§10. Characteristics of Self-sustained Detachment of He Plasma

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Divertor detachment is one of preferable operations in future fusion reactors to reduce the heat load to divertor plates. For past few years, characteristics of the self-sustained detachment of hydrogen H plasma are servyed and lots of diagnostics data were compiled. The detachment phenomina is expected to depend strongly on the gas because of differences of the radiation loss of main gas and the penetration length. Comparisons of detached plasmas with different gases will deepen the understanding of the detachement phenomena.

For divertor study, information of the electron density of divertor legs with a high temporal resolution is indispensable. A millimeter-wave interferomerter for the divertor leg plasma in LHD has been operated since the 11th experimental campaign. The millimeter-wave passes through the outer and upper divertor leg in the horizontally elongated plasma cross section at 3-O port. The measured position of the diverter leg is at the middle point between the X-point and the diverter plates. The temporal resolution is 10 μs and the present density resolution is $\pm 2.3\times10^{16}$ m^{-3}, which are enough to measure dynamics of detached plasmas.

Figure 1 shows a typical discharge of detached helium He plasmas. A solenoid valve for gas fueling made the density control easy and as a result detachement plasmas could be reproducibly obtained. The divertor detachment occures during the density ramp-up, at t = 0.6 s. While the detachment of He plasmas occurs at the lower electron density than that of H plasmas in tokamak[1)], there is almost no difference in the case of LHD (6-7×10^{19} m^{-3} for total port through power of 12 MW). In contrast to the H plasma, the Thomson scattering measurement shows that the peripheral region of the He plasma does not shrink and the ρ at an electron temperature of 100 eV is outside the last closed magnetic flux even after the detachment. Hence, the decrease in the stored energy is smaller than that of the H detachment. After stop of the gas fueling, the stored energy turns to increasing. During this phase the electron density profile changes from hollow to relatively flat. It is assumed that nuetral beams penetrate into the core region and then the temperature increases like Reheat mode.

Charactoristics of spiky density flushes to the divertor region are quite different between He and H detachments. In the case of H detachments, one large density flush seems to be bunching of small spikes as shown in Fig.2 (b). Whereas the bunching is not formed in He detachment. Height of individual spikes are about 1/2-1/3 of these of H detachments. The time width is ten times shorter, about 1 ms, and frequency is ten times larger, about several hundreds Hz, than these of H detachments. Since the density flushes do not correlate with signals of magnetics, they are not MHD instabilities. An observation of He detachemnts with an AXUVD array suggests that there is not large rotating radiation belts. The radiation region seems to localize and is static during the detachment phase, similar to island detachment discharges.

Even after gas replacement from He to H, plasmas are easy to detach. Recycling of He from the wall may play a radiator and enhance the detachment.

From the view points of the penetration length, the ionization rate, the charge exchange rate of He, differences of detachment plasmas should be considered. It is worth examining enhancement of the detachment by He seeding.

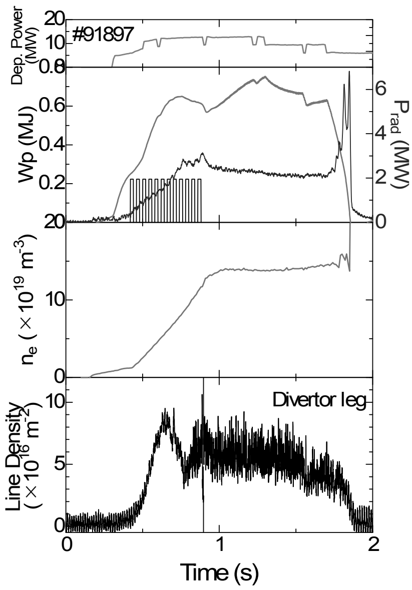

Fig.1: A typical He detached discharge in 13th experimental campaign.

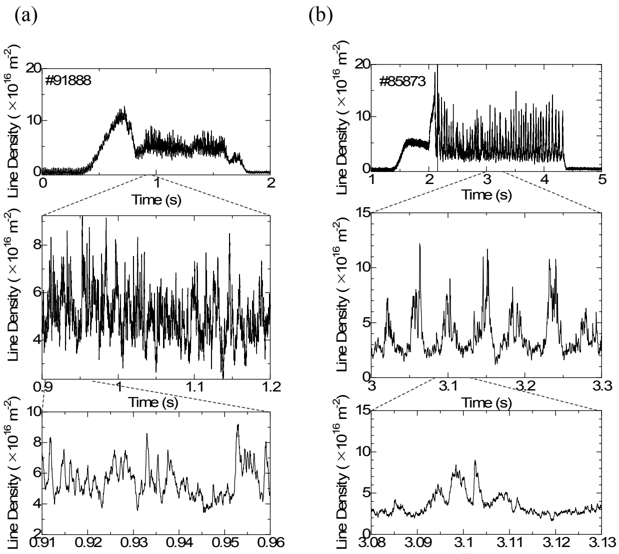

Fig.2: Spiky density flushes of (a) He plasma (R_{ax}: 3.70 m/ B_t: 2.676 T/ γ:1.254/ Bq:100%) and (b) H plasma (R_{ax}: 3.65 m/ B_t: 2.71 T/ γ:1.254/ Bq:100%)

1) Wischmeier, M. et. al., J. Nucl. Mat. **313-316** (2003) 980.