§13. Observations of Dust Trajectories in Long Pulse Plasma Discharge with a Stereoscopic Fast Framing Camera in LHD

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Long pulse discharges assisted by ICRF with ECRH in the Large Helical Device (LHD) have been routinely monitored with fast framing (>1,000fps) cameras and about thirty video rate (30fps) CCD cameras. Long pulse discharges in the previous (17th) experimental campaign in FY2013 were often terminated by radiation collapse induced by large amounts of dusts released from closed divertor regions, in which carbon ion emission drastically increased with moderate rise in iron ion emission just before the plasma termination.

In some long pulse discharges in the last (18th) experimental campaign in FY2014, a different plasma termination process was observed with a stereoscopic fast framing camera installed in an outer port (3-O). Figure 1 shows stereoscopic sequential images of a long pulse plasma discharge just before the termination. Left and right images in the figure are observations viewed from viewports at the left and right side of the port. The first frame shows a bright spot on the surface of the vacuum vessel on a helical coil can in the inboard side of the torus. The bright spot expanded as shown in the second frame. In the third frame, it presents that large amounts of dusts were released from a point near the top of the helical coil can. These sequential observations clearly prove that the long pulse plasma discharge was terminated by this dust emission.

In this discharge, a visible spectrometer for monitoring impurity emission in plasmas observed rapid increase in the intensity of iron ion emission just before the plasma termination, in which rise in the intensity of carbon ion emission is moderate. The observed time evolution of the impurity ion emission is different from that in the previous campaign. It is possible that iron grains sputtered from the vacuum vessel on the helical coil can (stainless steel) were observed as incandescent dusts with the stereoscopic camera, and the dusts penetrated into the main plasma to induce the radiation collapse.

The three-dimensional trajectories of the sputtered dusts can be derived from analysis of the stereoscopic images using a ‘pinhole camera model’ and the information of the three-dimensional positions of reference points set on components in the vacuum vessel in the field of view of the camera. It shows that the dusts locate approximately on a toroidal position where the plasma is horizontally elongated. Figure 2 gives the poloidal position of observed dusts with the cross-section of magnetic surfaces and the Last Closed Flux Surface (LCFS) for a typical magnetic configuration (R_{ax}=3.60m) and the vacuum vessel. It indicates that the dusts penetrated into the main plasma (inside the LCFS), and the positions reach to about 0.80 in the minor radius. The analysis proves the fact that penetration of the large amounts of dusts into the main plasma induced the radiation collapse to terminate the long pulse discharge.

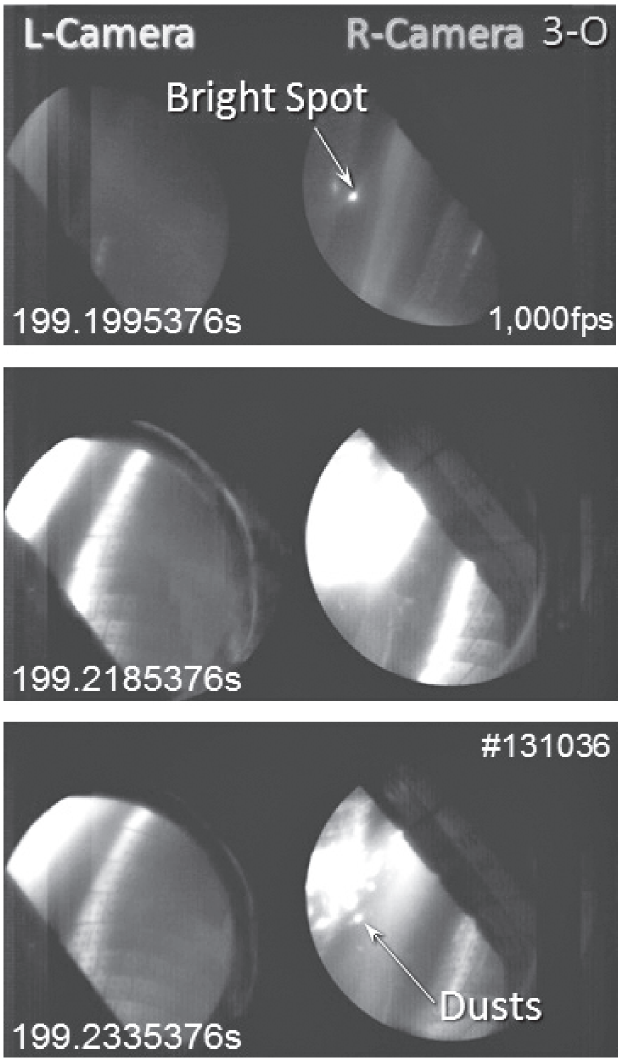

Fig. 1. Sequential stereoscopic images of a long pulse discharge observed with a fast framing camera installed in an outer port (3-O).

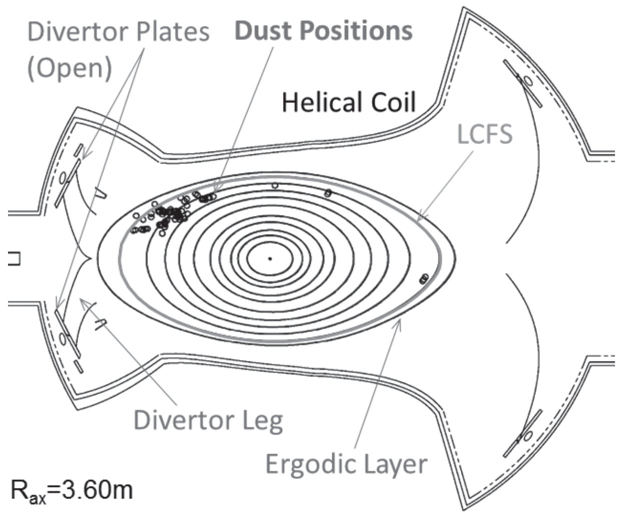

Fig. 2. The poloidal positions of the dusts observed with stereoscopic fast framing camera just before the plasma termination.