Laser-plasma interaction in hohlraum plasmas at SGII laser facility

Liu Shenye, Li Wenhong, Jiang Xiaohua, and Ding Yongkun

Research Center of Laser Fusion, CAEP
P. O. Box 919-986, Mianyang 621900, Sichuan, P. R. China

Abstract

A experimental study of laser-plasma interaction in hohlraum plasmas produced by short wavelength ($0.351\mu m$) at SGII laser facility is reported in this paper. Crucial processes in laser-plasma interaction are collision absorption and parametric instabilities such as stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS). The scattered energy fluence, angular distribution and time-resolved and time-integrated spectrum of scattered light by SBS and SRS have been measured in these experiments. The experiments show that SRS scattering occurs at laser entrance hole (LEH), and scattering loss produced by SRS is reduced to less more than 1% as the distance of focus point of laser from LEH is more than $400\mu m$. The scattering loss and amount of hot electrons can be controlled to acceptable level in implosion experiments at SGII laser facility by changing focus point position of laser beams entering cavities.

I. Introduction

In indirect-drive approach, laser beams irradiate wall of a high-z hohlraum target and convert laser energy into x rays, which drive the capsule filled DT fuel in hohlraum[1-3] to implode. Laser beams propagate through plasmas in cavity before they reach wall of cavities. Laser lights will be absorbed and scattered by plasmas through the way of light to wall. Significant laser-plasma interaction processes in cavity plasmas include collision absorption and parametric instabilities such as stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS). So laser-plasma interaction is a basic problem in ICF research field. Scattering processes not only scatter laser energy and lower the coupling efficiency, but also affect symmetry of an implosion. Some instabilities such as SRS and TPD could generate deleterious hot electrons. These hot electrons penetrate the ICF capsules and preheat fuel to limit the degree of compression achievable in an implosion. So parametric instabilities such as SRS and SBS in laser-produced plasmas are of interest for the inertial confinement fusion (ICF) [4-7].

SGII laser facility is designed to conduct so-called indirect-drive experiments in China. Before beginning the indirect-drive experiments, we must understand coupling of laser lights

with cavities at SGII laser facility. The absorption and instabilities are concerned particularly. The motive of these experiments is to measure the energy and spectrum of scattered lights, to study instabilities, and to determine the coupling of laser with cavities.

This paper is arranged as follows. In Sec. II we describe the laser conditions, targets and diagnostics used in the experiments. Some laser-plasma interaction experimental results are presented in Sec. III. These results include coupling efficiency, scattered fraction, spectrum of SBS and SRS scattered light as the focus point position of laser light entering cavities is changed. The discussion about our experimental results is also given in Sec. III. In the end we will conclude our discussion and present a summary.

II. Experiments

A. Laser conditions

The experiments were conducted on the SGII laser facility at Shanghai Cooperative Laboratory. The facility can deliver up to 2kJ of $0.351\mu m$ light in a 1-ns pulse onto a target. Each beam can give an energy output of about 0.6kJ of 1053nm laser light. 1053nm laser light can be converted to 351nm laser light with a conversion efficiency of about 40% for tripling. Eight laser beams of SGII are focused on target with f/3 aspheric lens. SGII laser facility is the 8-beam Nd: glass laser system.

The injecting efficiency through a hole and spot size are the important parameters describing quality of laser beams. So we checked these two parameters at beginning of these experiments. Figure 1 and Figure 2 show the relation of spot size with focus point distance from gold disks.
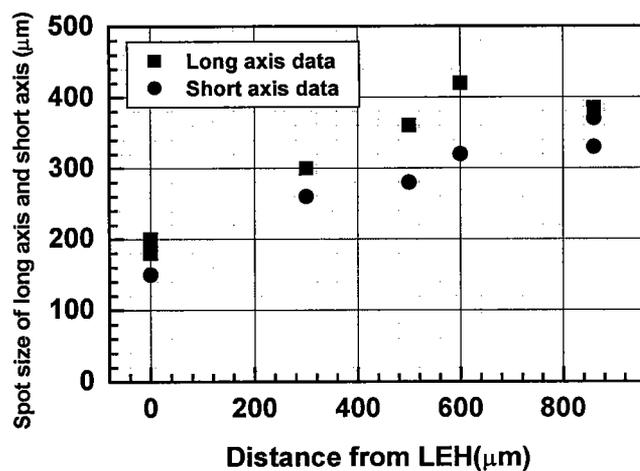

Fig.1 The relation of spot size with focus point distance from gold disks for the four beams focusing at same position
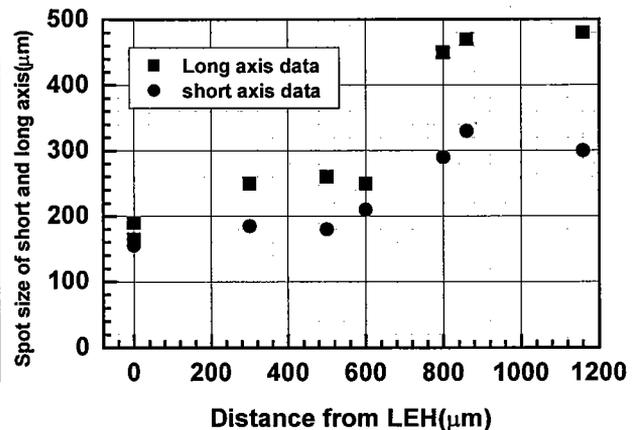
Fig.2 The relation of spot size with focus point distance from gold disks for the four beams focusing at different position

Figure 3 and 4 show the relation of laser light injecting efficiency through LEH with distance from LEH and diameter of LEH. The experiments have proved that the injecting efficiency of laser beams through LEH will be more than 90% when diameter size is large than 300μm and distance of focus point from LEH is less than 500μm.
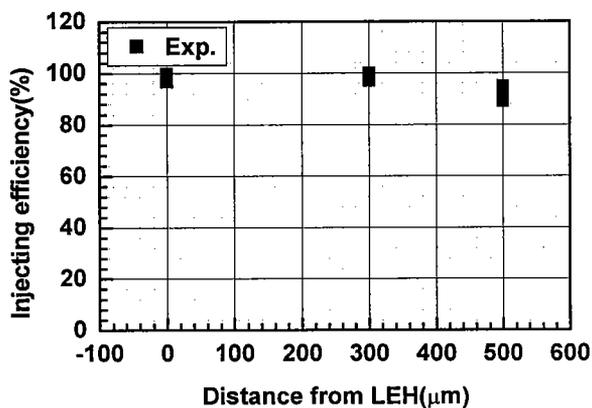

Fig.3 Injecting efficiency of laser beams through LEH is plotted versus distance from LEH as the diameter of LEH is 380μm
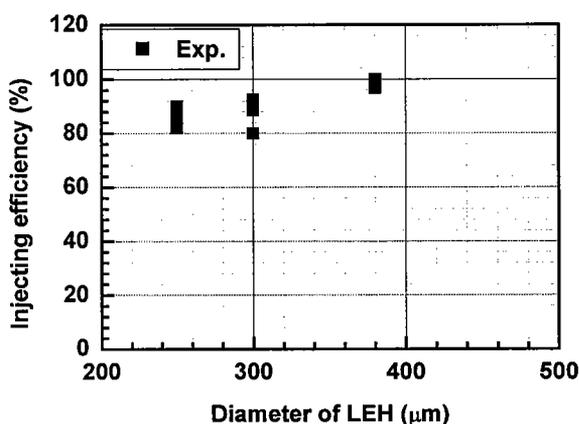
Fig.4 Injecting efficiency of laser beams through LEH is plotted versus diameter of LEH as laser beams are focused at LEH

B. Targets

Cylindrical cavities 1.4mm long and 0.8mmin diameter were used in these experiments. This size of cavities is standard size for implosions at SGII laser facility. LEH Diameter of cavities is 0.38mm. Some hole targets and gold disks are used during the condition experiments. On each side, four laser beams go through LEH to irradiate the wall of empty cavities. Sometimes some different size cavities were also used in order to compare.

C. Diagnostics

The diagnostics in the experiments included an array of PIN detectors, full aperture backscattering measurement system to measure the backscattering into the lens of one of the SGII laser beams, near-backscattering diagnostic system of concave mirror to detect the near-backscattered lights, and the time-resolved spectrometer with optical streak camera measuring SRS and SBS spectra. The time- and spectrum- resolutions of entire spectrometer system are 10ps and 0.05nm respectively. Two pinhole cameras are employed to measure spot sizes and to monitor entering efficiency of laser beams into cavities.

III. Experimental result and discussion
A. Scattered light spectra of SRS and SBS

A time-resolved optical spectrometer with a 300 line-per-mm grating measured the SRS

lights, which were collected by focus lens. The spectral range is from 450nm to 650nm. The lights were dispersed in time by an optical streak camera and in wavelength by a 0.5m grating spectrometer. The signals are recorded with an optical CCD camera. The entire system is sensitive for 300nm-800nm lights. Figure 5 shows the measured SRS spectra from different cavities. The measured SRS spectrum ranges from 450nm to 650nm and time history is very short and scattered signals last about 150ps. The smaller cavities are and the more intense SRS scattering is. The SRS scattering from smaller cavities appears at beginning of laser pulses, but SRS scattering from larger cavities appears at the middle of laser pulses. In smaller cavities the plasma expanding from wall by laser irradiation will filled the cavities, so SRS appears at the beginning of laser pulse. The SRS is very weak in larger cavities, and sometimes the SRS scattering cannot be detected. 526.5nm lights are from conversion crystals and this spectrum line can be served as a fiducial time and spectrum of scattered lights.
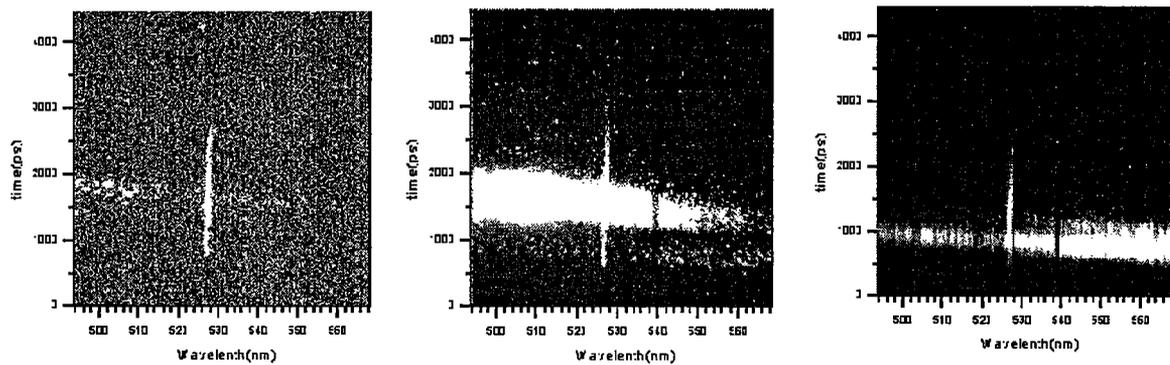
a) SRS spectrum for cylindrical cavities 2.1mm long and 1.2 mm in diameter

b) SRS spectrum for cylindrical cavities 1.4mm long and 0.8mm in diameter

c) SRS spectrum for cylindrical cavities 0.8mm long and 0.6mm in diameter

Fig. 5 Measured time-resolved SRS spectra from different cavities.

Time-integrated SBS scattering light spectrum is shown in Figure 6. The SBS spectrum ranges from 351nm to 352nm.
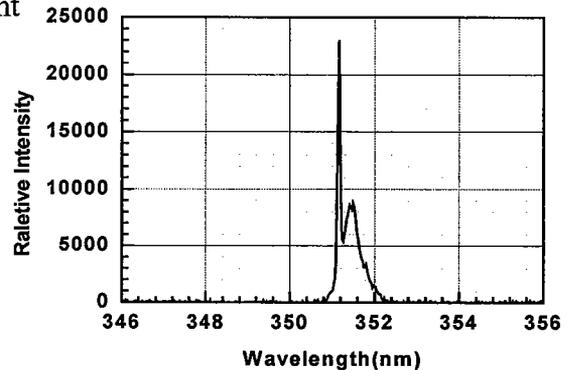

Fig.6 Time integrated SBS spectrum from standard cavities

B. Angular distributions and fraction of SRS

An array of PIN photodiodes measured the time-integrated fluence (J/sr). The bandpass filters were used to ensure that only the 450nm-650nm scattered lights of SRS are detected by photodiodes. The photodiodes with the bandpass filters were calibrated by laser light. The uncertain is estimated about 30%. The SRS angular distribution detected by PIN photodiodes is shows in Figure 7. The SRS fraction is calculated from SRS fluence distribution. The SRS fraction with relation of distance from LEH is presented in Fig.8. The SRS fraction is reduced as the distance of focus point from LEH increases. The SRS fraction can be controlled within 1% as focus point is 400μm away from LEH.
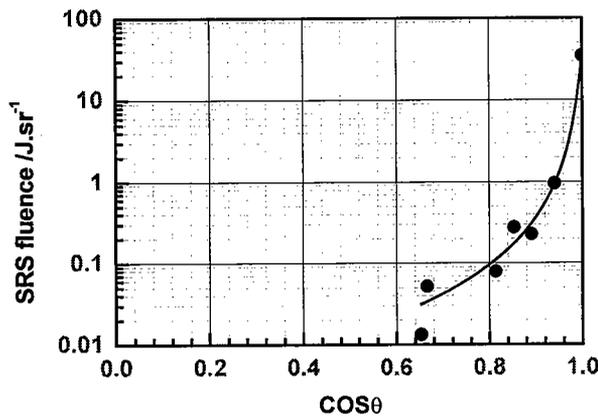

Fig. 7 Angular distribution of SRS scattered energy fluence measured by an array of PIN photodiodes
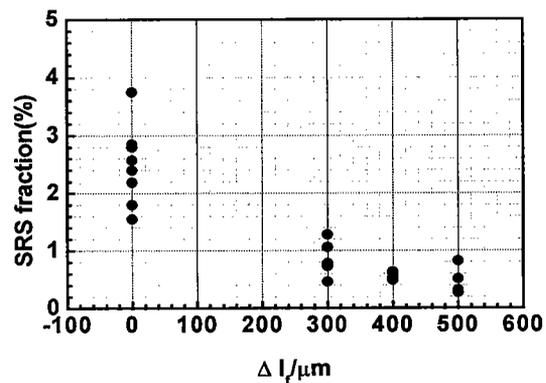
Fig. 8 The SRS fraction is shown as a function of the distance from LEH

The SRS scattering fraction as diameter of LEH and cavities is displayed in Fig.9 and Fig.10. The SRS fraction is lowered when diameter of LEH or cavity diameter increases.
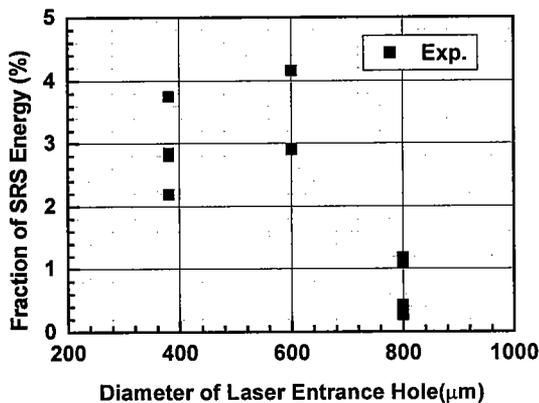

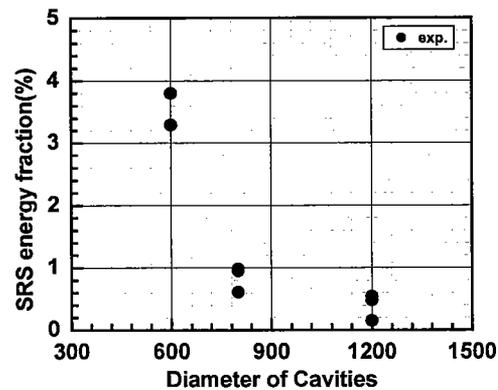Fig. 9 The SRS fraction is shown as a function of LEH diameter.

Fig. 10 The SRS fraction is shown as a function of the cavity diameter

IV. Summary

The experimental results of laser-plasma interaction at SGII laser facility have been

reported in this paper. When the laser beams are focused at laser entrance hole (LEH), Experiments show that the energy of SRS and SBS scattered lights is about 10% and 15% of total laser light energy. The distance between focus point of laser beams and LEH increase, then the scattered energy decreases. So these scattering can be controlled, when we change the position of focus point of entering beams. The SRS scattered energy can be lowered to 1% of total energy of laser beams. In this paper we also reported the spectrum of SRS and SBS scattered light. From the spectrum we can infer some information of plasma in cavities.

Acknowledgements

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