Experimental observations of the characteristics of hot electron and nonlinear processes produced in special material*

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Abstract Making use of disk targets composed of several peculiar materials (foam Au, foam C_8H_8) and hohlraum with a special structure, experiments have been done at "Xing Guang - II" laser facility, which study the characteristics of hot electrons and the related nonlinear processes such as Stimulated Raman Scattering (SRS), Two Plasma Decay (TPD), Stimulated Brillouin Scattering (SBS), etc.

Keywords Foam Au and Foam C_8H_8, Hot electron, Nonlinear Processes

1 Introduction

Hot electrons and the nonlinear processes such as SRS, TPD stimulated in indirect driven ICF are very harmful, which not only cause a great deal of laser energy to be dissipated and decrease the normal absorption of laser energy at the target, but also cause the capsule to be preheated so that the fuel will be more difficult to be compressed. The threshold of stimulating nonlinear processes more depends on the state of laser plasma. A few kinds of materials and target structures have been chosen to help suppress the production of hot electrons and the related nonlinear processes effectively and increasing laser absorption efficiency consequently. Symmetry experiments with a cavity full of gas Ar were conducted in 1995 at Nova laser facility[1], which made the conclusion that the gas filled in the cavity can suppress the plasma rapid motion, consequently the symmetry of several points of percentage can be obtained, and so it is very important for obtaining higher symmetry compression and higher gain in ICF.

2 Experimental conditions and configuration

2.1 Experimental conditions

The experiments were conducted at "Xing Guang -II" laser facility. The parameters of laser and targets are listed in Table 1 and Table 2, respectively.

Table 1 Laser parameters

$\lambda/\mu m$	E_L/J	τ/ps	I_L/Wcm^{-2}
0.35	30~50	500~700	$1\sim4\times10^{14}$

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Table 2 Experimental targets parameters

Target type	Disk target		Disk	
	ρ/gcm^{-3}	d/μm	Substrate	d/μm
Foam Au disk	14.5×10^{-2}	35	Au	4
	17.8×10^{-2}	8	Au	4
Foam C_8H_8 disk	0.048	40	Au	4
Monolayer disk (C_8H_8 film)	1	0.6	Au	4
Multilayer disk (Au foil+C_8H_8 film)		0.1~0.2	Au	4
cavity (with or without foam C_8H_8/C_8H_8 film)				

2.2 Diagnostic arrangement

The eight-channel K-edge filtered spectrometer (K·FS) is used to measure the X-ray spectrum ranging from about 10 to 88keV with low flux. The time-integrated spectra of $3/2\omega$ are measured with an optical multiple-channel analyzer (OMA-4). The K·FS and OMA-4 are, respectively, situated at southeast 45° , northeast 45° (or 70°) with respect to the laser beam direction from the east to the west.

The OMA-4, composed of a grating spectrometer with focal distance of 0.75m and a 512×512 array CCD record system, is coupled with optical fibers so that the time integrated spectra of SRS and SBS are measured at several discrete angles (at the back direction of laser beam, southeast 30°, northeast 45°, northeast 70° with respect to the laser beam direction). The efficiency of SBS back scattering is measured with an ultraviolet light energy meter at the back direction of laser beam.

3 Experimental results and analysis

3.1 The characteristics of hot electrons and the related nonlinear processes from different targets with different materials

Hot electrons are produced from electron-plasma wave which is stimulated in a variety of nonlinear processes such as SRS, TPD in laser plasma. How to produce the hot electrons and the related nonlinear processes is closely related to the plasma state (scale, uniformity, target material and the geometric structure). The experimental results from the targets made of five different materials at about the same experimental conditions show as follows (1) There is no obvious difference in the production of hot electrons and the related nonlinear processes such as SRS, TPD, and SBS from the foam gold disk and from the gold disk (see Table 3), which perhaps means that the miniature aperture in the foam gold is not big enough to affect the plasma state. (2) Hot electrons from the foam gold disk are about several times or even one order of magnitude lower than that from the monolayer or multilayer disk, and the SRS from the foam gold disk is one times lower than that from the monolayer disk (see Fig.1). (3) The SBS reflectivity from the foam C_8H_8 disk is one order of magnitude bigger than that from the gold disk or the foam gold disk, and is about two to three times bigger than that from the C_8H_8 film disk. Both E_{hx} and T_h in the foam C_8H_8 disk are about one times bigger than that from other disks. The SRS from the foam C_8H_8 disk increases severely compared to that from other disks. (4) The SBS reflectivity from the 3μm thick C_8H_8 film disk is three to five times larger than that from the gold disk, and so is hot electrons. Consequently the laser absorption efficiency decreases. Generally speaking, hot electrons and the related nonlinear processes from the C_8H_8 disks or the C_8H_8 film disk increase obviously compared to other disks. It is mainly because of the C_8H_8 being the low-Z atom number matter, which leads to the more rapid plasma expanse velocity because of

$$C_s = \sqrt{\frac{Z \times T_e}{AM_p}} \quad (1)$$

where Z=5.5, A=7 for C_8H_8, Z=40, the A=197 for gold, and T_e is about the same for C_8H_8 and gold. The plasma density scale length ($L = C_s t$) in the C_8H_8 film disk or the foam C_8H_8 disk is obviously longer than that in the gold disk, then the threshold of the SRS could be downward greatly, and the instability develops. Consequently, the SRS is easier to be stimulated and hot electrons increase. From the Table 4, it is possible to know that the amount of hard X-ray at each channel is five to ten times bigger, the X-ray is harder, and the hot electrons temperature increases obviously in the foam C_8H_8 disk in comparison with the gold disk as well. Because of $\lambda_h \propto T_h^2$, it is bad for suppressing the hot electron preheating to use the foam C_8H_8. Results in Table 3 show that the X-ray conversion efficiency (η_x) and laser absorption efficiency (η_a) from the foam gold disk increase.

Table 3 Comparison of the hot electron characteristics produced from different targets and different materials

Disk target material	E_L/J	$\theta/(°)$	$E_{hx}^{1)}/\mu J \cdot sr^{-1}$	T_h/keV	η_x/%	η_a/%	Off focus/μm
Foam Au	44.3	NE45	0.394	10.4	36.3	79	200
Foam Au	47.8	NE45	·0.763	5.2	32.8	74	200
Au foil+C_8H_8 film (multilayer)	50.4	NE 45	7.81	4.0	27.8	73	200
Au	44.8	NE45			30.6	75	200
	56.2	NE45	0.45	11.4			200
	58.5	NE45	0.896	8.14			200
Foam C_8H_8	58.0	NE5	11.52	12.33			0
	56.0	NE5	9.10	10.0			0
Au	55.0	NE5	6.78	5.32			0
	41.0	NE5	5.4	5.64			0
Foam Au	29.0	SE45	0.15	8.2			200
C_8H_8 film(monolayer)	24.0	SE45	1.05	5.16			200
	34.0	SE45	2.35	5.1			200
Au	50.0	SE45	0.35	8.5			200

1) E_{hx} is the total energy of the high-energy X-ray (10~70keV) spectrum at per unit solid angle

Table 4 Comparison of superthermal channel between the foam C_8H_8 disk and the gold disk

Energy channel	X-ray energy /keV	Foam C_8H_8 disk detector record signal (N)[1)]	Au disk detector record signal(N)[1)]
4	17.0	5548	1394
5	29.0	5875	382
6	46.3	4565	352
7	53.8	1222	223
8	67.4	1311	351

1) N is the value of signal at the detection channels of detector produced by hard X-ray

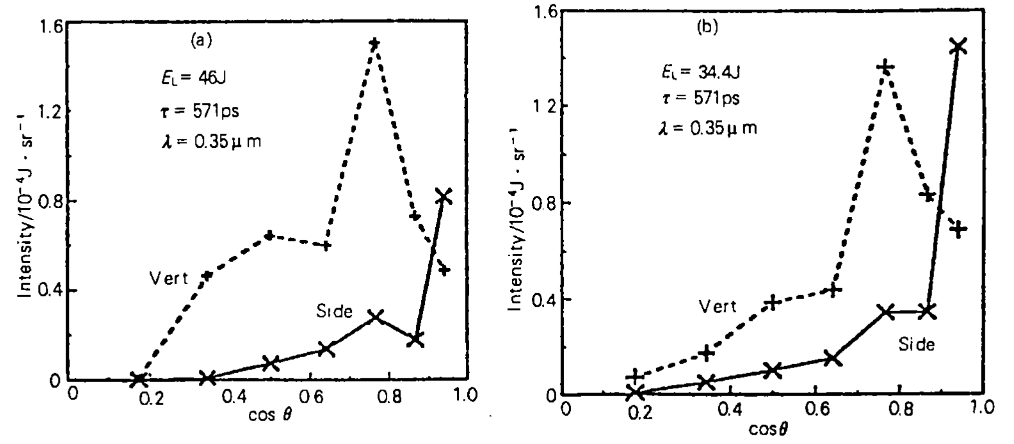

Fig.1 Angular distribution of SRS
(a) Foam Au disk, (b) Monolayer disk

3.2 Characteristics of scattering light spectrum in nonlinear processes from disk target made of different kind of materials

Under the conditions of 1×10^{14} W/cm^2 $\leq I_L \leq 4\times10^{14}$ W/cm^2 only the SBS scatting light spectrum (see Fig.2) and the shift-to-red of $3/2\omega$ at the direction of eastnorth 70° from gold disk are observed. However from the foam C_8H_8 or C_8H_8 film disk, not only the light spectrum of the shift-to-red of $3/2\omega$ with the structure of double-peak at the direction of eastnorth 45°C and the light spectrum of $3/2\omega$ at the direction of eastnorth 70° (see Fig.3), but also the time-integrated spectra of SRS (see Fig.4) at the several different directions are observed. So the following conclusions can be made from the above: hot electrons from the gold disk are mainly stimulated from the TPD, whereas hot electrons from the foam C_8H_8 or C_8H_8 film disk are mainly stimulated from SRS and TPD.

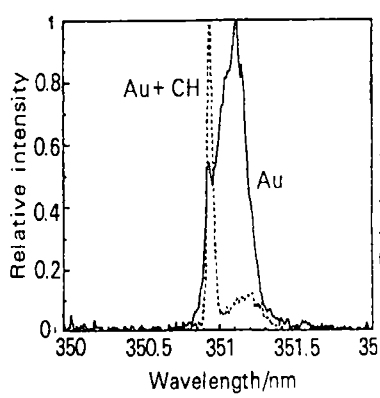

Fig.2 Time-integrated spectrum of the SBS

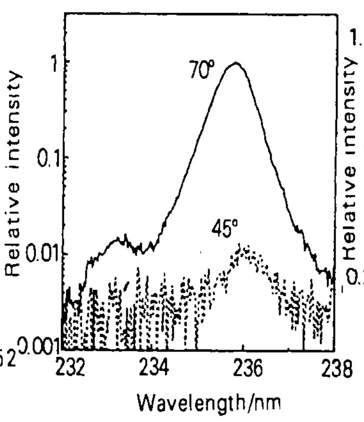

Fig.3 Spectrum of $3/2\omega$

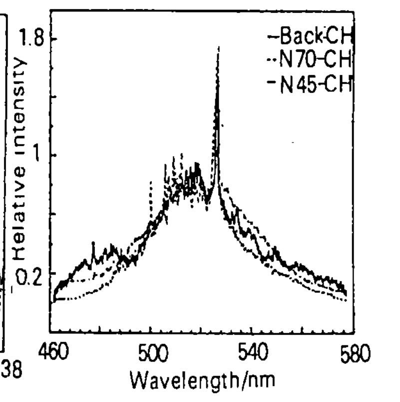

Fig.4 Angular distribution of the SRS

3.3 Characteristics of hot electrons and the related nonlinear processes from the hohlraum targets with different geometric structures

The results listed in Table 5 show as follows: there is no obvious change in the production of the hot electrons and the related nonlinear processes (SRS, TPD etc.) when the cavity is filled in with the foam C_8H_8 or C_8H_8 film but the laser does not directly illuminate the surface made of the foam C_8H_8 or the C_8H_8 film. Nevertheless, when the laser illuminates the surface made of the foam C_8H_8 or C_8H_8 film[2] directly there is greatly increasement. It can be imagined that when laser interacts with the foam C_8H_8 or C_8H_8 film directly the plasma expanse velocity increases greatly, which results in the bigger plasma scalelength, and then the SRS and hot electrons increase.

Table 5 Comparison of hot electrons characteristics from a variety of cavity targets

In cavity	E_L/J	$\theta/(^\circ)$	E_{hx}/μ J·sr^{-1}	T_h/keV	Remark
With foam C_8H_8	46.8	NE5	9.825	13.87	Not as the surface illuminated by laser directly
Without foam C_8H_8	56.0	NE5	32.88	9.56	
	52.6	NE5	15.40	7.73	
	49.0	NE45	2.6	7.0	
With foam C_8H_8	44.0	NE45	3.6	6.7	as the surface illuminated by laser directly

4 Conclusion

The following conclusions can be made from the above experiments at the "Xing Guang-II" facility limited by the present foam technique:

(1) Hot electrons, SBS, SRS and TPD from the foam C_8H_8 disk or 3μm thick C_8H_8 film disk increase obviously compared to that from the gold disk or the foam gold disk, and so it is bad for suppress the production of hot electrons to use the foam CH or CH film.

(2) Hot electrons and SRS from the monolayer or multilayer CH disk increase obviously compared with that from the foamed gold disk.

(3) It is better that laser doesn't directly illuminate at the surface made of the foam CH or CH film in the cavity.

References

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