§37. Laser Ablated Plasma Plume Energetics (APPLE) Study

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The first walls in the magnetic and inertial confinement fusion reactor walls (MFER & IFER) receive anomalous load due to the ELM and/or disruption modes and fusion reactions. The loading power is 10^5 W/m^2 for the current ELM modes and will be 10^9 W/m^2 for the forthcoming ITER disruption. IFER walls may receive even higher power 10^{12} W/m^2. At these extremely high loading states, the material may not stand anymore with its original state. The surface may be damaged and ablated into clusters, gas, liquid, and plasmas. It is of critical importance to study the conditions where these wall materials can withstand at such high loading power. Once the materials are ablated a plume is formed. This plume may be called "vapor dome" [1]. The vapor dome is expected to have some positive function to absorb further incoming loading power and to help protecting the MFER and IFER wall materials as armor.

At the IFER, the expanded plumes may come together at around the center of the reactor chamber since the chamber shape is most likely cylindrical symmetry for the sake of laser beam irradiation. If the colliding plumes stay for sometime of the order of 100 msec they could affect the laser beam irradiation. At the divertor of MFER once the plumes are formed due to ELM or disruption modes, the plumes may forwarding their energy to the surrounding structures via. Kinetic and radiation energy transport depending on the states of the plumes. These predicted phenomena have not been studied in detail. A main reason was that it has been very difficult to set up a laboratory scale experiment with a real time diagnostics under extremely loading power capability with a good accuracy.

In turn the high energy density physics (HEDP) using high performance and high intensity laser systems has made a considerable progress in last two decades. It is well know that the National Ignition Facility at the Lawrence Livermore National Laboratory, U.S.A. is about to achieve a fusion ignition a very good example of HEDP [2]. Introducing and making use of the laser beams, it is possible to irradiate the wall materials at any desired loading power. By using this laser scheme, it is possible for a university laboratory to study the plume characteristics and wall damage characteristics in detail in a very fast track. It will be necessary later in the development of this scheme to compare the driver species among laser, electron, and ion and to study any difference in loading characteristics. In these HEDP researches, various high speed (up to pico second) and high spatial resolution (up to hundred nanometer) diagnostics have been developed and can be made use of for the study [3, 4].

We have performed series of colliding plumes experiments using the setting shown above. A fast framing photo camera is used to capture the development of the plume ablation and subsequent collision. The exposure time is 25 nsec and the framing interval is 50 nsec.

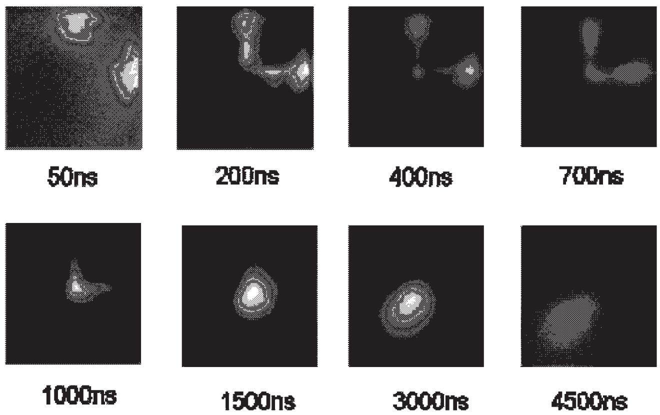

Figure shows interesting features of plume ablation and collision. At 50 nsec right after the laser irradiation is over the focal spots are heated strongly. Then two components are ejected toward the forward direction fairly symmetrically from 200 to 700 nsec. The two plumes start merging together and made one stacked could from 1500 to 3000 nsec. At 4500 ns the cloud start moving toward the down left corner. It is obvious that the each plume absorbs the kinetic energy of the other forming the stacked cloud. he each frame covers 3.25 cm x 3.25 cm spatial extent. The observed wavelength region is from 300 nm to 600 nm. The laser pulse width is 5 nsec at 351 nm wavelength. The laser intensity is 10^8 W/cm^2, while the total energy is about 0.1 J. The color indicates the intensity of the integrated wavelength observed.

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[3] H. Shiraga et al., Rev. Sci. Instr., 74, 2191 (2003).
[4] M. Kado et al., Opt. Lett. 16, 109 (1991).