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Efficient Coupling of 527 nm Laser Beam Power to a Long Scalelength Plasma

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Abstract

We experimentally demonstrate that application of laser smoothing schemes including smoothing by spectral dispersion (SSD) and polarization smoothing (PS) increases the intensity range for efficient coupling of frequency doubled (527 nm) laser light to a long scalelength plasma with $n_e/n_{cr} = 0.14$ and T_e = 2 keV.

Introduction

Indirect drive ignition designs for the National Ignition Facility (NIF) show improved performance in simulations if the energy coupled into the capsule is increased[1]. Frequency tripled (351 nm) laser beams provide up to 1.8 MJ of energy to the hohlraum with about 10% of this coupled into the fuel capsule[2]. The energy available at 351 nm is limited by optical damage and the frequency tripling efficiency of the laser. Frequency doubling (527 nm) has a greater efficiency and can provide 4 to 5 MJ of energy to the hohlraum. Optimized target designs for 527 nm laser light can couple from 10% to 30% of the higher available laser energy into the capsule.

Even though the available energy at second-harmonic is higher it is possible that the coupling is poor compared to third-harmonic due to increased backscattering from parametric instabilities (PI). Significant and reproducible fusion yield relies on having the capability to predict and control the laser coupling. Control of parametric instabilities has been demonstrated at 527 nm and 351 nm by application of spatial and temporal smoothing as well as intensity variation and polarization smoothing. Experiments exploring the coupling and propagation of a 527 nm laser into a long scalelength high temperature plasma would provide important data for assessing the 527 nm ignition designs.

The main result of this paper is that application of SSD and PS laser smoothing together is the most effective smoothing combination and increases the intensity limit for which a 527 nm interaction beam can couple well to a long scalelength plasma by a factor of about 2 to 3.

Laser, target and diagnostic characteristics

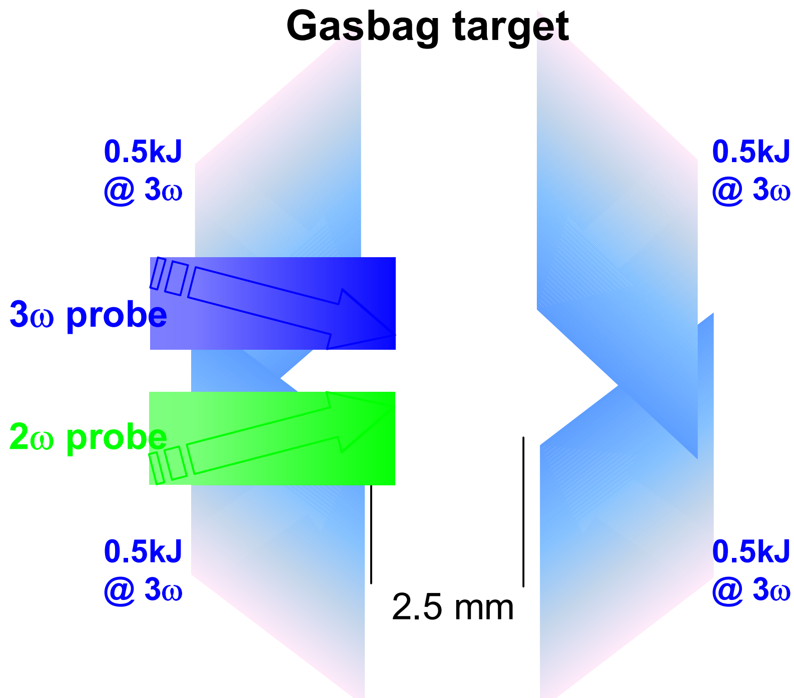

Figure 1. Sketch showing a typical gasbag target with heater beams from both sides and 527 nm and 351 nm probe beams from one side.

The experiments used gasbag targets[3] such as pictured in Fig. 1. This target consists of two circular polyimide membranes attached to the edges of an aluminum washer. The region between the membranes is filled with a hydrocarbon gas to about 1 atm causing the membranes to expand outward in the shape of a balloon. The fill gasses consist of various CH mixtures with a small fraction of Argon or Xenon dopant. The resulting plasma density is varied between about 5% and 12% of critical density for 351-nm light by changing the gas type and fill pressure.

The experiments were performed using 41 beams of the Omega laser located at the Laboratory for Laser Energetics at the University of Rochester, New York. 39 beams heated the target with 12 kJ of 351 nm laser light in a 1 ns square pulse. The resulting plasma consists of a central plateau region surrounded by an inward propagating blast wave. Outside the blast wave is a blowoff region which has a rapidly decreasing density. Two 1 ns square pulse probe beams (one at 351 nm and the other at 527 nm) turn on 0.5 ns after the start of the heater beams. The probe beams have variable energy and are smoothed with a distributed phase plate giving a spot size of about 200 microns in vacuum.

Backscattered light from both probe beams is measured using a full aperture backscattered diagnostic and a near backscatter imager (NBI). Light collected only by the beam focus lens is directed to a set of calorimeters and spectrometers combined with streak cameras which measure the total energy and the time-resolved spectra of SRS and SBS light separately for both probe beams.

Thomson scattering measurements at 527 nm and 263 nm indicate that the electron and ion temperature within the gasbag plasma are approximately 2 keV and 0.5 keV just after the heater beams turn off.

Backscatter measurements

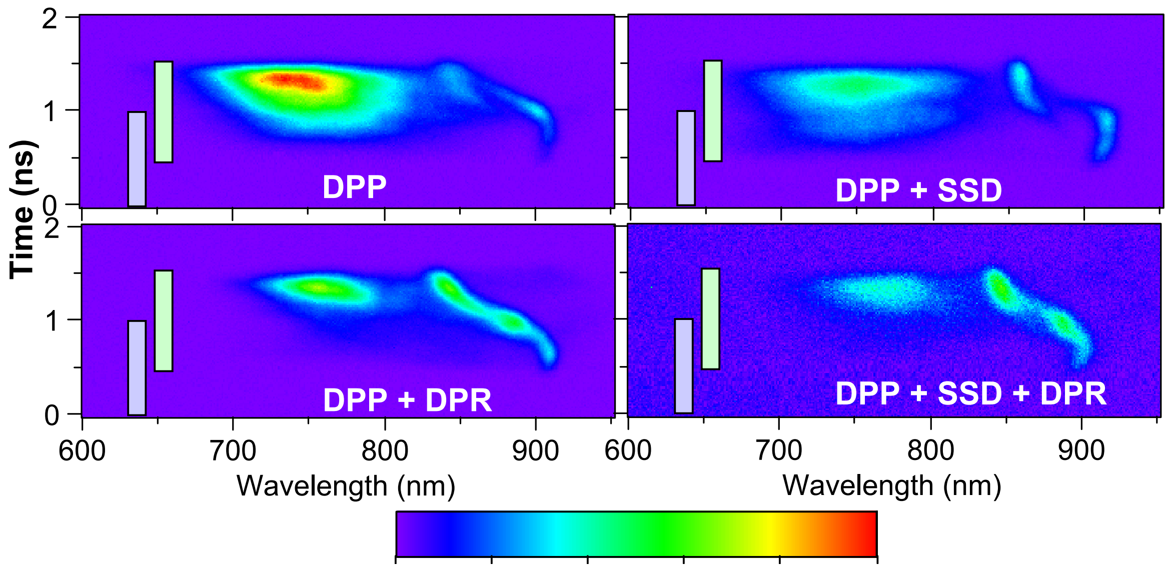

Figure 2. Temporally and spectrally resolved SRS from the 527 nm probe beam for different beam smoothing conditions.

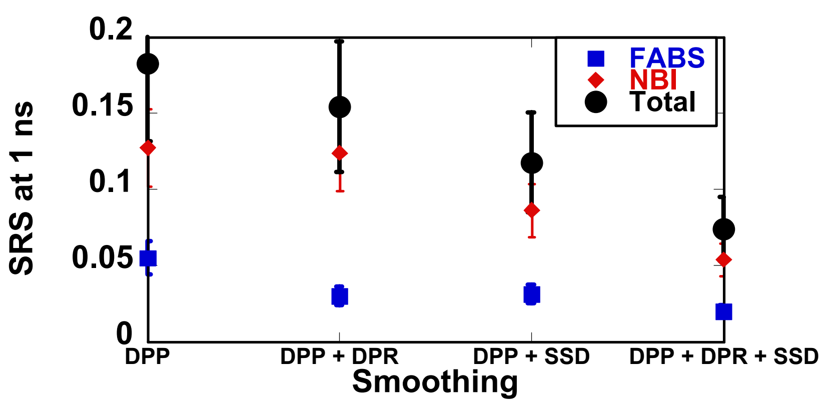

Figure 3. Plot showing the effect of different laser smoothing on the backscattered SRS from the plateau and blowoff plasma region.

Figure 2 shows the time-resolved SRS spectra from the 527 nm probe beam for the different beam smoothing combinations. The SBS scattered light amplitude is negligible. The SRS spectra typically show a narrow spectral feature and a broad feature. Simulations indicate that SRS scattering in the blowoff region produces the broad spectral feature and SRS in the plateau region produces the narrow feature. Application of beam smoothing shows the greatest effect on the SRS in the blowoff. In addition, we see that the combination of SSD and PS results in the greatest SRS reduction.

Summary

Experiments in long scalelength plasmas using a 527 nm probe beam show favorable coupling at 8×10^{14} W/cm^2 if both SSD and PS schemes are used. Without SSD and PS the SRS must be controlled by reducing the intensity to about 2 to 3×10^{14} W/cm^2. These experiments show the capability to control the SRS in the gasbag blowoff plasma; this plasma has similar scalelength and density to the blowoff plasma near the LEH in a NIF ignition hohlraum. Future experiments will explore these effects in a high temperature plasma.

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