§7. Experimental Observations of Poloidal Asymmetries in Radiation Profiles during N_2 seeding in LHD

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Radiative cooling by impurity gas seeding will be an important tool for the reduction of the heat load to the divertor of a fusion reactor. Candidate impurity gasses include N_2, Ne, Ar and Kr, with lighter gasses being used to cool the lower temperature plasma in the divertor and higher Z gasses used to cool the higher temperature plasma near and inside the last closed flux surface (LCFS). In LHD radiative cooling through impurity seeding with Ne and Kr has been demonstrated [1]. The InfraRed imaging Video Bolometer (IRVB) [2], which produces an absolutely calibrated image of the line-integrated radiation from the plasma, is useful for understanding the complicated radiative structures existing particularly in the three dimensional (3D) magnetic geometries of helical devices like LHD.

N_2 is seeded in the Large Helical Device (LHD) to reduce the divertor heat load through enhanced radiation. With N_2 seeding, strong poloidal asymmetries are observed in the radiation profiles. The radiation enhancement was also observed to be around 20%, while the reduction in divertor heat load indicated by I_{sat} was more than 50% in some locations but varied strongly toroidally. At the vertically elongated cross-section, in the case of N_2 seeding, bolometric images show outboard radiation in the vicinity of the upper divertor x-point trace, while normally only inboard radiation is observed in the case of Ne. Also, only the inboard radiation is seen in the lower divertor x-point trace with N_2 seeding, indicating an up/down asymmetry.

In Fig. 1 the time traces of the main parameters of a discharge in which N_2 gas was seeded are shown. After N_2 seeding the radiation enhancement was ~20%, while probe signals indicate at least a halving of the flux to the divertor. However, there is a strong toroidal variation in the change in divertor flux with some locations showing even a slight increase in I_{sat}, while with Ne it is very toroidally uniform. The slight increases in density and stored energy indicate no degradation in confinement. Also, the lack of volume recombination indicated by no change in the H_γ/H_β ratio means that this is not the case of detachment, but rather just radiative cooling.

In Fig. 2 during N_2 seeding (but not with Ne seeding) both lower (a) and upper (b) IRVBs show a bright outboard radiation stripe coming from the vicinity of the upper x-point trace as indicated by the direction of the stripes. The upper x-point in the IRVB field of view is closely connected by magnetic field lines to the vicinity of the N_2 gas inlet and separated by 36° toroidally and 180° poloidally, which in combination with the low recycling of N_2, may explain the up/down asymmetry and the localized appearance of the outboard stripe, which are not seen with Ne seeding.

[1] K. Mukai *et al.*, Nucl. Fusion **55** (2015) 083016.
[2] B.J. Peterson *et al.*, Rev. Sci. Instrum. **74** (2003) 2040.

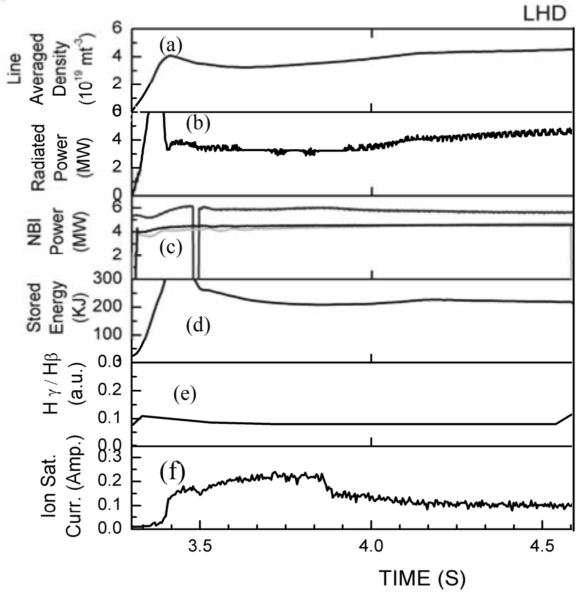

Fig. 1. Time evolutions (#123366) of (a) line averaged density, (b) radiated power, (c) heating power, (d) plasma stored energy, (e) H_γ/H_β, (f) ion saturation current in divertor. Period of N_2 puffing begins at 3.8 s.

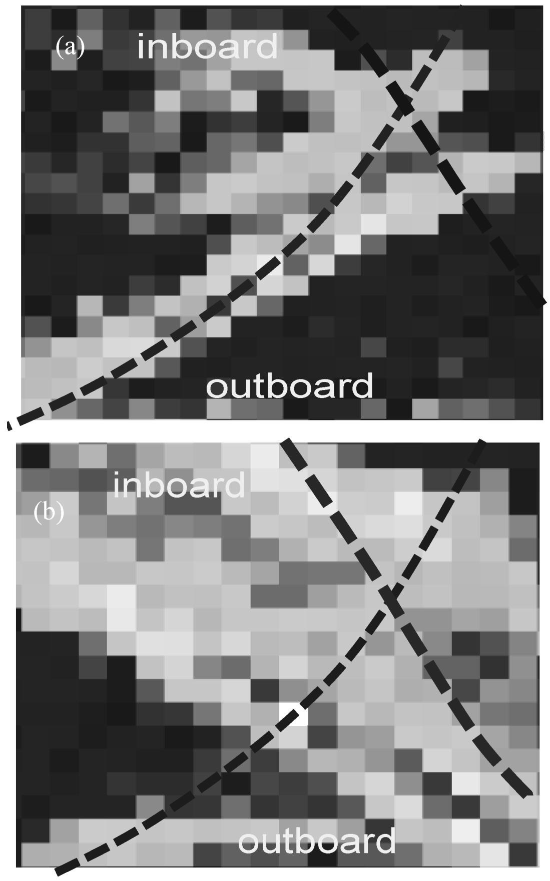

Fig. 2. IRVB data during N_2 puffing at 4.4 s (#123366) from (a) lower and (b) upper ports on LHD. Dashed lines show upper (grey) and lower (black) divertor x-point traces.