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Confinement of fast ions during applied resonant magnetic perturbations in TEXTOR using collective Thomson scattering diagnostic

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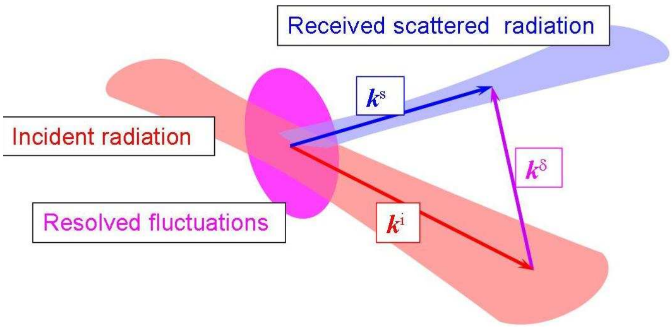
Introduction

Edge localized modes (ELM) are considered to be one of the greatest challenges for the operation of ITER which have to be overcome by the fusion community. Experiments on several machines during the last several years proved that resonant magnetic perturbations (RMP) applied to the edge region of the plasma attenuate or even completely eliminate ELMs [1, 2]. This is achieved by increased transport in the region with the ergodized magnetic field causing the pressure gradient to be widened. We performed experiments on the TEXTOR tokamak to investigate the influence of RMPs on fast ion confinement. TEXTOR is a medium-size machine with a major radius of 1.75m, 9MW auxiliary heating, and a dynamic ergodic divertor (DED). The DED is a set of magnetic field coils designed to produce 3/1, 6/2, or 12/4 magnetic field perturbations which can be rotated with various angular velocities [3]. Measurements of fast ion dynamics were performed by means of collective Thomson scattering (CTS) [4]. The CTS diagnostic allows the inference of spatially and temporally resolved components of fast ion velocity distribution functions at different angles to the magnetic field. Even so, this paper only shows the results of preliminary analysis of the spectral power density. The CTS diagnostic on TEXTOR operates with a 110 GHz gyrotron launching O-mode waves into the vacuum chamber. A receiver detects scattered signal coming from the scattering volume defined by the intersection of the probe and receiver beams (see figure 1) [4].

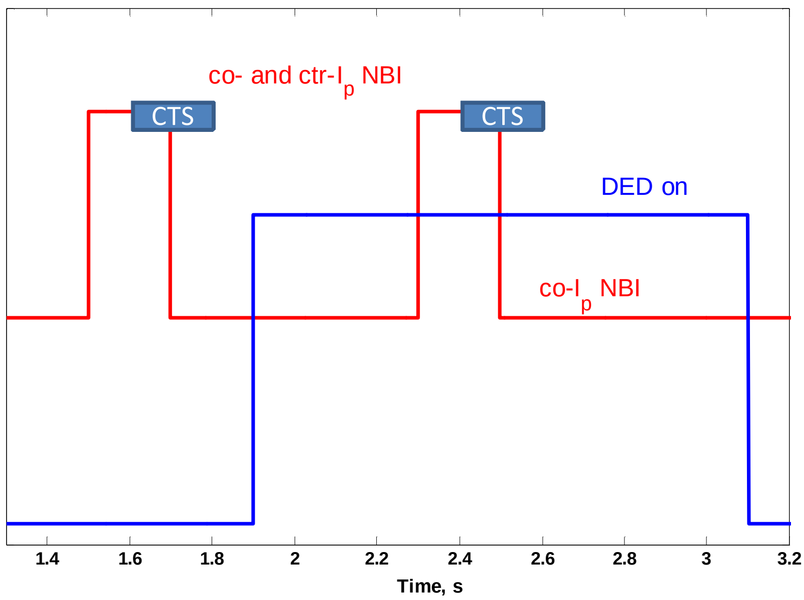


1. Principal sketch of the CTS scattering geometry.

Fast ion driven perturbations in the electron distribution cause collective Thomson scattering resulting in frequency shifts in the received signal.

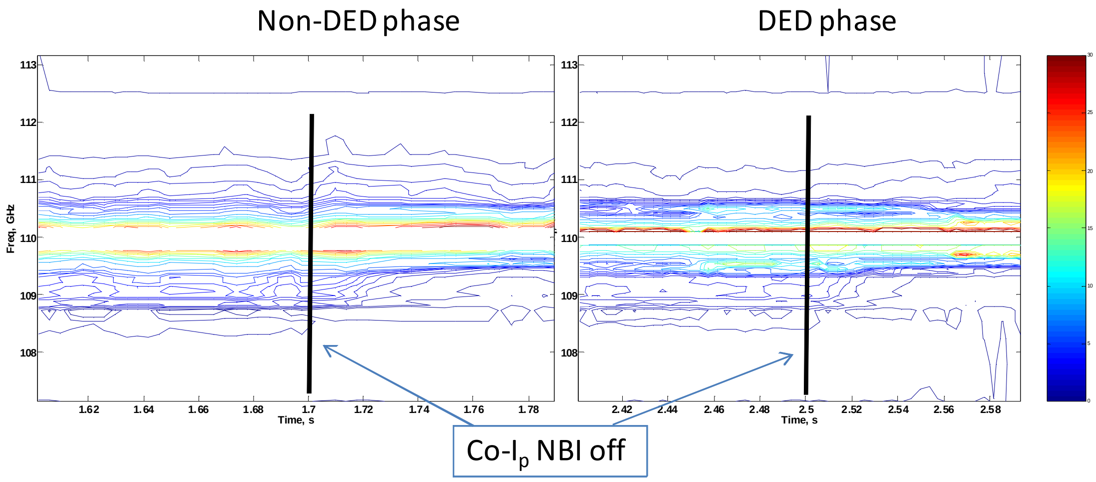
Experimental description

During the experiments, slow-down and confinement effects of fast ions were studied. We investigated the decay of signal in the fast ion channels after switching-off the co-Ip NBI in both the RMP and non-RMP phases of the discharges. TEXTOR was run at I_p=-340kA and B_T=2.6T. We divided each shot into two parts in which the DED coils were switched off and on, respectively. The magnetic perturbations were set externally to the 3/1 mode with no rotation. In each phase we performed 200 ms CTS measurements; 100 ms before each CTS measurement co-I_p beam was switched on for 200 ms (see figure 2) allowing 100 ms measurements of NBI and 100 ms of slowing down.



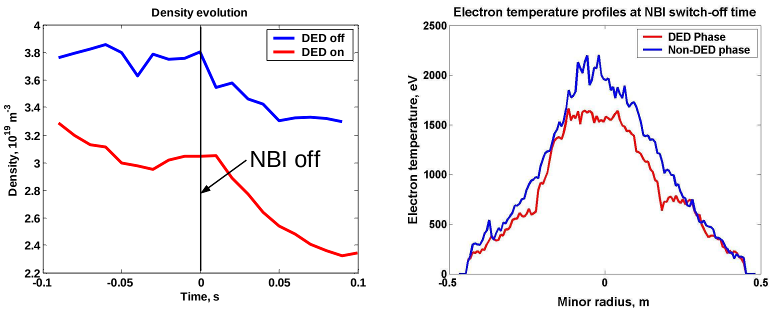
2. Schematic of the time traces of the experiments. CTS measurements were taken in both RMP and non-RMP parts of discharge.

After switching off the injector, the scattered signal in the fast-ion channels decreased. Present results were obtained at R=1.8m (plasma center) with a resolved fast ion velocity component of 55° with respect to the magnetic field.

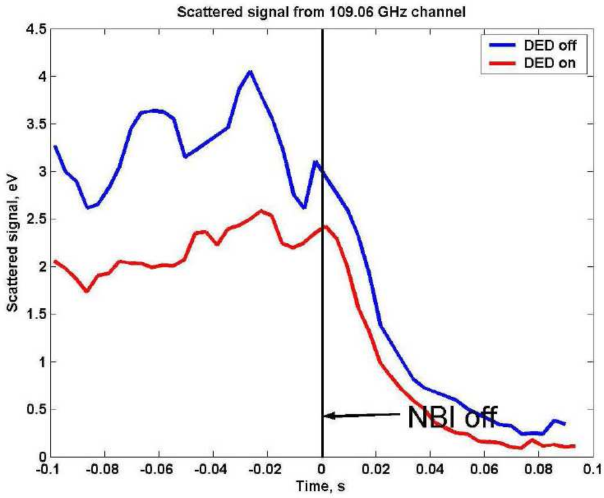


3. Contour of the scattered signal during DED-off (left) and DED-on (right) phases. Black vertical line shows the time of co-I_p NBI switching off. The scattering geometry for this data is set where the scattering volume was located at R=1.8m (at the center) and the angle of resolved component of velocity with respect to magnetic field is 55°.

In figure 3, one can see the temporal evolution of scattered signal. One must be aware of plasma Shafranov shift during NBI blips. However, the investigations showed that changes in the vertical and horizontal positions of the plasma during the discharge were in the order of 2 cm, while the characteristic size of an overlap region is about 8 cm. There must also be caution from analysis of fast ion physics from only the spectral power density (SPD) because of direct proportionality between SPD and plasma density. However, one can extract information on fast ion slowdown from the slope of the decaying signal in fast ion channels. Density changes reach a value of 30% for the DED phase and 15% for the non-DED phase (see figure 4, left). If we assume a simplified model where $\tau_{sd} \sim \frac{T_e^{\frac{3}{2}}}{n}$ [5] and calculate slowdown time at the moment when NBI is switched off (figure 4) we find that that ratio between slow down times of fast ions during DED and non-DED phases is about unity. According to [2] we assume that electron temperature behaves similarly with and without DED, so for simplicity we set $T_e(t)$=const. By these estimations, we expected to get more rapid decay of the CTS signal during DED operation compare to non-DED part of the discharge. However, it is observed (figure 5) that the decay of the scattering signal has a similar rate for both parts of the discharge with and without RMP which allow us to deduce that RMPs seems not to cause extra losses of fast ions at least at the center.



4. Density evolution during experiment at R=1.8 m (left). Upper (blue) line corresponds to period without DED, lower (red) shows a period with DED. The ordinate is the relative time when the NBI is switched off. Electron temperature instant profiles (right).Taken for DED and non-DED phases of identical discharges 109165 and 109170 at the moment of NBI switch-off.



5. Evolution of scattered signal in the fast ion co-I_p channel in non- RMP (upper blue line) and RMP (lower red line) phases. The ordinate is the relative time when the NBI is switched off.

Results and conclusions

This topic needs further experiments and investigations, particularly more experiments on resolving projections of fast ion velocity at different angles with respect to magnetic field at different radial positions in the plasma. The inference of the fast ion velocity distribution function is in progress. Nevertheless, the preliminary findings which are shown in figure 5 look very encouraging because up to now they show little influence of the dynamic ergodic divertor on fast ion confinement.

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