§9. Stereoscopic Measurement of Ablation Clouds of Tungsten Embedded TESPELs with a Fast Framing Camera

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Tracer-encapsulated solid pellets (TESPEL) have been effectively used for investigating impurity and energy transport in LHD plasmas. One of the advantages of the TESPEL is the local deposition of impurities encapsulated in the pellet in the plasmas. Identification of the three-dimensional position of the ablation of the embedded impurities is indispensable for detailed analysis of impurity transport.

The ablation process of the pellets was observed with a newly installed fast framing camera (Photron SA-X) with a stereoscopic optics which can convert two images transferred from two different positions to one image. A rotatable interference filter wheel has been inserted behind the stereoscopic optics, which enables to measure visible light from neutral tungsten (W^0: 400.9nm) and the ions (W^{26+}: 389.4nm). The wavelength of these two visible lights is carefully selected so as not to be interfered by lights having wavelengths near to the above two ones. An image intensifier (Hamamatsu C9547) has been installed in just before the CMOS image sensor in the fast camera, which is for amplifying the low signal of emission from tungsten.

The three-dimensional trajectory and ablation process of tungsten embedded in TESPELs were observed from two different positions which locate in the right and the left side of an outer port (3-O). The two observed images are transferred to the stereoscopic optics via quartz bundled image fibers. Figure 1 (a) and (b) show images of a W^0 filtered ablation cloud and the time trend of the intensity at the center of the cloud, respectively. It is easily recognized that the intensity drastically increases just before the end of the ablation. In the case without the embedded tungsten, no drastic increase of the intensity just before the end of the ablation was observed, demonstrating that the position of the ablated tungsten and the impurity ablation process can be measured by the fast camera system.

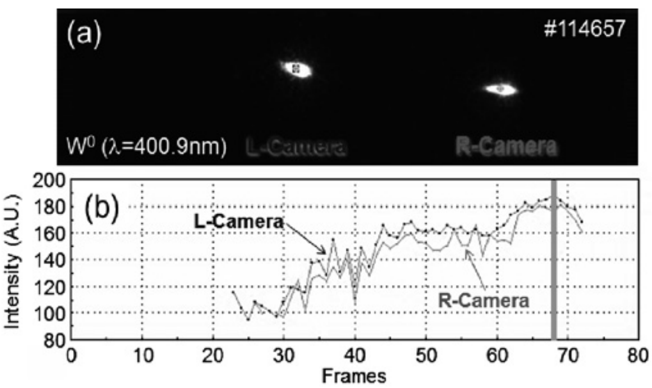

Fig. 1 Images of a W^0 filtered ablation cloud just before the end of the ablation (a), and the time trend of the intensity of the cloud observed with a fast camera with a stereoscopic optics (b).

Analysis of the moving positions of the center of the ablation cloud on the two images observed from the two different positions provides the three-dimensional trajectory of pellets. Two colored lines in Figure 2 gives a bird's eye view of the trajectories observed in the case with the interference filters for emission from W^0 and W^{26+}. The last several dots in the two colored lines in the plasma center side approximately correspond to the ablation positions of the embedded tungsten. Figure 3 gives a poloidal cross-section of magnetic field lines indicating the trajectories of the pellets projected to the poloidal plane. It clearly shows that the normalized minor radius at the position of the impurity (tungsten) deposition by the pellets is about 0.8, which gives absolutely indispensable information for detailed analysis of impurity transport in LHD plasmas.

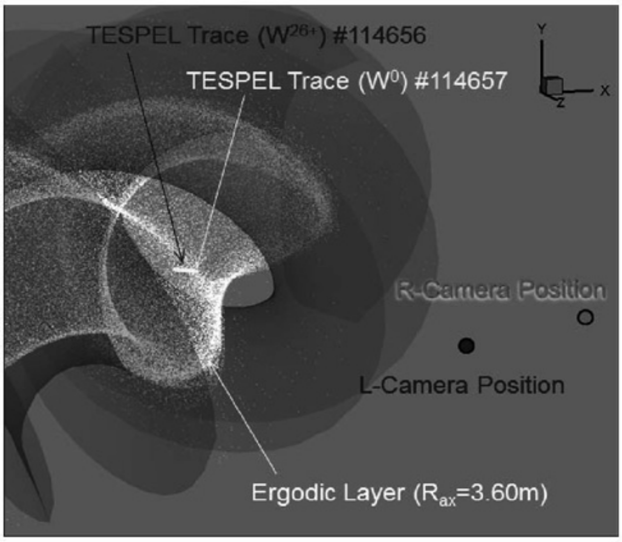

Fig. 2 Bird's eye view of the three-dimensional trajectories of TESPELs observed with interference filters for measurements of emission from W^0 and W^{26+}.

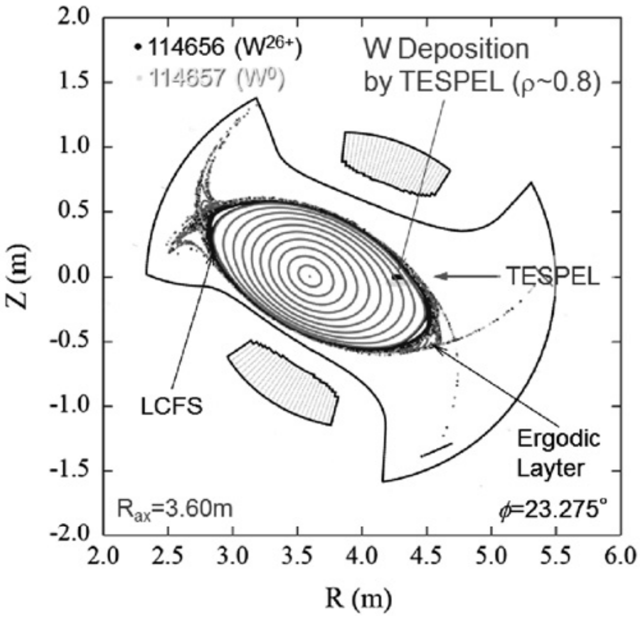

Fig. 3 Ablation positions of tungsten embedded in TESPELs projected to a poloidal cross section of magnetic field lines.