24P162-B

Target material dependence of collisionless shock wave in counter-streaming plasmas
対向プラズマ中における無衝突衝撃波のターゲット材質依存性

T. Ide[1], Y. Sakawa[2], Y. Kuramitsu[2], T. Morita[2], K. Nishio[3] *et al.*
井出尭夫[1], 坂和洋一[2], 蔵満康浩[2], 森田太智[2], 西尾健斗[3], 桒田三沙[3], 井手張良[3], 坪内邦男[1],
丹治浩樹[1], 乗松孝好[2], 富田健太郎[4], 中山和貴[4], 井上和哉[4], 内野喜一郎[4],
C. Gregory[5], 中堤基彰[5], 中堤晴美[5], A. Pelka[5], A. Diziere[5],
M. Koenig[5], S. Wang[7], Q. Dong[7], 高部英明[2]

[1]*Graduate School of Engineering, Osaka University 2-1, Yamadaoka, Suita, Osaka 565-0871, Japan*
大阪大学大学院工学研究科　大阪府吹田市山田丘 2-1
[2]*Institute of Laser Engineering, Osaka University*
2-6, Yamadaoka, Suita, Osaka 565-0871, Japan
大阪大学レーザーエネルギー学研究センター　565-0871 大阪府吹田市山田丘 2-6
[3]*Graduate School of Science, Osaka University 1-1, Machikaneyama, Toyonaka, Osaka 560-0043, Japan*
大阪大学大学院理学研究科　大阪府豊中市待兼山 1-1
[4]*Interdisciplinary Graduate School of Engineering Sciences Kyushu University 6-1, Kasugakoen, Kasuga, Fukuoka 816-8580, Japan*
九州大学総合理工学府　816-8580 福岡県春日市春日公園 6-1
[5]*LULI, École Polytechnique, Route de Saclay, 91128 Palaiseau Cedex, France*
[6]*Institute of Physics, Chinese Academy of Sciences Beijing 100190, China*

Collisionless shock wave generation in counter-streaming plasmas for several target materials (Al, C, Cu, and Pb) is investigated using a high-power laser system. Counter-streaming plasmas are produced by irradiating double-plane targets. As a result of interaction of the plasmas, collisionless shock waves are observed using C, Al, and Pb in self-emission measurements. Mean-free-paths of heavier materials become longer because the ionization degrees of each material are not much different.

1 Introduction

The laboratory simulation of astrophysical phenomenon has been tried to perform for many years. Physics of cosmic ray acceleration is one of the unsolved problems in astrophysics, and collisionless shock waves are one of the most important subjects. Y. Kuramitsu *et al.* [1] and T. Morita *et al.* [2] have reported the collisionless shock formation in counter-streaming plasmas produced by high-power laser systems using double-plane targets made of CH. In this presentation, we report target material dependence of shock wave generation using targets made of different materials (C, Al, Cu, and Pb) with different atomic mass [3].

2 Experiment

The experiment was performed with Gekko XII HIPER laser system at Institute of Laser Engineering, Osaka University. There were nine main beams in which the energy was about 120 J/beam in 351 nm (3ω) and pulse length was 500 ps. The target we used in this experiment was double-plane target as shown in Fig. 2. In this experiment we used C, Al, Cu and Pb targets. We put two planes parallel, and the material of two planes of each target was identical. The dimensions of the planes were $3\,\mathrm{mm} \times 3\,\mathrm{mm}$ and $200\,\mu\mathrm{m}$ thick, and the distance between two planes was 4.5 mm. One of the nine beams was focused on the inner surface of the 1st plane with $300\,\mu\mathrm{m}$ in diameter (intensity : $3.4 \times 10^{14}\,\mathrm{W/cm^2}$), and ablation plasma was formed from the 1st plane. Almost at the same time, a plasma from the 2nd plane was created by radiation from the ablation plasma and the ablation plasma itself. In this way, counter-streaming plasmas were generated, and shock waves were formed by an interaction of these plasmas. Figure 2 shows schematic of the experiment setup. The interaction of plasmas was diagnosed with a probe laser and with the self-emission. With the probe laser we obtained two-dimensional information of density by shadowgraphy with intensified charge coupled device (ICCD) cameras (200 ps gate width) and Nomarski inter-

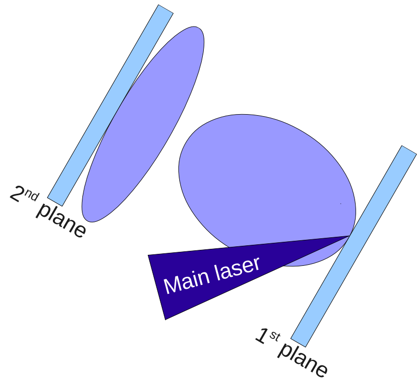

Figure 1: Schematic view of the target design. The main laser beam is focused on the 1st plane. Two planes are made of the same material.

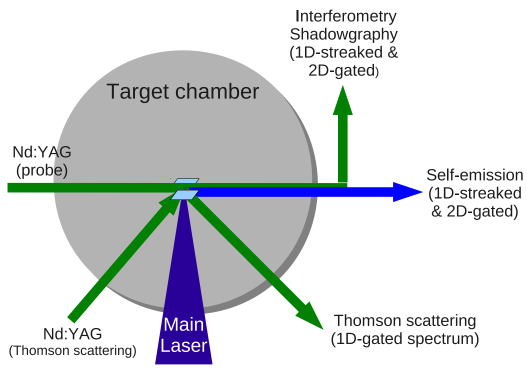

Figure 2: Experimental setup. The green line is the path of Nd:YAG laser and the blue line from target chamber center (TCC) is the path of self-emission at the wavelength of $\sim 450\,\mathrm{nm}$.

ferometry with gated optical imager (GOI) (250 ps gate width). We also measured one-dimensional time evolution of the plasma by streaked interferometry with a streak camera. The self-emission was gated at the wave length of 450 nm using interference filters. We obtained two-dimensional image of self-emission with ICCD cameras (1.6 ns gate width) and one-dimensional time evolution with a streak camera, which is called streaked optical pyrometer (SOP). The plasmas were probed by Nd:YAG laser beam whose wavelength was 532 nm and duration time was $10 \sim 14\,\mathrm{ns}$. Another Nd:YAG laser beam for Thomson scattering was focused at the meddle of two planes. We used triple-grating spectrometer and ICCD camera to obtain spectrum of Thomson scattering.

3 Result

Two-dimensional images of self-emission for different materials are shown in Fig. 3. As shown in

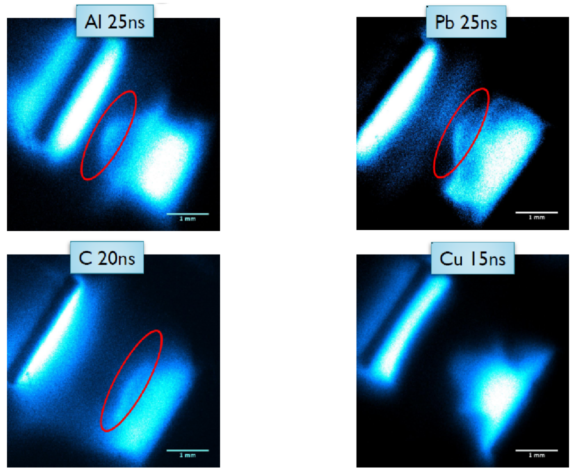

Figure 3: Two-dimensional images of self-emission taken at $15 \sim 25\,\mathrm{ns}$ from the laser timing. The 1st plane is on the right side.

Fig. 3, counter-streaming plasmas are formed and discontinuous structures of self-emission marked with red ovals in Fig. 3 appear as a result of interaction of the two plasmas except for Cu target. These are shock waves according to steepening of the line profile in SOP(not shown). We obtained electron density n_e from interferometry and flow velocities of plasmas from Thomson scattering. Using these parameters, ion-ion collision mean-free-paths λ_{ii} of all materials are much larger than the width of the shock wave. Therefore, these shock waves are collisionless shock waves. Furthermore, λ_{ii} of the heavier materials become longer because the calculated values of ionization degree Z vary only within a factor of two.

4 Conclusion

Counter-streaming plasmas are produced by irradiating double-plane targets made of Al, C, Cu, and Pb. As a result of interaction of the plasmas, collisionless shock waves are generated using C, Al, and Pb. Mean-free-paths of heavier materials become longer because the ionization degrees of C, Al, Cu, and Pb are not much different.

References

[1] Y. Kuramitsu *et al.* *Phys. Rev. Lett.*, 106, 175002 (2011).

[2] T. Morita *et al.* *Phys. Plasmas*, 17, 122702 (2010).

[3] T. Ide *et al.* *Plasma Fusion Res.*, 6, 2404057 (2011).