

## Microwave Reflectometric Studies on TEXTOR-94

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### Introduction

In neutral beam heated TEXTOR plasmas sudden MHD mode transitions e.g. from a sawtooth plasma to a tearing mode dominated plasma were observed [1]. A strong density peaking and a sharp temperature drop quench the sawtooth activity. This process is accompanied by drastic loss of plasma energy. We suspect that possibly a microturbulence process is responsible for this sudden deterioration of energy confinement. Out of this phase the  $m = 2$  tearing mode is born. The further development often leads to plasma disruption. In order to illuminate this situation the evolution of density fluctuation spectra between the  $q = 1$  and  $q = 2$  surface was observed by heterodyne microwave reflectometry. Special attention was paid to plasma rotation effects. The toroidal rotation was monitored by charge exchange recombination spectroscopy. A microwave correlation reflectometer permitted the evaluation of the perpendicular motion of turbulent plasma phenomena.

### Experimental Set-up

The principle of the poloidal heterodyne correlation reflectometer is shown in Fig.1 (for general info see e.g. [2]). A tunable microwave source ( $26 \leq f_0 \leq 37$  GHz) radiates an O-mode wave in the tokamak equatorial plane from low field side into the density gradient regime of the TEXTOR plasma. The reflected waves, poloidally displaced by a few centimeters above and below the equatorial plane, were received from reflecting density layers  $n_e^c = 0.7 - 1.7 \cdot 10^{19} \text{ (m}^{-3}\text{)}$ . Amplitude and phase measurements could be done under different tokamak operating conditions. Fig. 2 presents calculated correlations of reflected MW-signals at two different times in a beam heated plasma. Cross correlation investigations between the two poloidally displaced channels gave systematic signal delay times indicating a rotation of a plasma structure in perpendicular direction to the magnetic field. A change in poloidal rotation direction is observed here. The Crossphase spectrum, i.e. the phase difference common to both signals, was calculated. From the distance of the two reflecting zones  $\Delta X$  (cm) and the delay time  $\tau$  ( $\mu\text{sec}$ ) a perpendicular velocity  $V_{\perp}$  (km/sec) was deduced. A velocity  $V_{\perp} \approx 2$  km/sec was found here in radial depth  $R_0 + 22.4$  cm, i.e. at approximately half plasma radius.

### Experimental Results

In the following two neutral beam heated plasmas but with slightly different beam powers are compared (# 80404 and # 80405, Co- plus Counter beam injection). In the first discharge (#80404) a characteristic situation was met. The sawtooth activity is suppressed by the action of 2-nd opposing neutral beams. The toroidal plasma velocity profile  $V_{\phi}(R,t)$  was intentionally lowered and the radial velocity gradient became small. Later in time the toroidal

velocity even reverses and increases slightly with radial position. A rigid plasma body rotation was obtained now /1/. A low perpendicular plasma velocity  $V_{\perp} = 6-2$  km/sec was deduced now from cross phase evaluation. In this phase a tearing mode  $m/n = 2/1$  became visible and dominated the macroscopic plasma behavior for the rest of heating phase.

In the discharge # 80405 the counter beam power was reduced by 30 % and a good toroidal plasma rotation was maintained. The sawtooth activity was preserved during the both heating phases (Co- beam heating and Co- plus Counter beam heating). A tearing mode instability was not encountered.

Density fluctuation spectra obtained from heterodyne reflectometry are compared now for the two plasma types at different time intervals. During Co- beam heating the Fourier amplitude spectra show a pronounced broad frequency band with a decay of the fluctuation amplitude with frequency (see Fig. 3a and 3c;  $t = 1.2$  sec). With the onset of the second neutral beam (now Co- plus Counter beam heating;  $t = 2.0$  sec) typical differences become visible. For #80404 in the low frequency domain below 10 kHz sharp lines appear (Fig. 3b). These lines were identified as MHD-tearing modes (here  $m/n = 2/1$ ). In the higher frequency domain a broad band maximum ( $f = 100 \rightarrow 150$  kHz) is detected. This band indicates another instability which goes parallel with the tearing mode.

# 80405 remains a sawtooth discharge still during Co- plus Counter beam injection. A strong increase of the fluctuations in the low-frequency range below 30 kHz is found (Fig.3d). The spectra decay monotonically like  $1/f$  for higher frequencies. The turn-off of the Counter beam renders the situation encountered already with the Co- beam alone. It also lowers the amplitude of the broad band spectrum.

### Summary

Typical differences were found in the amplitude spectra of reflected O-mode millimeter waves in plasmas with different macroscopic MHD instabilities. The neutral beam Co-injection generates a broad band microturbulent fluctuation spectrum. The addition of a second but counter beam enhances the amplitude spectra very much in the low frequency range below 30 kHz. With the onset of a microscopic tearing mode instability, triggered by a flattened gradient of the toroidal plasma rotation, the density microturbulence level is strongly modified. Broad frequency maxima above 50 kHz up till 150 kHz were recorded. This suggests that an additional instability is launched. The identification of its physical nature remains to be done.

### References

- /1/ G.Waidmann et al., 25<sup>th</sup> EPS-Conference on Controlled Fusion and Plasma Physics, Praha, (1998), ECA Vol. 22 C (1998) 556-556
- /2/ A.E. Costley et al., Report JET-P (93) 102, (1993)
- /3/ V.Vershkov et al., 16<sup>th</sup> IAEA – Conference on Plasma Physics and Controlled Fusion, Montreal (1996), Vol.1, Vienna (1997) 519

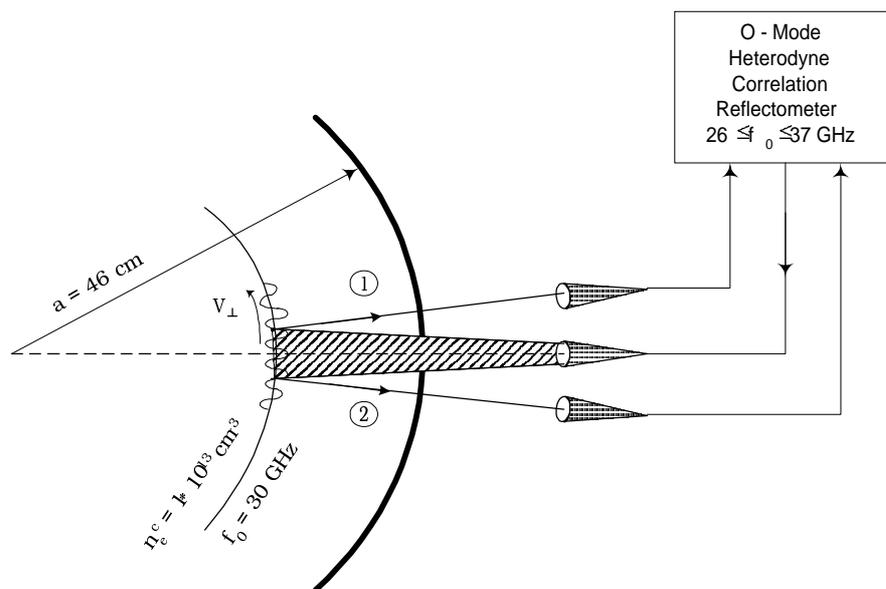


Fig. 1 Principle of the heterodyne reflectometer  
 Range of correlation reflectometer:  $0.7 \cdot 10^{13} \leq n_e \leq 1.7 \cdot 10^{13} \text{ (cm}^{-3}\text{)}$

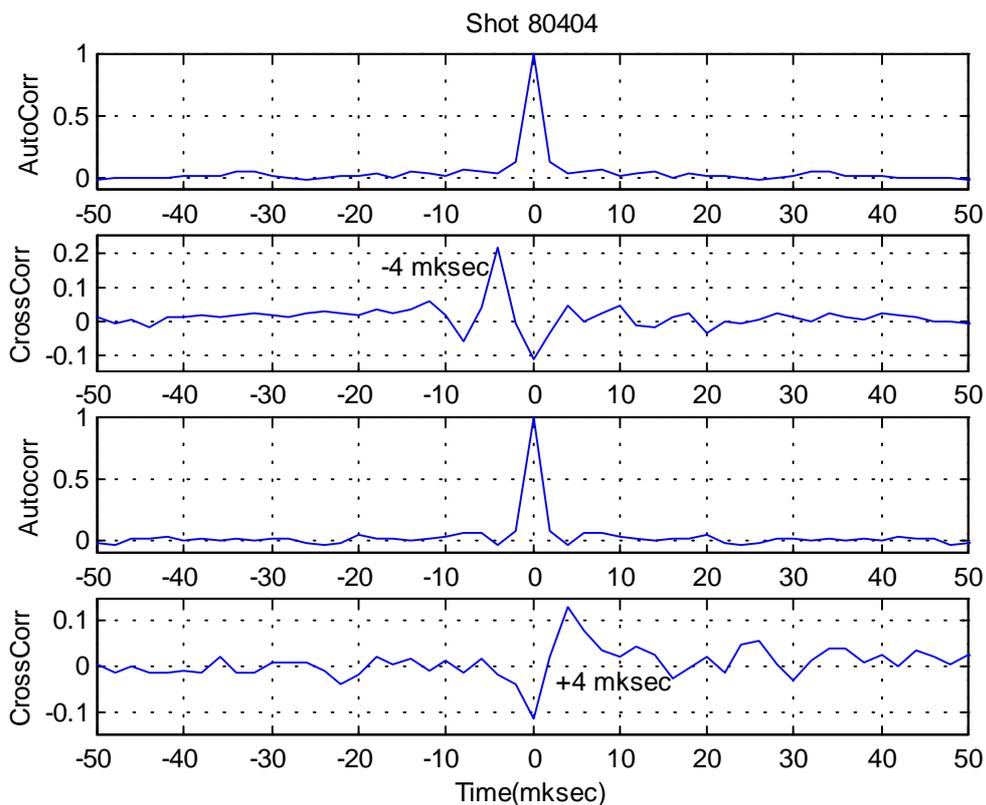


Fig.2 Autocorrelation signal (a,c) of one reflectometer channel and Crosscorrelation signal (b,d) of both channels for different time of #80404 Shot: - 1.2 sec with Co- Injector only  
 - 1.6 sec with Co+Counter Injectors

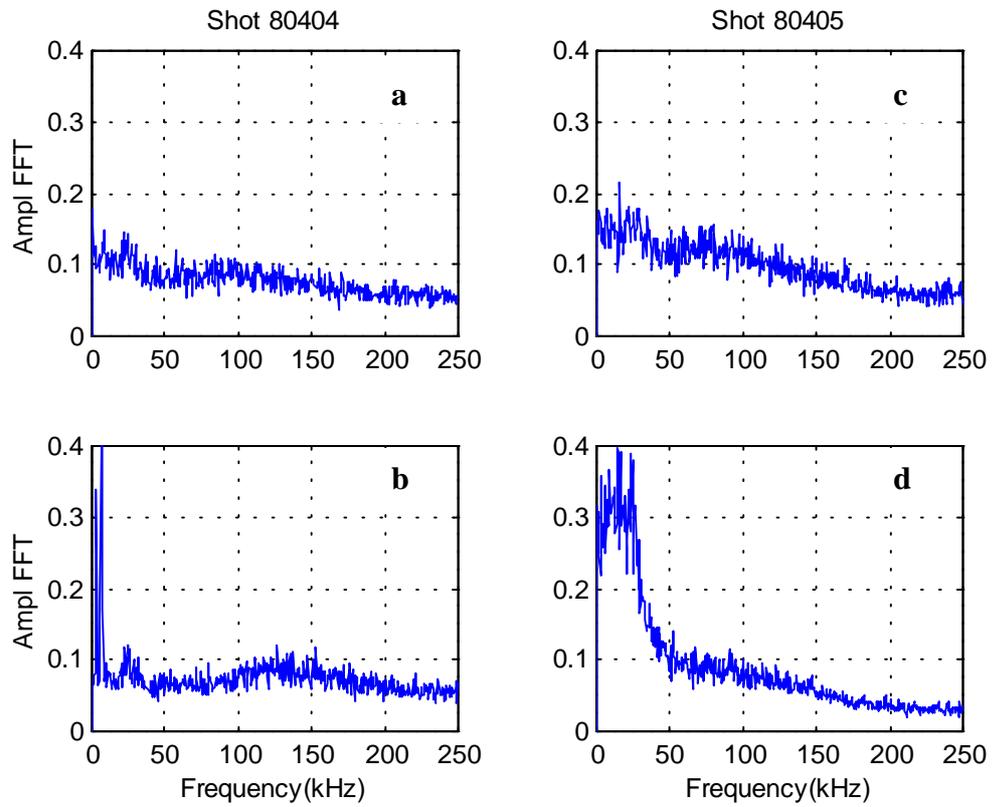


Fig.3 Fourier spectrum amplitude of the reflected signal.  
LHS: # 80404 and RHS: #80405  
a,c - time 1.2 sec with Co- Injector only  
b,d - time 2.0 sec with Co+Counter Injectors