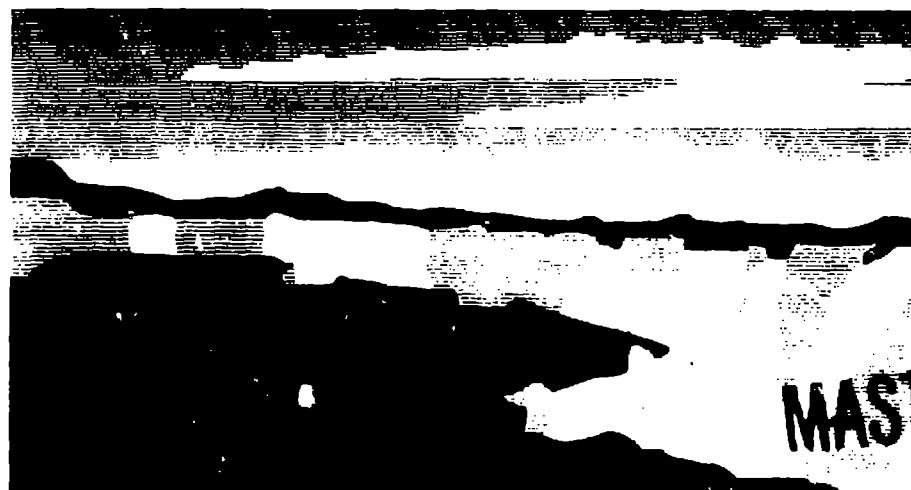
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Submitted to:

ECLIM.
September 19-23, 1994
Oxford, UK

Los Alamos
NATIONAL LABORATORY



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Form No. 836 R5

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Laser-Plasma Instability in Hohlraums

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Abstract. A gas-filled hohlraum designed so as to approach plasma conditions expected in future ignition hohlraums has been fielded at the Nova laser. Radiation hydrodynamics modeling of these Nova hohlraums predicts reasonably well the measured plasma parameters. The measured reflectivity of a probe beam by Stimulated Brillouin scattering[Forslund *et al.*, PRL 30(1973)739] is modest. Some observed dependencies of reflectivity on laser and plasma parameters are understood theoretically, while others are not.

1. Introduction

Controlling laser-plasma instability is important for the success of indirect-drive laser fusion in the National Ignition Facility (NIF). Because of the relatively long duration of NIF laser pulses, ignition hohlraums are expected to fill with large (size \sim few mm) underdense plasmas (electron density $n_e \sim 5 - 15\%$ of n_{cr}), with electron temperatures in the KeV range. ($n_{cr} = 9 \times 10^{21} \text{ cm}^{-3}$ is the critical density above which the 351 nm light to be used in the NIF cannot propagate.) In these plasmas, Stimulated Brillouin scattering (SBS)[1] could be important, particularly back-scatter, which is expected to have the highest gain.[2] In order to understand SBS in these large plasmas, it is important to study simpler, open targets such as gas bags (see MacGowan *et al.*, these proceedings) or foams. However, in order to extrapolate to NIF conditions, it is also important to study the more complex hohlraum plasmas. The wide range of densities, temperatures and gradient lengths in such a system, particularly with a wall of high-atomic-number material, could lead to various instabilities which could either seed each other or compete with each other. This paper presents results from a Los Alamos program to study hohlraum SBS using the Nova laser at Lawrence Livermore.

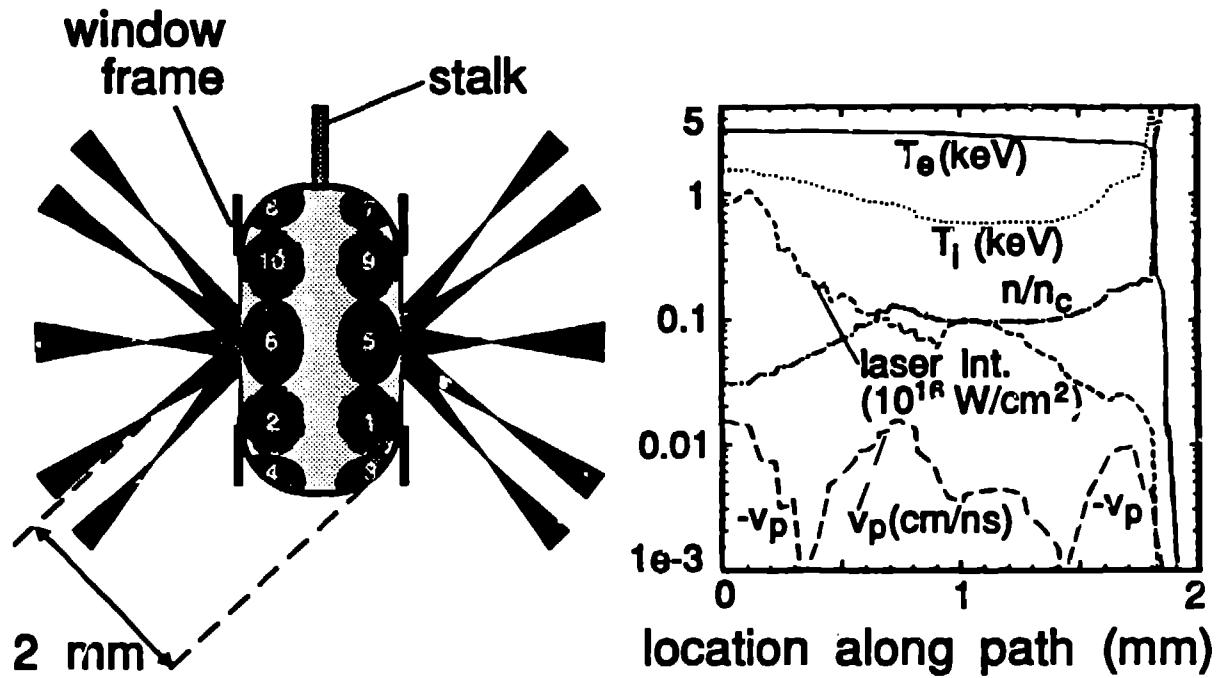


Figure 1. Left: The toroidal gas-filled hohlraum is illustrated along with the footprints of the ten Nova beams incident on the inner wall. Footprints on the far wall are drawn with a dashed outline. Right: Calculated parameters along a beam path are plotted for time 1 ns.

2. Hohlraum design

A hohlraum for the Nova laser was designed at Los Alamos (see Fig. 1, left) so as to approximate plasma conditions expected in NIF hohlraums. Despite the much lower energy of Nova when compared to NIF, various key plasma parameters in these gas-filled gold Nova hohlraums theoretically approach simultaneously NIF-like values. These design parameters include relatively high electron temperature ($T_e \approx 3$ keV), radiation temperature ($T_r \approx 200$ eV) and electron density ($n_e \approx 0.1n_c$), but ion temperature $T_i \approx T_e/2$. These conditions are maintained for about 0.5 ns with density and velocity gradient scale lengths down from NIF scales by only a factor of ≈ 2 . Fig. 1 (right) shows radiation hydrodynamic modeling predictions for various plasma parameters along the beam path when the hohlraum is filled with 1 atm of neopentane gas (C_5H_{12}). In the experiment, nine 351 nm f / 4.3 Nova beams are turned on at time 0 to a power level of 2 TW each. Power linearly ramps up towards 3 TW at time 1.4 ns, when the beams are turned off. The beams diverge for a distance of 3.4 mm from best focus before hitting the hohlraum wall. The pulse shape on the probe beam (# 7) has been varied, but is typically a 1 ns square pulse which turns on at time 0.4 ns.

The evolution of T_r has been measured with the Dante diagnostic.[3] Peak T_r measurements in four hohlraums filled with neopentane and illuminated using the same laser pointing yield 202 ± 5 eV. T_e has been diagnosed radially

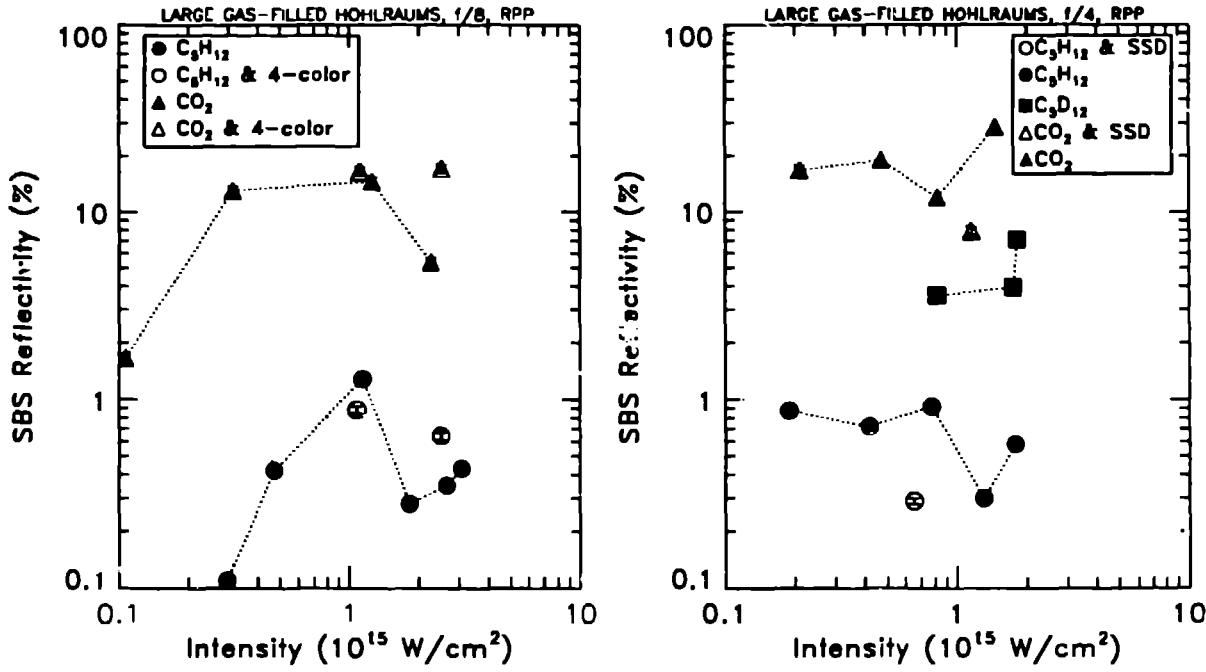


Figure 2. SBS reflectivity of a probe beam versus beam intensity from toroidal hohlraums filled with various gases. On the left plot, the probe-beam focusing lens had an $f/8$ optic, while on the right it had $f/4.3$.

at an axial position near the hohlraum midplane by Cr/Ti isoelectronic X-ray spectroscopy[4] (see Gobby *et al.*, these proceedings) using time-resolving Bragg-diffraction spectrometers.[5] Around the hohlraum center, measurements yield $T_e = 3 \pm 0.5$ keV. The biggest discrepancy between modeling and measurement has been in electron density. Whereas it is predicted that $n_e \approx 0.10 - 0.15 n_{cr}$ where any of the beams cross the midplane, Stimulated Raman sidescatter and $(3/2)\omega$ emission (from two-plasmon decay) indicate the presence of $n_e/4$ there.

3. Reflectivity measurements

The SBS reflectivity of the probe beam is shown in Fig. 2. The 351 nm probe beam generally had a random-phase plate to spatially smooth the beam.[6] In some $f/4.3$ experiments, 3 Angs. of bandwidth was also added to the probe beam for temporal smoothing (SSD).[7] The beam was normally focused at the hohlraum midplane, but sometimes near the laser-entrance hole. The probe beam is divided into four quadrants. For some $f/8$ experiments, the laser wavelength of successive quadrants has been displaced by 2 Angs. (8 Angs. separation between the bluest and the reddest quadrant). This four-color configuration is a good approximation to the NIF, where four beamlets form an effective $f/8$ cone.

Fig. 2 shows a dramatic effect of the ion species on SBS behavior, presumably due to differences in the Landau damping of the daughter ion wave. Based on the T_e from modeling, it is calculated that in neopentane the H ions are very

effective in Landau damping the ion waves, whose acoustic speed is dominated by the C ions. As the ratio of ions masses in the mix gets closer to unity for C₅D₁₂ and for CO₂, the damping rate decreases.[8] The saturated level (at higher intensity) of reflectivity is strongly anticorrelated with the damping level, as expected theoretically. It is noteworthy that present NIF designs use a He/H mixture, which projects to an even higher level of Landau-damping than neopentane.

The qualitative shape of the reflectivity curves versus intensity for the f / 8 probe beam is similar to that predicted theoretically.[9] There is an onset critical intensity I_c where SBS turns on sharply and saturates. And as observed, with an increasing normalized damping rate, the calculated I_c increases because it is necessary to drive SBS harder to get significant gain. The reasons why, for f / 8, the reflectivity decreases at the highest intensities could include significant scatter outside the beam cone, which we do not measure.

The f / 4.3 data are more puzzling. As the f-number decreases, I_c should theoretically increase, as long as the velocity-gradient scale-length is much longer than the length of hot-spots ($l_s \approx 8f^2\lambda$, where λ is the laser wavelength[10]). So with l_s about four times smaller with f / 4.3 than with f / 8, I_c should be higher for f / 4.3. Yet, I_c for f / 4.3 has been bounded by a very low intensity.

In conclusion, the SBS reflectivity from neopentane-filled toroidal hohlraums (the most similar to NIF hohlraums) is low, even for high intensities. The observed reflectivity dependence on ion species and the SBS-onset intensity observed for f / 8 are qualitatively in agreement with theoretical expectations. But the lower value for the SBS-onset intensity for f / 4.3 is not understood.

The authors wish to thank the Nova operations team and the Los Alamos technicians supporting Nova for their excellent help. Mike Salazar (LANL) and Gary Stone (LLNL) did copious and dedicated work supporting the target gas-fill operations. This work is supported by the US Department of Energy.

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