§14. Stereoscopic Observation of Impurity Ablation Positions by Tracer Encapsulated Solid Pellet Injection in Long Pulse Discharges in LHD

Shoji, M., Tamura, N., Kasahara, H.

Recent long pulse discharges sustained by ICRF and ECRH in the Large Helical Device (LHD) have often been terminated by radiation collapse by large amounts of dusts released from closed divertor regions. After the experimental campaigns, traces of exfoliation of carbon-rich mixed-material layers deposited on the surface in the divertor regions have been found on the site. Thus, it is probable that the impurities such as iron and carbon included in the deposition layers, which were released as dusts and penetrated into the main plasma, induced the radiation collapse to terminate long pulse discharges.

In order to investigate the influence of the impurities included in the dusts on the sustainment of the long pulse discharges, impurity grains were artificially injected into plasma using a Tracer Encapsulated Solid PELlet (TESPEL) injector in the last (18th) experimental campaign in FY2014. In this experiment, three different materials such as carbon, iron and tungsten were used for encapsulated impurity tracers. In addition, the quantity of the encapsulated impurities in the pellets was changed to get information on maximum tolerable impurity contents in the plasmas for sustainment of the long pulse discharges.

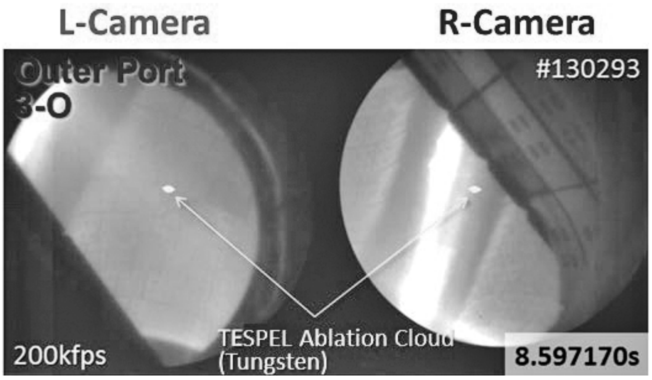

Fig. 1. A stereoscopic image of the ablation cloud of an impurity (tungsten) tracer by TESPEL in a typical long pulse discharge (superimposed).

To identify the position of the ablation of the encapsulated impurities in the plasmas is essential for investigating impurity transport in the plasmas and physical mechanism causing the radiation collapse by dusts in the long pulse discharges. The three-dimensional positions of impurity ablation by the TESPEL injection were observed with a stereoscopic fast framing camera installed in an outer port (3-O). Figure 1 shows a typical stereoscopic image of the ablation cloud of the TESPEL encapsulating tungsten grains under a typical experimental condition for long pulse discharges (a superimposed image).

In order to obtain the three-dimensional positions of the ablation cloud from the stereoscopic images, a spatial calibration of the stereoscopic camera system was performed after the experimental campaign. Some marker positions, which locate in the viewing area of the camera, had been set on some components in the vacuum vessel, and the three-dimensional positions of the markers had been surveyed on the site before the experiment. The spatial configuration of the camera system was reproduced in a laboratory. The viewing angle of optical lenses for the camera was adjusted so as to reproduce the position of the markers on the image taken in the last experimental campaign. A flat board on which some grids were described was moved from the front to back along the central axis in the field of view of the camera. A pinhole camera model has been adopted to obtain the three-dimensional positions of the ablation cloud from the stereoscopic images. Since a 'camera matrix' is necessary for this model, a database for one-to-one correspondence between 'the three-dimensional positons on a point on the grids' and 'the positions on the stereoscopic image' was produced for totally 832 points to make the 'camera matrix'.

The positions of the deposition of the ablation cloud of the impurity tracers are obtained using the 'camera matrix' and a program written by a technical computing language (MATLAB). Figure 2 shows the poloidal cross-section of a LHD plasma on the plane at the toroidal angle of TESPEL injection in a typical magnetic configuration (R_{ax}=3.60m). Small circles in the figure indicate the typical positions of deposition of the encapsulated impurity tracers (iron: #129489, tungsten: #130292 and #130293), which were determined by the last stereoscopic image of the positon of the ablation clouds. It proves that the ablation positions locate inside of the Last Closed Flux Surface (LCFS) and it is almost at about 0.8 in the minor radius of the LHD plasma.

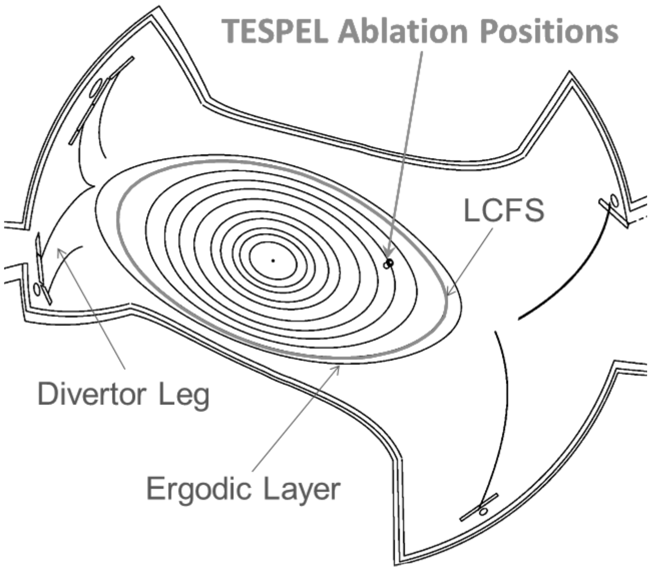

Fig. 2. The ablation positions of encapsulated impurity tracers on a poloidal cross-section of a LHD plasma and the vacuum vessel at the toroidal angle of TESPEL injection.