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Observations of Ablation Clouds of Impurity Encapsulated Pellets with a Stereoscopic Fast Framing Camera in Plasmas in the Large Helical Device

ステレオ視高速カメラによる大型ヘリカル装置(LHD)プラズマ中における不純物内蔵ペレットの溶発雲の観測

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A stereoscopic fast framing camera has observed the three-dimensional positions of the ablation clouds and the trajectories of tracer encapsulated solid pellets in the large helical device. The ablation positions were successfully controlled by changing the propellant gas pressure and by varying the plasma densities, which controlled the ablation position in the range of 0.65~0.85 in the minor radius. Injection of tungsten encapsulated pellets induced significant drop of the electron temperature and increase in impurity radiation in the core plasma, which were observed in all cases. It indicates the presence of impurity transport to the core plasma from the ablation positions. A tangentially viewing fast camera observed self-organized rotating filament structures which appeared around the core plasma after the pellet injections.

1. Introduction

Study of impurity transport in plasmas is one of critical issues to be clarified for nuclear fusion research. It has been studied using conventional impurity injection methods which have disadvantages such as a broad profile of injected impurity sources and ambiguity of the impurity amount in the pellets, etc. A Tracer-Encapsulated Solid PELlet (TESPEL) installed in the Large Helical Device (LHD) has many advantages to overcome these conventional methods due to the flexible choice of the tracer impurities and the total impurity amount, etc [1].

The presence of a barrier of impurity transport in LHD plasmas was experimentally found. For identifying the radial positon of the barrier in more detail, control of the ablation positions of the encapsulated tracer impurities can a useful experimental technique [2].

2. Control of Ablation Positions of Encapsulated Impurities

In order to control the ablation positions of the encapsulated impurities, the following two experiments were tried in the last campaign:

1. Changing the propellant gas pressure for the pellet injection to control the injection speed.
2. Changing the plasma density to raise the electron/ion temperature for enhancing the ablation, in which high-energy fast ions injected by NBIs enhance the ablation for low density plasmas.

The three-dimensional ablation positions of the encapsulated impurities were observed with a stereoscopic fast framing camera installed in an outer port (3-O) with an image intensifier.

Figure 1 is a top view of a LHD peripheral plasma showing the dependence of the encapsulated impurity (tungsten) ablation positions on the propellant gas pressure P_p changing in the range from 4.5 to 35atm for a plasma density n_e of $2{\times}10^{19}$m^{-3} as indicated as small colored dots. The ablation positions tend to move to the plasma center as the gas pressure rises. It shows that the ablation positions can be changed in the minor radius ρ in the range from 0.65 to 0.85. In the all propellant gas pressure cases, tungsten ion accumulation in the core plasma was observed at about 0.5s after the

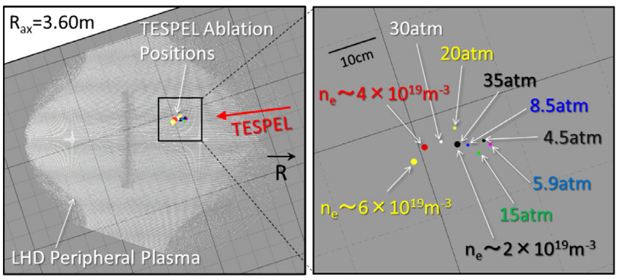

Fig.1. Top view of a LHD peripheral plasma with indication of the three-dimensional ablation positions of the encapsulated impurity (tungsten) injected by the TESPEL when the propellant gas pressure and the plasma density were changed.

injection with observable drop of the central electron temperature. It was recovered at about 1.0s after the pellet injection.

Large colored circles in the right figure give the ablation positions in three plasma density cases (n_e~2, 4, and 6×10^{19}m^{-3}) for a gas pressure of 35atm. The ablation positions move into the core plasma according to increase in the plasma density. It shows that the ablation positions can be controlled in the range of 0.75~0.65 in ρ.

3. Self-organized Rotating Filament Structures after Pellet Injection

A tungsten grain encapsulated in pellets was injected at about 3.8s, causing drastic drop of the electron temperature in the core plasma. Figure 2 shows sequential images of the LHD plasma observed with a tangentially viewing fast-framing camera (20,000fps) after the pellet injection [3]. It shows visible radiation in the peripheral plasma before the appearance of the effect of the pellet injection (a). About 0.563 seconds after the injection, a bright band appeared in the plasma center (b). The band expanded from the plasma center to form a bubble-like structure, which locates on a magnetic surface around the core plasma (c). After a while, self-organized bright filament structures appeared on the surface of the bubble (d). The filament began to rotate in poloidal/toroidal directions (e, f). The images show that the bright filament is formed along the magnetic field lines on the surface of the bubble.

4. Summary

A stereoscopic fast framing camera identified the three dimensional positions of the ablation of the encapsulated impurity (tungsten) in the pellets. Changing the propellant gas pressure made the ablation positions vary in the range of $0.65\leq\rho\leq0.85$. And, changing the plasma density from ~2×10^{19}m^{-3} to ~6×10^{19}m^{-3} made the ablation positions vary from 0.75 to 0.65. In the all above cases, accumulation of tungsten ions in the core plasma was observed, indicating the presence of a physical mechanism of impurity transport to the core plasma from the plasma periphery ($\rho\leq0.85$ at the least). A tangentially viewing fast framing camera observed self-organized rotating filament structures around the core plasma after the pellet injection due to the impurity (tungsten) accumulation in the core plasma. Research on the rotating filaments can contribute to understanding of impurity transport mechanisms in magnetically confined plasmas.

5. Acknowledgements

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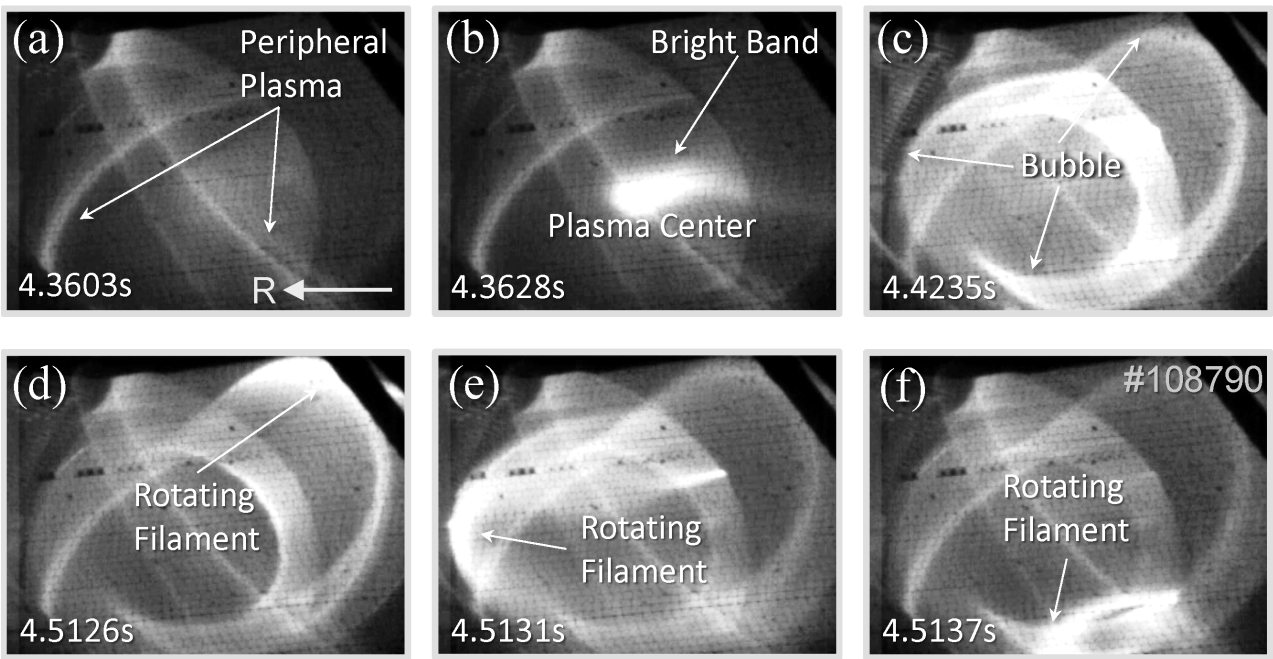

Fig.2. Sequential images of a tangential view of an LHD plasma observed with a fast-framing camera after tungsten encapsulated pellet injection. A self-organized rotating filament structure appeared around the core plasma.

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