Experiments on X-ray-ablated C_8H_8 samples*

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Abstract The behavior of materials heated by X rays to high energy density state is a very interesting and active research field for application in inertial fusion, astrophysics and so on. Some new experiments on X-ray-ablated C_8H_8 samples were designed and performed on Xingguang one beam frequency-tripled Nd:glass laser facility. The ablation velocity and the mass absorption coefficient of C_8H_8 foam, and the self-emission spectrum of C_8H_8 foil were experimentally obtained. The experiments and results are briefly described.

Keywords X-ray-ablated C_8H_8 samples, Ablation velocity, Absorption spectrum, Self-emission spectrum

1 Introduction

X-ray fluxes produced by high-power laser irradiating high-Z targets can heat sample to a high-energy density matter. The characteristics of these plasmas are very important in the field of inertial fusion, astrophysics and so on.

The X-ray fluxes can be obtained from the rear side of high-Z foil or the cavity target irradiated by high-power laser. According to themselves condition and idea the experimental investigations of the characteristics of matter in hot dense had been performed based on the two kinds of target in American, England, Japan, Germany and so on.[1~9] We have also researched in this field for some years. The radiation heat wave driven by the intense soft-X-ray radiation in a cylindrical cavity, which was heated by the intense laser pulse, was observed on Shenguang Nd-glass two beams laser facility.[10]

Recently we performed some new experiments on one beam frequency tripled Nd:glass laser facility. Using the targets based on Au foil and novel cavity-configuration, we primarily investigated the ablation and absorption properties of C_8H_8 foam sample and the self-emission of C_8H_8 foil, respectively. The foam material has been noticed in inertial confinement fusion. First, the velocity of heat wave has been measured with $0.53\mu m$ laser beam by Afshar-rad method[5]. Then we performed the experiments with $0.35\mu m$ laser beam and measured the absorption spectrum of the foam in hot dense for the first time. The experimental idea, methods and basic results are briefly given in this paper.

2 Experimental

According to the condition of Xingguang facility, our targets based on Au foil and novel cavity-configuration are schematically shown in Fig.1(a) and (b), respectively. As shown in Fig.1 (a), the X-ray radiation from the rear side of Au foil irradiated by the intense laser pulse was used to ablate and heat the C_8H_8 foam sample. The thickness of Au foil is (170 ± 20) nm. The C_8H_8 foam is of $0.085\,g/cm^3$ density and about $20\mu m$ thickness. A supersonic heat wave can be maintained in low density foam. By measuring the time-resolved spectrum of radiation emitted from the rear of the sample, we can obtain the ablation velocity. Measuring and comparing the spectra of radiation emitted from the rear of targets with and without sample, we can primarily study the X-ray absorption of the sample in hot dense. Defining the target shown in Fig.1(a) as the model of basic gold foil, the targets of the radiation-intensified model and semi-sample configurations have also been considered. Then a basic target-sample config-

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uration was designed to observe self-emission as shown in Fig.1(b). The novel cavity target which is $\phi 300\mu m$ Au cylinder connected with a semi-cylinder is designed. The C_8H_8 sample covered on the diagnostic hole of the wall of the semi-cylinder is heated by the X-rays emitted from the wall of the cylinder heated by intense laser pulse. In order to observe the self-emission of C_8H_8 foil we designed a special geometry of laser-beam-target-detector, with which the X-ray produced on the wall of target will be not in sight of detector, and the detector was directed towards AB as shown in Fig.1(b). It means that the X-ray source ablating the sample can not be detected. The experimental set-up is schematically shown in Fig.2. The set-up shown in Fig.2(a) was used to investigate the features of ablation of C_8H_8 foam. A transmission grating (TG) with 1050 L/mm was used to measure the spectrum of X rays emitted from the rear side of the target. An X-ray streak camera coupled with TG was used to diagnose the time-resolved spectra. A sub-keV X-ray spectrometer (Dante) calibrated absolutely was also used to detect the spectrum and to deduce the X-ray flux. A pinhole camera was used to monitor the X-ray spot. The experimental set-up shown in Fig.2(b) was used to research the self-emission of the C_8H_8 foil in hot dense. A transmission-grating spectrometer (D_1) was used to measure the spectra and a pinhole camera (D_2) to observe the radiation resolved spatially for the target.

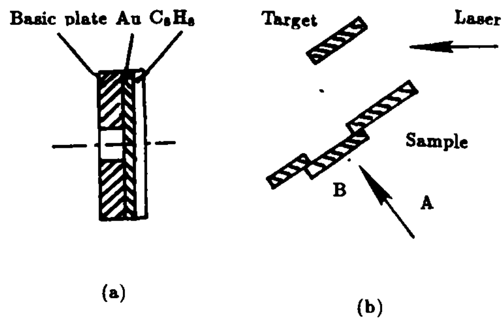
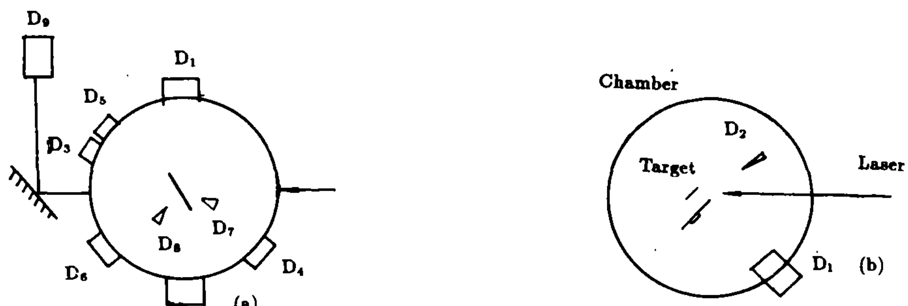


Fig.1 Targets and cavity-configuration

(a) For ablation and absorption experiments; (b) For self-emission experiments

D_1, D_2: sub-keV X-ray spectrometer; D_3: transmission grating spectrometer; D_4, D_5: pinhole transmission grating spectrometer; D_6: time-resolved X-ray transmission grating spectrometer; D_7,D_8: pinhole camera; D_9: optical calorimeter laser



D_1: transmission-grating spectrometer, D_2: pinhole camera

Fig.2 The schematic arrangement of the laser beam-target-detector

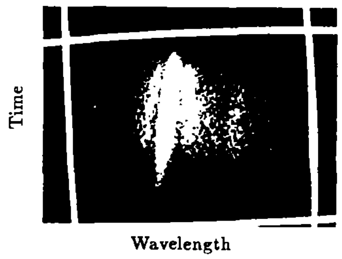
(a) For ablation and absorption experiments; (b) For self-emission experiments

3 The main experimental results

3.1 Ablation

The temporal spectrum of soft X rays emitted from back side of C_8H_8 foam, measured by the X-ray streak camera combined with T.G. is shown in Fig.3. Two groups of spectra, mainly from shine-through and burn-through, are observed. The spectra of radiation are mainly in 0.6~1.9 nm and 2.6~3.7 nm range and the delay between them is (310±68) ps. Defining the this delay as burn-through time, we obtained that the ablation velocity is 6.4×10^6 cm/s. According to the results measured by the sub-keV

X-ray spectrometer, the X-ray flux ablating the C_8H_8 foam is about 1.1×10^{13} W/cm^2.



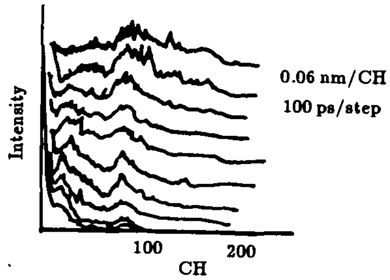


Fig.3 Time-resolved spectra of C_8H_8 foam

The experiments were performed with one beam of $\lambda = 0.35\mu$m light from Xingguang laser facility. The typical laser energy was 29J with the pulse duration 0.6 ns.

3.2 Absorption

The source spectrum and the absorption spectrum are shown in Fig.4. They were obtained from the targets located at the rear side of Au foil without and with C_8H_8 foam, respectively. The C_8H_8 foam was the thickness of 20μm and the density of 0.085 g/cm^3. The laser facility was operated with energy 32.4 J and 31.0 J and the pulse duration 0.62 ns and 0.68 ns for the source and the absorption spectra, respectively. It should be noted that both of them are almost the same. Therefore, comparing the source and absorption spectra, we can roughly obtain the mass absorption coefficient as a function of wave length, as shown in Fig.5. The dots describe the absorption for thermal C_8H_8 foam and the theoretical curve for the absorption of cold carbon. It can be seen that the absorption of thermal C_8H_8 foam is lower than that of cold carbon. It is true because the opacity of carbon in hot dense is lower than that of cold carbon.

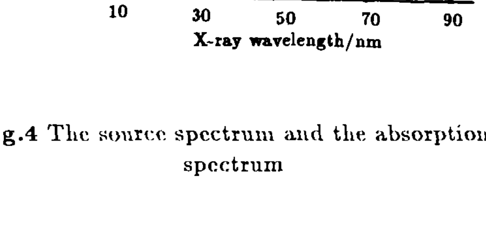


Fig.4 The source spectrum and the absorption spectrum

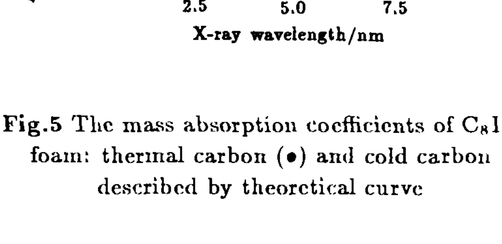


Fig.5 The mass absorption coefficients of C_8H_8 foam: thermal carbon (•) and cold carbon described by theoretical curve

3.3 Self-emission

Self-emission is a basic nature for a material in hot dense. The experiments were carried out with one beam of 0.35μm radiation from the Nd-glass laser facility. The laser energy was about 40 J and pulse duration about 0.7 ns. The laser beam was injected into a novel cavity target. The sample of C_8H_8 foil covered on a diagnostic hole of target was irradiated by the X-rays produced in the wall of the target. The spectra obtained from diagnostic hole with and without sample are shown in Fig.6, which were roughly obtained under the same condition of laser beam. The spectrum obtained from diagnostic hole without sample can be considered as background or noise. Thus, the self-emission spectrum for C_8H_8 foil sample (1μm thick) was obtained as shown in Fig.7.

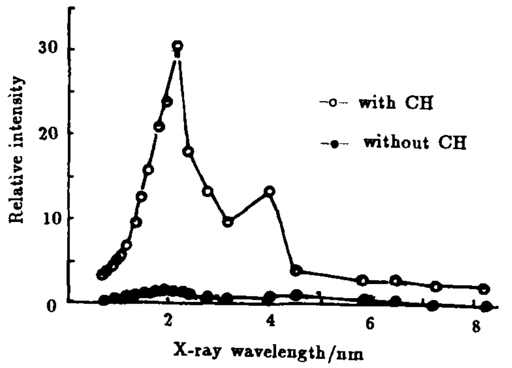


Fig.6 The spectra obtained from the diagnostic hole with and without C_8H_8 foil sample

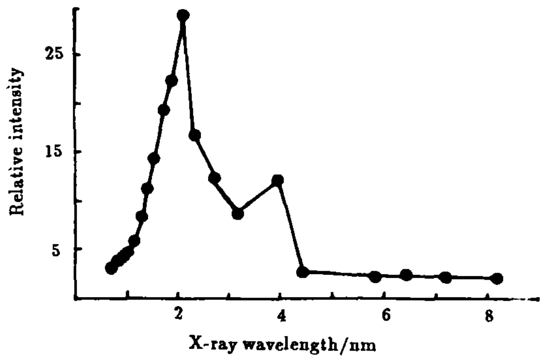


Fig.7 The self-emission spectrum for C_8H_8 foil

4 Summary

We have studied properties of C_8H_8 sample ablated by X-rays created in laser-plasma interaction. The ablation velocity and mass absorption coefficient of C_8H_8 foam and the self-emission spectrum of C_8H_8 foil are obtained. It opens up the possibilities for investigation on characteristics of matter in a state of high-energy density in the laboratory, which is of very interest for obtaining a basic insight into the state of matter at high temperature and into the opacity of material in hot dense, and has potential applications in inertial confinement fusion. We are going to study them further.

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References

1 Celliers P, Eidmann K, Phys Rev 1990, 41A:3270

2 Edwards J, Dunne M, Gizzi L *et al.* Rutherford Appleton Laboratory Report, RAL-91-025, 1991:13

3 Schwands W, Eidmann K. Phys Rev Lett, 1992, 69:3507

4 Sigel R, Tsakiris G D, Lavarenne F *et al.* Phys Rev, 1992, 45A:3987

5 Afshar-rad T, Dunne M, Edwards J. Rutherford Appleton Laboratory Report, RAL-93-031, 1993:29

6 Winhart G, Eidmann K, Iglesias C A *et al.* Phys Rev, 1996, 53E:R1332

7 Springer P T, Fields D J, Wilson B G *et al.* Phys Rev Letts, 1992, 69:3735

8 Perry T S, Springer P T, Fields D J *et al.* Phys Rev, 1996; 54E(5):5617

9 Wang P, Macfarlane J J. Rev Sci Instru, 1997; 68:1107

10 Ding Yao-Nan, Yao Zhen-Yu, Miao Wen-Yong *et al.* Nuclear Science and Techniques, 1997; 8:43