§12. Study on Plasma-wall Interactions Making Use of Laser and Ion Beam Experimental Platforms

Tanaka, K.A. (Graduate School of Engineering, Osaka Univ.),
Nagata, M. (Univ. Hyogo),
Yoneda, H. (Univ. Electro-Communications)

LHD fusion reactors are known to hold fusion plasmas with a good stability. Even so it is of importance to study the extreme conditions at the parameter ranges where divertor plates could be damaged at the ELM or other modes. At a steady state of LHD operation mode, the divertor plate is expected to receive more than kW/m^2 plasma heat flux and even more with arching conditions. Systematic studies under these extreme conditions have lacked in order to have deep understanding of physics and engineering of reactor design areas. Making use of the high energy and/or high intensity outputs of laser and/or ion beams can create these extreme conditions in small space and fast time frame experimental platforms.

Magnetized Coaxial Plasma Gun has been upgraded at the University of Hyogo. The plan is to reach 2MJ/m^2 ion beam irradiation energy density that is expected in the Type-1 ELM at ITER. The upgrade included two categories: (1) Increase of capacitance from 1mF to 2.9 mF and (2) Installation of tapered drift tube to increase the ion beam flux. Installed tapered tube is shown in Fig. 1. The test operation has been conducted to confirm the designed output energy density.

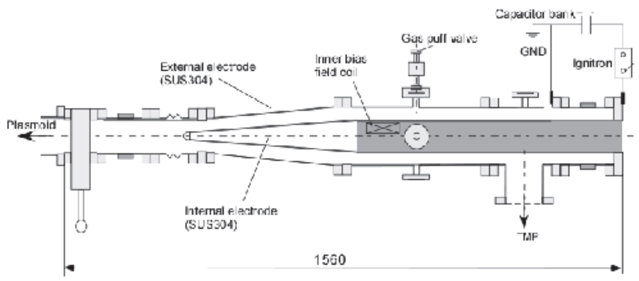

Figure 1 Tapered ion guiding tube. With this tube and increase energy of capacitors for ion generation from 1mF to 2.9 mF, the magnetized coaxial plasma gun will reach its ion irradiation intensity up to 2 MJ/m^2.

Another exotic experimental platform has been used to model stagnated plasma and/or plasma vapor shielding at Osaka University under the close collaboration with Prof Y Hirooka at the National Institute of Fusion Science [1]. The idea is to ablate any material such as W (Tungsten) and C (Carbon) using laser beams. The laser can deliver any required heat flux up to 10^{14} W/cm^2 by changing the laser system parameters. The laser out-put is split into two beams at the wavelength 351 nm. The two blue beams irradiate two orthogonally oriented targets of W or C. The beams are focused in line of about 1 cm and 0.1 mm spot area. Since the targets are concave shape with 1.4 cm radius, the ablated plasma plumes tend to focus at this distance [2].

Carbon target case shows that the two plasma plumes intersect each other. The observation has been made possible with the use of high-speed intensified CCD camera.
ICCD camera can take 50 nsec time window frame photo of the plasma plumes with variable delays. Since our experimental platform is operated at 10 Hz for the condition fixed, we can make the ablation plasma plumes reproducibly for many shots. The ICCD camera took the plume photo frame with 50 nsec delay for thousand of shots. Later each frame can be put together to create a high-speed movie of the ablated plasma plume motion.

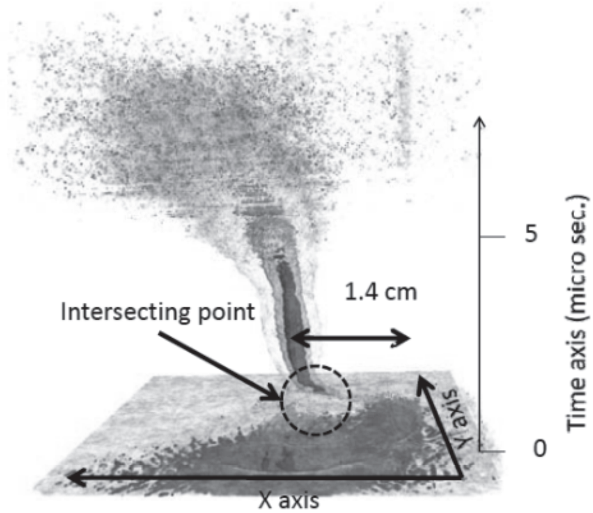

Figure 2. Volume Rendering technique shows that the two orthogonally oriented curved targets snows ablated plasma plumes in green color. The two plumes intersect at 1.4 cm away from the target. Then the plumes stay at a same place for relatively long duration of several microseconds.

Then using the volume rendering technique developed in the artificial intelligence field, the whole movie can be put into one page figure as shown in Fig. 2 [3]. Figure 2 shows a clear collision of the two plumes and subsequent stagnation. The duration of the stagnation is surprisingly long in time like several microseconds. We understand this long duration of the stagnation is related to the Carbon molecular formation since the separate experiments revealed that Carbon Nano tubes, Carbon micro tubes and Carbon onions are recovered from these stagnated carbon plasmas. The formation of carbon molecules functions to absorb the kinetic energy of the plasma plumes through the collision and stagnation.

1) Y Hirooka et al., J Phys. Conf. Ser., 244, 032033(2010).
2) H. Sato et al., J Plasma Fusion Res., 9, 432 (2010).
3) KA Tanaka et al., To appear in Fusin Science and Tech. 2011.