Plasmoid drift during vertical pellet injection in FTU discharges

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Abstract

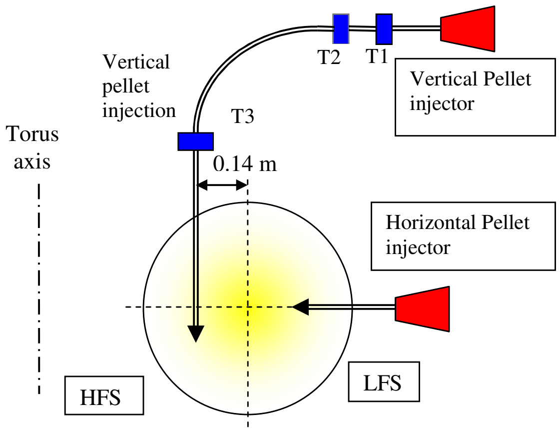
MHD and plasmoids are key elements in pellet injection experiments on FTU. The plasmoid drift can take particles from the pellet ablation region to the q=1 surface in high field side (HFS) pellet injection on FTU. Then MHD reconnections could take density from that region to the plasma center. A strong MHD event would be triggered by the injected pellet in high current (1.1 MA) discharges. A preliminary comparison between the post-pellet experimental density profile in low current discharges (0.8 MA) and the result of a pellet ablation code is presented. Strong magnetic fluctuations develop during pellet ablation. They may be Alfvén waves generated by the drifting plasmoids, preliminary results are shown.

Introduction

Fuelling the central plasma region is a key issue in tokamak experiments. FTU tokamak (major radius R = 0.935 m, minor radius a = 0.3 m, maximum magnetic field $B_t = 8$ T, maximum plasma current $I_p = 1.6$ MA) allows the study of pellet ablation at high field and density typical of a fusion reactor.

Two pellet injectors are installed on FTU. The vertical one has been used to study pellet ablation and plasmoid drift. Pellets with ~1.5×10^{20} particles and a speed of 500 m/s are injected along a vertical chord on the high field side with a/2 impact parameter. The horizontal (equatorial) injector is capable of delivering up to 7 deuterium pellets from the LFS with mass: 1.0×10^{20} particles each and speed: 1200 m/s (FIG. 1).

Experiments with the vertical system have been mainly carried at a magnetic field of 7.1 T with plasma currents of 0.8 MA and 1.1 MA. The central temperature of the target plasma was between 1.2 keV and 2 keV and, the line averaged density range was between 1×10^{20} m^{-3} and 2.5×10^{20} m^{-3}. Optical fiber were used to monitor D_α emitted during pellet ablation. They were aligned along the pellet paths, and could observe the same pellet from two different directions. The horizontal fiber is mainly sensitive to lights emitted from a region close to the midplane. The pellets would penetrate near to the midplane in almost all discharges with vertical injection, it went beyond in some cases (FIG. 2).



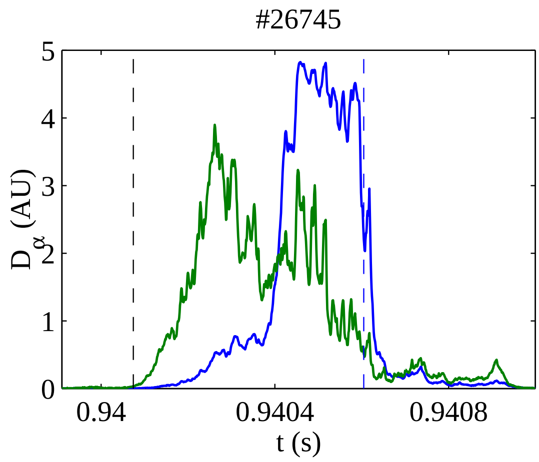


Figure 1. Schematic view of the pellet injection systems installed on FTU (Major radius R = 0.935, minor radius a = 0.3 m). T1, T2, T3 are optical targets which measure the pellet speed. Similar targets are placed on the horizontal pellet injector.

Figure 2. D_α signals for the shot #26745. The blue line correspond to the horizontal optical fiber while the green line correspond to the vertical fiber. The pellet enter the plasma at the black dashed line, and gets to the midplane at the blue dashed line.

Central Fuelling

Two main mechanisms contribute to transporting the pellet material to the plasma center on a fast time scale, namely plasmoid drift, and advection by MHD events [1,2]. Plasmoids formed during pellet ablation drift along the radial direction and take the pellet particles near the q=1 surface. Then MHD events (basically formation of islands with m=1 dominant poloidal number), advect the density to the plasma center, resulting in very peaked profiles. A strong inward pinch is also necessary to explain density evolution on longer time-scales. Thomson scattering density measurements were available in some discharges (low current, 0.8 MA, vertical injected discharges) just after pellet ablation, before any MHD event. As expected the density profile was hollow at that stage (green traces in FIG. 3).

Pellet injection in high current vertical injected discharges triggers a fast reconnection as soon as the ablated material get close to the q=1 surface. This has prevented the measurement of hollow density profiles with the Thomson scattering.

Simulation of pellet deposition

The post pellet density measured by the Thomson scattering has been compared with a pellet ablation and plasmoid drift code [3]. The density has been measured about 1 ms after pellet ablation has taken place. The code is based on a description of plasmoids as they cross the magnetic field lines including effects due to the pressure, curvature and safety factor profiles. Preliminary results give a fair agreement between the measured and the simulated density.

Thomson scattering data give a deeper penetration of the ablated material than that obtained with the code. It seems that the simulated ablation is more external than the experimental one, while the plasmoid drift is well reproduced (FIG 4).

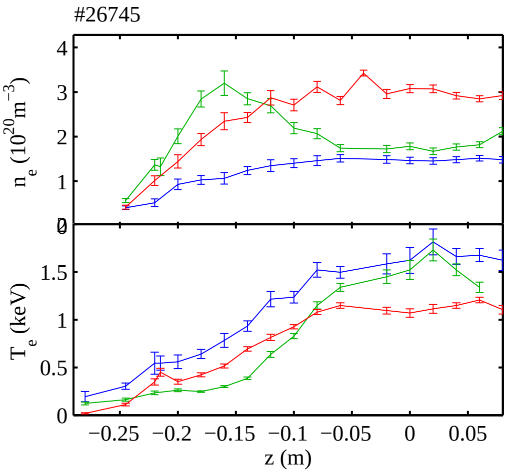


Figure 3. Shot #26745. Density and temperature before (blue), 1 ms after (green) pellet injection, 35 ms after (red) pellet injection.

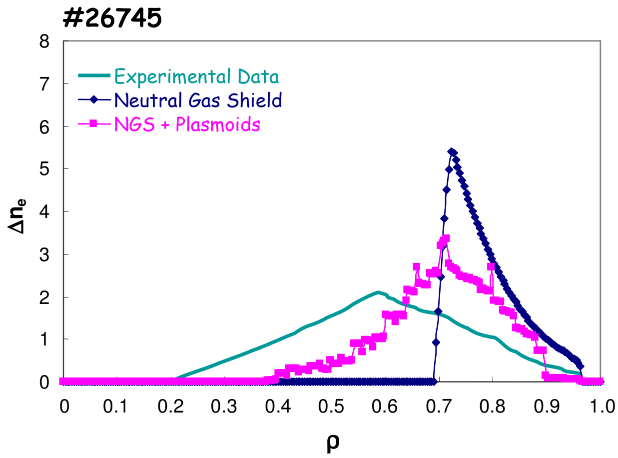


Figure 4. Density increment after pellet injection as measured from the Thomson scattering compared with the ablation code results, and with NGS model.

The pellet penetrates close to the midplane as measured by D_α (FIG. 2), while the ablation simulated without plasmoid effects (that named NGS on the figure), gives an ablation completed before the pellet could reach the midplane. No diffusion of the density profiles was taken into account in the simulation and this may also have affected the measured density profile.

MHD phenomena during pellet injection

During pellet ablation broad band and strong magnetic activity at very high frequency (up to 500 kHz) has been observed. This MHD activity disappears as soon as the pellet ablation is completed, as shown by comparison between magnetic fluctuations and D_α signals (FIG. 5). This kind of MHD activity is present at all plasma current. It is visible well before any MHD advection event (FIG. 5-6).

The same MHD activity is visible during LFS pellet injection (FIG. 6); in this case it is several times more intense. This may be due to the higher speed of LFS pellets and their faster ablation, but further analysis is needed. A possible explanation of this MHD activity is the formation of Alfvén waves during plasmoid drifts [4]. The relation between this MHD activity and the triggered m=1 reconnections in high current discharge is under investigation.

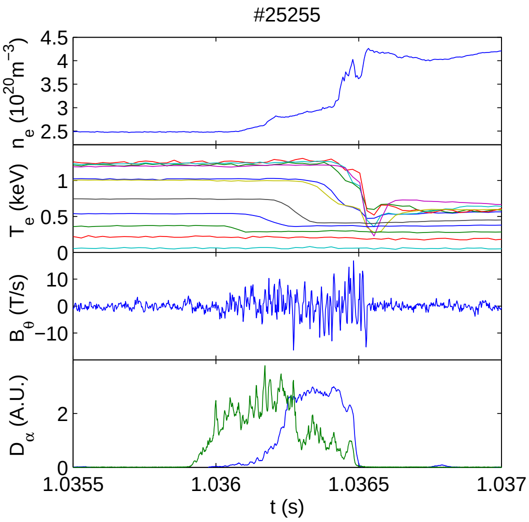


Figure 5. MHD during vertical pellet injection in a 1.1 MA, 7.1 T discharge.

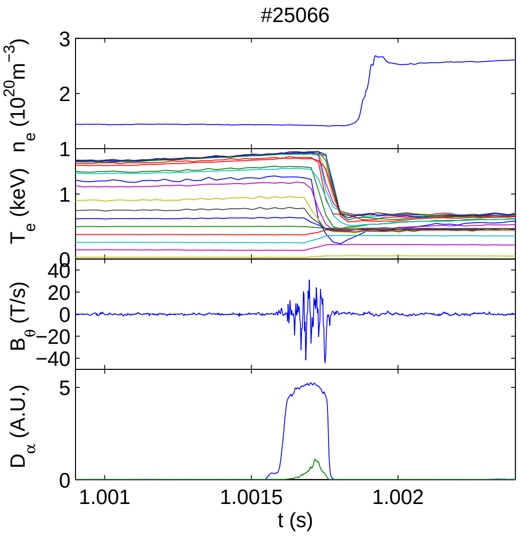


Figure. 6. MHD during horizontal pellet injection in a 0.8 MA, 7.1 T discharge

Conclusions

Pellet ablation data have been compared with code calculations including plasmoid drift. A fair agreement between the experimental data and the code has been found. MHD advections and inward pinches, on a longer timescale, are key elements for the central fuelling of pellet injected discharge on FTU. Bursty magnetic signals have been discovered during pellet ablation, which are likely to be due to the formation of Alfvén waves during plasmoid drifts.

References

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