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Study of MHD events initiated by pellet injection into T-10 plasmas

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There are several events which might be responsible for ultra fast transport [1] of heat and particles during pellet ablation stage in a tokamak. Those are jumps of transport coefficients, plasma drifts in the pellet vicinity [2] and MHD events with time scale significantly shorter than the pellet ablation time [3]. The role of the latter is still not very well understood due to a lack of studies. This paper is devoted to detailed study of the effects during the pellet ablation phase (~one millisecond) with main objective to determine the relation between pellet (material Li, C, KCl, size and velocity) and plasma parameters (q-value a the pellet position, plasma density and temperature) which initiate microsecond MHD events in plasma.

The pellets were injected into both into Ohmic and ECE heated plasmas (up to 3 MW) in the T-10 tokamak (see Fig.1) at various stages of the plasma discharge, in a wide range from the very beginning up to the post-disruption stage.

It is observed that at some conditions a pellet ablates in the plasma without accompanying MHD events. This occurs at the highest plasma densities even if a pellet penetrates through q=1 magnetic surface. The ablation rate corresponds to NGSM in this case. Pellet trajectory demonstrates then a weak pellet acceleration in toroidal direction (Fig. 2a,b).

Small scale events may occur near rational magnetic surfaces. A typical ablation rate curve for this case is given in Fig.3a. A significant toroidal pellet acceleration is detected at the maximum of the ablation rate (Fig.3.b). Pellet acceleration in the direction of electron current was observed in a few cases, which points at generation of back current during pellet penetration (Fig.3c).

Large scale MHD events envelop a region inside q<3. It is observed that the MHD-cooled area is not poloidally symmetric (Fig. 4a,b). Although the pellet was injected from top, the Te perturbation starts to develop at the HFS and then in ~100 microseconds fills in the central plasma zone. ECE, bolometer and interferometer data confirm fast penetration of pellet matter into the plasma core. At a lower pellet penetration and size the core region may not reconnect (Fig. 5a). In this case double sawteeth oscillations were detected after the pellet injection (Fig. 5.b).

The cooling wave accompanying pellet penetration into plasma propagates in step by step manner. Several knot points in which the temperature doesn't vary when outward/inward region is cooled are seen in the profile of the Te-perturbation (marked by arrows in Fig. 6). Appearance of a pellet near the plasma border damps large scale core oscillations of m=1 mode, which denotes long distance propagation of the plasma perturbations by pellet (Fig.7).

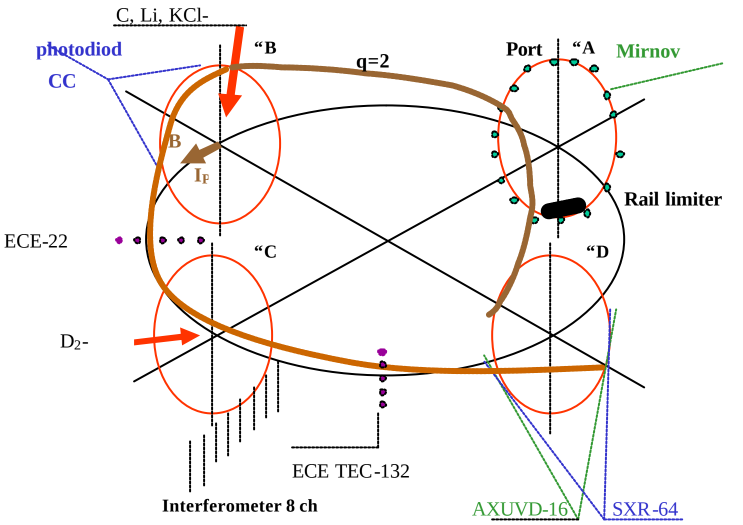
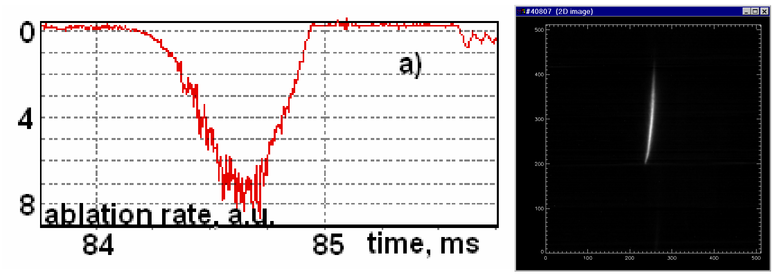


Fig.1



pellet trajectory, b)

Fig.2. C-pellet, 0.53 mm, 382m/s, n(0)=8.2x10^{13} cm^{-3} **B tor →**

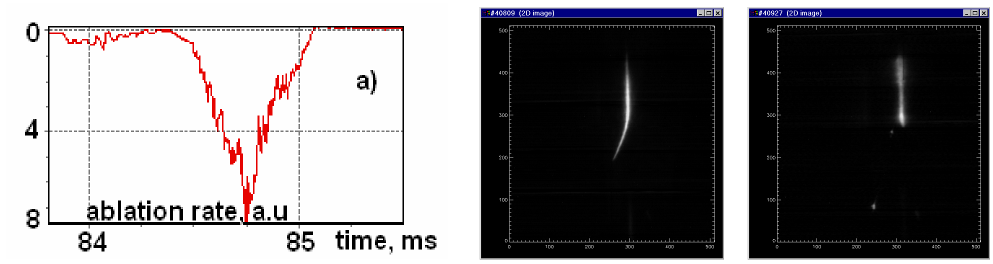


Fig. 3. C-pellet, 0.56 mm, 363 m/s, n(0)=7.8x10^{13} cm^{-3} **pellet trajectory, b), c)**

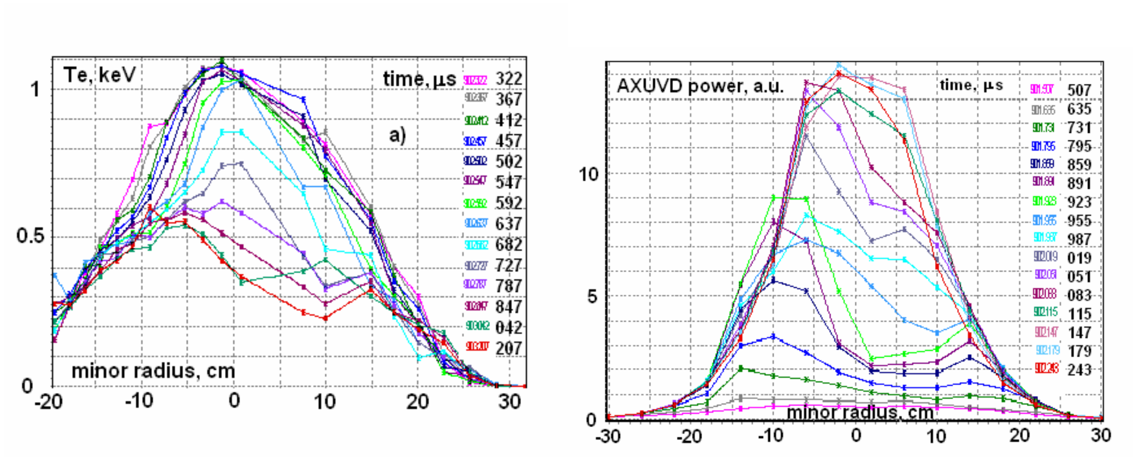


Fig.4. Te and bolo profile evolutions. Central zone reconnection. b)

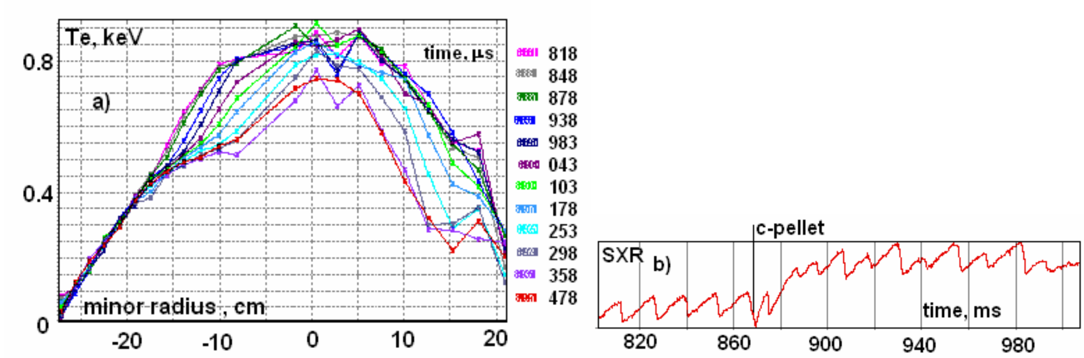
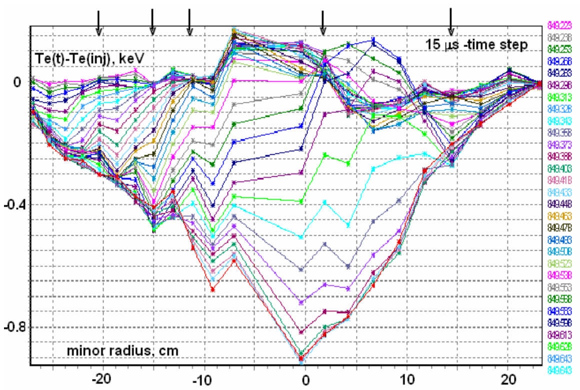


Fig. 5. Te profile and SXR temporal evolution. Middle zone reconnection. b)



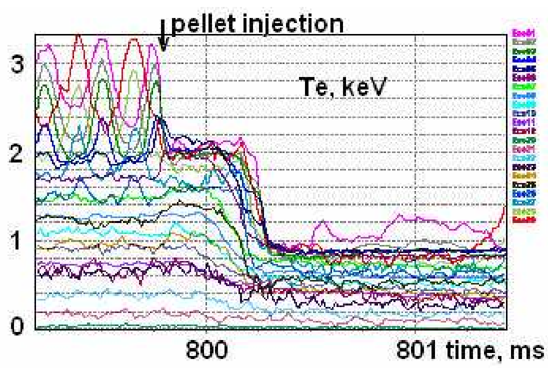


Fig. 6. Cooling wave propagation **Fig.7. Central mode stabilization by pellet.**

According to Wesson [5] the reconnection time τW is defined by plasma resistivity, electron inertia and collisionless viscosity

$$\tau W = \frac{\tau A}{\sqrt{\frac{\tau A}{\tau R} + \left(\frac{c}{r_1 w_p}\right)^2 \left[1 + \left(\frac{\beta \cdot M_i}{m_e}\right)^{\frac{1}{2}}\right]}}$$

Characteristic times of the processes for typical T-10 parameters are as follows:

$\tau A = 0.01 \mu s$ -Alfven time, $\tau R = 0.5\, s$ -resistive time,

$\tau K = \sqrt{\tau A \tau R} = 100\, \mu s$ -Kadomtsev time (resistive reconnection), $\tau W = 1 \mu s$ - Wesson time (collisionless reconnection), $\tau P = 500\, \mu s$ -pellet ablation time.

It is clear that the reconnection times are significantly shorter than the pellet ablation time. Therefore it is possible to make the magnetic structure destroyed during pellet penetration into the plasma.

Both increase of the longitudinal heat flow due to plasma convection from higher temperature region and growth of the electric field generating supra-thermal electrons may be responsible for the enhanced ablation. Further studies are necessary.

Summary. Experiments on T-10 show that MHD processes are very important during pellet ablation in the whole plasma volume. The following effects point at the MHD events in plasma: increased pellet ablation and prolonged ablation curves; local pellet acceleration; fast penetration of pellet material into the plasma core and fast symmetrization of perturbations; propagation of the cooling wave with step by step character; back current generation; correlation of ablation with magnetic surfaces.

Equilibrium variation and island growth during pellet ablation, reconnection and quasi-interchange modes [5-7] may be responsible for the effects observed. The characteristic times of MHD processes correlate with experimental observations. Partially enhanced ablation may be produced by suprathermal electrons both existing before and generated during reconnections [8].

The processes of pellet-plasma interaction require a 3-D MHD approach [9].

Faster and deeper penetration of the pellet matter into the plasma may be an advantage of MHD processes. LFS and HFS injections may have different effects on plasma.

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