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Cover: False colour pinhole picture of a NUHART implosion

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STUDY OF INSTABILITIES IN LONG SCALELENGTH PLASMAS WITH AND WITHOUT LASER BEAM SMOOTHING TECHNIQUES

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INTRODUCTION AND BACKGROUND

The interaction of intense laser light with large underdense plasmas is of great interest for inertial confinement fusion since fusion pellets will be surrounded by large plasma coronas. Under these conditions various parametric instabilities such as Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS) and laser beam filamentation may be very effective in reducing the laser−plasma coupling efficiency, in the production of high energy electrons and in the nonuniform heating of the plasma corona. To simulate fusion conditions, plasmas with scalelengths of up to 1mm were produced by focussing four green laser beams of the CLF high power VULCAN laser system onto thin foil targets in a line focus configuration. A delayed green laser beam was focussed axially into the preformed underdense plasma with an electron temperature and density of about 0.5 keV and 0.1 n_c respectively. The levels of SRS and SBS generated were recorded [1]. Laser beam filamentation and whole beam self−focusing was clearly observed [2,3]. Further, direct experimental observations showed that a significant level of the SRS and SBS were being generated in the filamentory structures [4,5]. When the incident laser beam was smoothed either by Random Phase Plate Arrays (RPPA) or Induced Spatial Incoherence (ISI) a significant reduction in the absolute levels and the virtual suppression of filamentation was observed [5−7].

PRESENT EXPERIMENTAL INVESTIGATION

In this contibution experimental results of a recent investigation (February,1990) are reported. The preformed plasma was again formed by a line focus configuration using four heating beams irradiating a thin aluminium foil target (700nm thick, 0.7mm long, 0.3mm wide). However, in this experiment the heating beams were also smoothed by ISI in contrast to previous measurements in order to produce a more uniform preformed plasma. The two pairs of opposing green laser beams were smoothed using an ISI and RPPA combination and superimposed in a line focus configuration. Typical irradiances of 10^{14}W/cm^2 were used. Either an ISI smoothed infrared (1.05 μm) laser beam or a broadband beam (the ISI beam with the echelons removed) delayed by 2.2 ns was focussed axially into the plasma. An extensive set of diagnostics was used to investigate the plasma conditions of the preformed plasma and the nonlinear interaction of the laser beam with the plasma.

Measurements were made of the absolute levels of SBS backscattering with the broadband beam ($\Delta\omega/\omega \approx$ 0.1%) or with an ISI laser beam to study the effect that spatial incoherence played in the reduction of the backscattered instabilities. At the time of interaction the nominal electron density was about 0.3 n_c (n_c= 1.1x10^{21} cm^{-3} is the critical density for the infrared laser light) and the electron temperature was about 500 eV of the preformed plasma. The uniformity of the preformed plasma was investigated transversely to the exploding foil target by using optical Moire deflectometry techniques with a probe wavelength of 350 nm. The density profile was also measured interferometrically with 350 nm probe beam propagating along the axis of the preformed plasma. The electron temperature of the plasma was obtained from time resolved x−ray streak spectroscopy. The backscattered Brillouin signal generated by the interaction beam was imaged out via the incident focussing lens onto a calibrated photodiode. In addition, time resolved SBS spectra were recorded with a S1 optical streak camera. A four frame x−ray pinhole camera with a gating time of about 150 ps was used to observe the x−ray emission of the preformed plasma and of the interaction beam.

Figure 1 shows the absolute levels of SBS backscattering for the ISI and broadband interaction beams as a function of the incident irradiance.

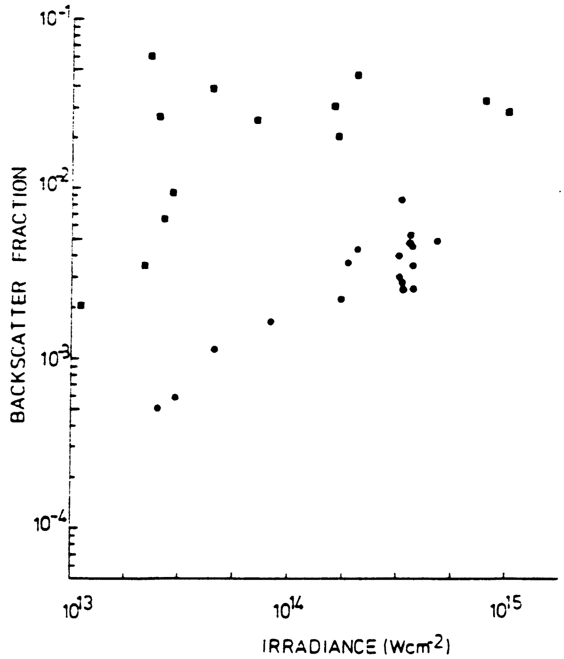

Fig. 1. Variation of SBS backscatter fraction with average irradiance for an ISI (illustrated by the solid circles) and broadband (squares) interaction beam.

The focal spot of the interaction beam was 140 μm in diameter and was kept constant for all the data shots. For the broadband laser beam a threshold at an irradiance of about 3x10^{13} Wcm^{-2} is observed with a saturation level between 2 to 6% of the incident laser energy. For the ISI interaction beam an exponential behaviour is seen with an average SBS value of 0.5% at an irradiance of 7x10^{14} Wcm^{-2}. The SBS backscattering levels are significantly higher than observed in a previous experiment [4,5] in which a green interaction beam was used, the plasma was less uniform and the electron density was lower (by about a factor of 3) during interaction. However, SBS levels were also recorded in the present experiment for thinner targets (500nm thick). For these targets a similar electron density (0.1n_c) as used previously is expected. However, the level of SBS did not vary significantly when compared with thicker targets. The estimated electron density is consistent with backscattered Simulated Raman Scattering (SRS) which was detected by diodes filtered with narrowband interference filters. For the 700nm targets virtually no SRS backscatter is observed. On the other hand, clear SRS signals (at a wavelength of about 1.5 μm) are seen with the 500 nm. These results indicate that the electron density was below 0.25 n_c during interaction.

For some of the data shots anomolously high levels of SBS (larger by about a factor of 8 compared to the data shown in fig.1) were observed when an ISI interaction beam was used. On these shots the x− ray framing camera images as well as the optical probing diagnostic indicated that whole beam self−focusing may have occurred. A channel like structure was observed in the x−ray emission with a diameter of about 40 μm. In addition, a substantially higher transmitted laser energy was measured at the output plane of the the preformed plasma.

In conclusion the absolute levels of SBS in long scalelength underdense homogenous preformed plasmas were measured for a broadband laser beam and a beam smoothed by ISI which interacted axially with the preformed plasma. Whole beam self−focusing of the ISI interaction beam may have been observed for some of the shots.

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