§42. Study of Behaviors and Characteristics on Laser Ablated Plumes

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An ablated plasma plume could be generated on either wall of an IFE reactor or divertor of an MFE reactor by debris and high energy particles such as DT particle, neutron, alpha particle and high energy X-ray by the implosion or ELM/disruption modes. Most of the IFE fusion reactor take spherical or cylindrical geometry, [1,2]whose geometry may guide plumes stagnating at around the center of the reactor. If this stagnation is substantial and serious, the subsequent laser irradiation will become difficult. The density at around the center could be 10^{11} to 10^{13}/c.c. depending on 1D to 3D assumption when LiPb wall is ablated based on a reactor design[3]. The purpose of this research is to study of Ablated Plasma Plume Energetics (APPLE). The laser ablation technique has been employed in the many fields of material processing etc [3]. The physics of plasma ablation has been heavily studied in laser fusion research [4]. In this work, the plasma generated on the furnace wall was produced by laser ablation. The collision of plumes was achieved by placing two plasma plumes at right angle with a density relevant to the fusion reactor. The spatial and temporal distributions of the collision were measured by an intensified CCD camera

The schematic view of the experimental set-up is given in Fig. 1. The third harmonic output (355nm) of a 6ns Nd:YAG pulsed laser, operated at a repetition rate of 10HZ,has been focused onto fusion reactor wall samples in the vacuum chamber (evacuated to 10^{-3}Pa).The fusion reactor wall samples are either carbon or tungsten.

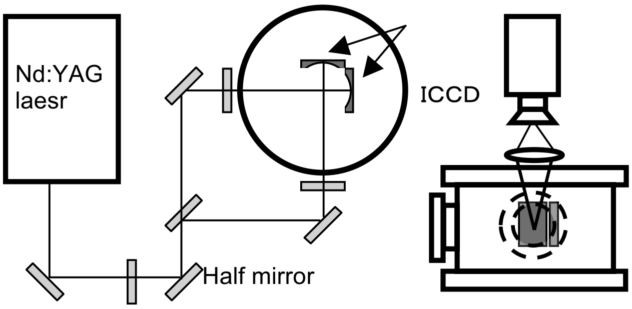

Fig.1 (a) Schematic of plume collision set up, (b) Schematic of plume emission observation by ICCD

The target size is 1.5 cm x 0.5cm x 5.0 cm. The laser was divided into two beams with a 50 % half mirror to create two plumes on the samples. The collision of plumes was achieved by placing the samples in a right angle as can bee seen in Fig. 1.The line focused laser is used to create a focal spot 1mm×0.1 mm on the cone cave shape target. The radius cone cave is 1.3cm. The plasma expansion was recorded by ICCD camera (ANDOR iStar DH734).The ICCD camera was set at the top of the sample surface at 35cm distance away. A lens was used to image the plasma on to the detector (spectral range 150nm~600nm).The temporal and spatial resolutions were about 50 ns and 26μm. Figure 2 is for low energy (12J/cm^2 and 4J/cm^2) for Carbon showing the temporal evolutions of the plasma emission recorded by ICCD. Plasma images were recorded during the ablation in vacuum for different delays between the laser pulse and observation gate. Figure 2 shows that the two Carbon plume components collided at 900 nsec. The stagnated cloud stayed at the collision point for a little more than 2μ sec. after 3000 nsec. The cloud diffuses and moves in the direction toward the vector sum of the two momentums. It should be also pointed out that the whole cone cave target lit up with the laser irradiation.

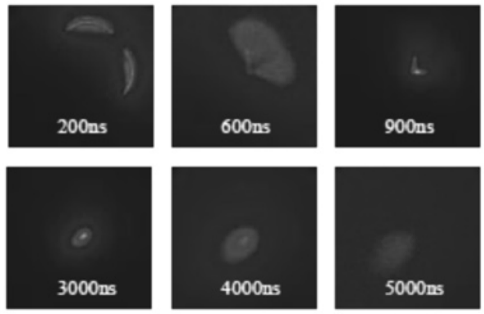

Figure 2 Collision of plumes Each box has 3.58x3.58cm)

One notices that the collided plumes stagnate for very long time. The stagnated plumes move slowly toward the direction of the vector sum determined by the two plumes. Each plume's speed is 6 x 10^6 cm/sec. After the collision the speed of the stagnated plumes appear to slow down drastically and to have 2 x 10^5 cm/sec more than one order slow speed.

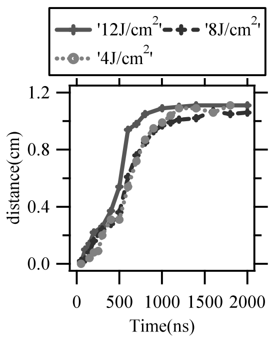

Figure 3 The relation of plume position and time for Carbon/Carbon plume collisions.

The distance and time relation is plotted in Fig. 3 for three different laser energy densities from 4J to 12 J/cm^2. The behaviors of these plumes, especially the stagnation are clearly observed. Substantial stagnation is only observed for Carbon plume collisions, not for Tungsten or Cupper plumes. Understanding of the stagnation will contribute to the gaseous cloud behaviors possibly expected in the IFE chamber and/or divertor.

[1] K. Yamamoto et al., J. Plasma Fusion Res., 82, 441 (2006).
[2] K. Yamamoto et al., J. Plasma Fusion Res., 82, 838 (2006).
[3] R.A. Burdt et al., J. Appl. Phys., 106, 033310 (2009).
[4] K. Matzen et al., Phys. Fluids, 22, 654 (1979).