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Experimental Studies with the Improved CTS Diagnostics on FTU and Evidences of Scattered Wave Signals with Short Time–Scale

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Experimental studies with the improved CTS diagnostics on FTU and evidences of scattered wave signals with short time-scale.

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The Collective Thomson Scattering (CTS) diagnostics is an important mean in ITER to determine the fast ions distribution function, inferred from the spectrum of the wave scattered around the frequency of a powerful mm-wave source. But the spectrum itself may be disturbed by some phenomena, as the recent observations [1, 2] possibly attributed to parametric decay instabilities (PDI) [3]. An EUROfusion Enabling Research project [4] aiming at investigating such phenomena in conditions close to those expected in ITER, i.e. at high density and with probe frequency lower than the electron cyclotron (EC) frequency in the plasma, is under implementation on the FTU tokamak. The investigation is done with the existing CTS diagnostics [5], now exploiting two lines of sight of the FTU EC launcher provided with mirrors movable in real-time [6, 7] and recently upgraded [8]. The experiments were performed at two toroidal magnetic fields, at 4.7 T (in which the fundamental EC resonance is on the high-field side) and in the ITER-like conditions at 7.2 T (with the fundamental EC layer located out of the plasma on the low-field side, actually in the equatorial port).

Using a symmetric arrangement of the probe and the receiving antennas, the scattering volume was usually located on the equatorial plane (Fig.1, left). Only in some special shots the volume was placed at the intersection of the q=2 surface with the EC resonance on the low-field side (Fig.1, center). The probe beam (500 kW/140 GHz, line 4 of the EC system) has been launched at a 5° toroidal angle in order to avoid direct reflection in the port. The receiving antenna was swept during the probe pulse with a toroidal forward movement from 1° to 9° and backward from 9° to 1°, in order to cross the probe beam and allow to discriminate the phenomena originated in the scattering volume. Different plasma conditions were tested, in particular in plasma shots with and without MHD activity.

Common observations at B_T=7.2 T and B_T=4.7 T.

a) Strong signals are seen at the end of the pulse, visible as lines at approximately 0.5 and 1 GHz from the gyrotron line (Fig.1, right): the possible explanation is in terms of gyrotron satellite lines at the end of the pulse (mode jumps).

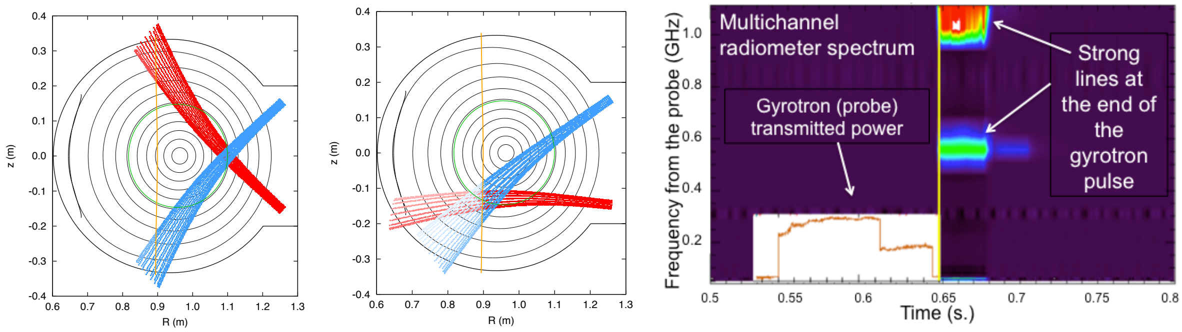

Fig.1: *Beam tracing at 4.7 T with trajectories crossing on the q=2 surface either on the equatorial plane, with symmetric launch (left) or on the resonance with asymmetric launch (center). Right: Multi-channel radiometer spectrum during probe pulse, showing strong emissions close to pulse end, possibly due to gyrotron mode jumps.*

b) Broad spectra are observed from 30 to 100 ms after the start of the gyrotron pulse (Fig.2). Possible explanation is the local breakdown that can be excited by the probe power at the location of the 1st (at 7.2 T) or 2nd (at 4.7 T) harmonic of the EC frequency, positioned close to the launching mirror. Breakdown plasma can propagate close to the receiving antenna.

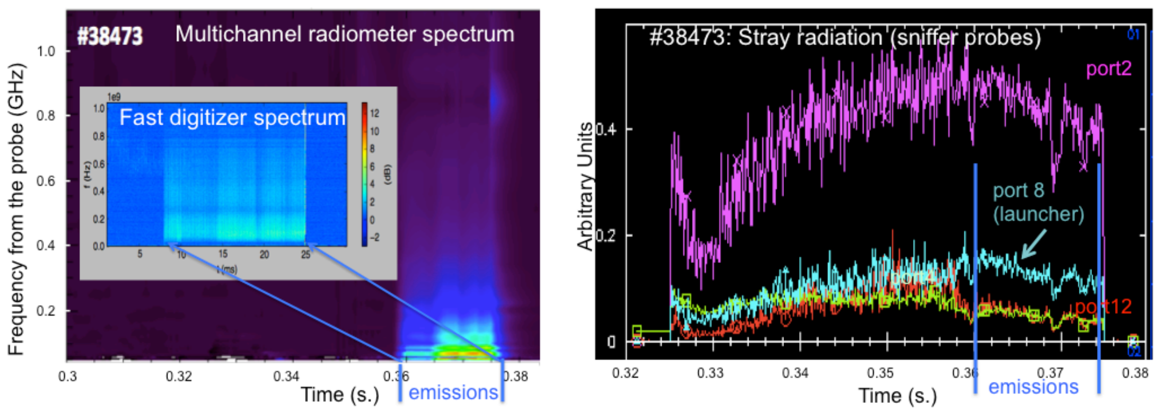

Fig.2: Left: Multi-channel radiometer and fast digitizer spectra during pulses. Right: Sniffer probes signals show a relatively higher stray radiation measured at the launcher port 8 in coincidence with intense spectral emissions.

Observations at B_T=7.2 T:

This is the case in which the fundamental EC resonance is out of plasma, as in the CTS of ITER. Signals appear as broad lines at frequencies rapidly changing in time, in the 0.6-1.1 GHz range away from the probe frequency, seen only with the time resolution allowed by the digitizer (Fig.3). The signals appear in shot with a very low MHD activity, as seen from the MHD probe (Mirnov coil) signals. The explanation for these signals is presently not clear.

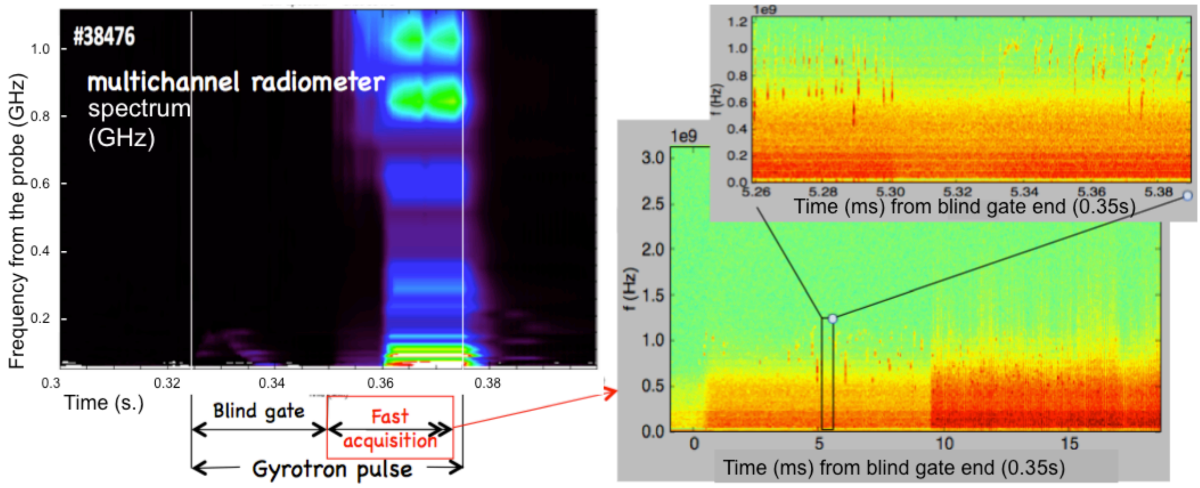

Fig.3: Received spectrum with the multi-channel radiometer (left) and with the fast digitizer (right): the increased resolution of the latter allows to see signals appearing as lines at frequencies rapidly changing in time.

Observations at B_T=4.7 T (asymmetric trajectory):

In this case the 1[st] EC harmonic is in the plasma on the high field side, the scattering volume is at the intersection of between the resonance and an m:n=2:1 magnetic island. Burst of emissions are detected in particular when the MHD island is slowly rotating, and are apparently stronger when the beam trajectories overlap, at 5° toroidal angle (Fig.4).

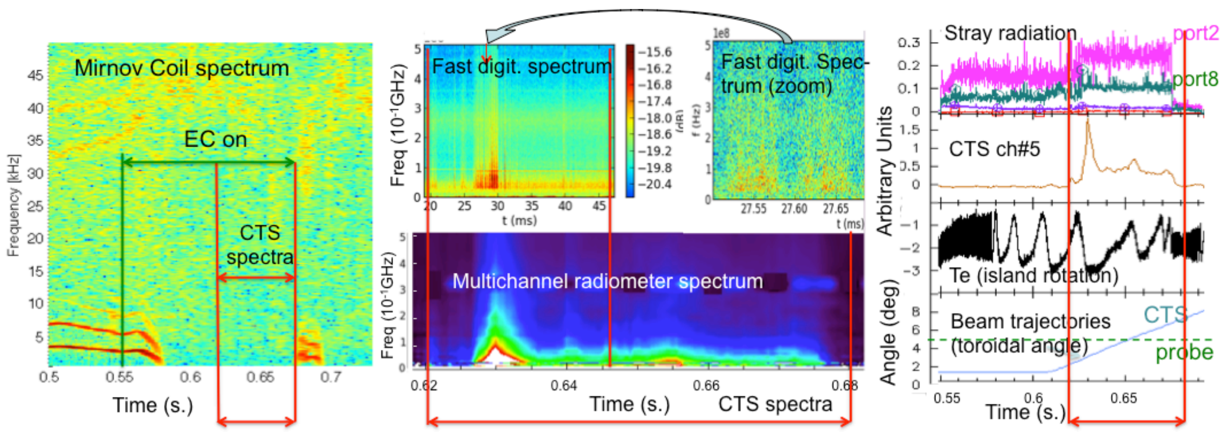

Fig.4: Left: Mirnov coil spectrum showing a MHD island with rotation speed slowing down to zero during pulse. Center: Spectra showing emissions that can be resolved as single bursts. Right: stray radiation correlates with ch#5 emission, ch#5 intensity correlates with beam overlapping, and bursts in ch#5 correlate with island rotation.

Observations at B_T=4.7 T (symmetric trajectory):

In this case the EC resonance is in the plasma on the high field side, and the scattering volume is located where the q=2 surface crosses the equatorial plane on the low field side (see Fig.5). In this case magnetic islands are absent. The evidence is an emission in short bursts with spikes repeating at high frequencies, with no MHD activity seen by magnetic probes.

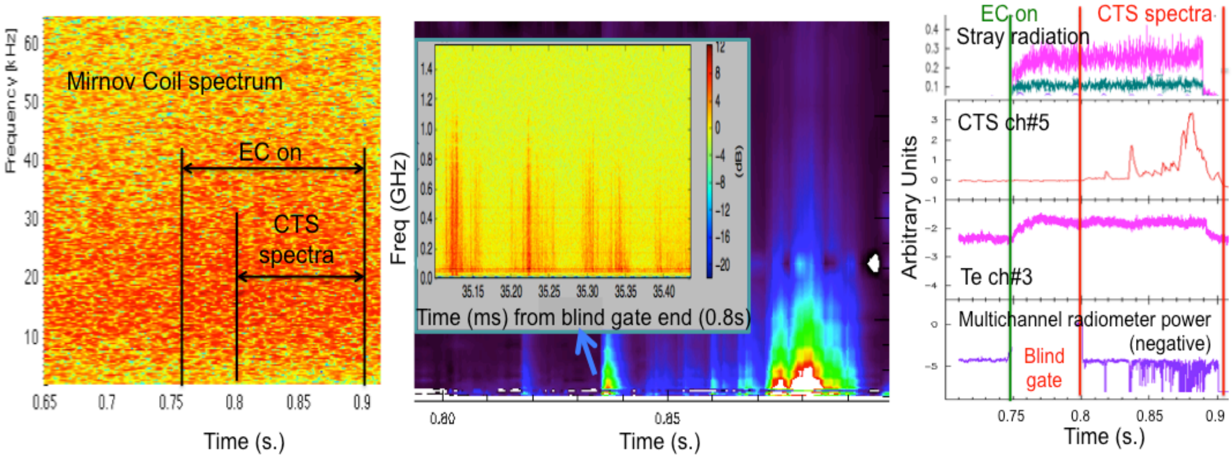

Fig.5: Left: No MHD activity is present during pulse. Center: radiometer (bottom) and digitizer (top left) spectra, showing emissions in bursts shorter than 10μs. Right: intensity is not correlated to stray radiation or temperature.

Conclusions

Anomalous signals were detected by the receiver in a frequency band of 1.2 GHz around the probe frequency, either as spectral lines or as continuum. The analysis of the data recorded with an ultra-fast digitizer allowed to detect rapid spectral changes with high frequency resolution. The MHD activity can only explain some instances of anomalous scattering while in other cases signals are not synchronous with magnetic island rotation or MHD is not relevant at all. Other spectral features may be attributed to plasma formation at the resonances close to the antennas during the gyrotron pulses, causing also gyrotron mode jumps possibly due to reflections. These results are particularly important and worth to be further investigated in relation to the design of the ITER CTS diagnostic system.

[1] E. Westerhof et al., Phys. Rev. Lett. 103 (2009) 125001

[2] S K Nielsen et al., Plasma Phys. Control. Fusion 55 (2013) 115003

[3] E.Z. Gusakov and A.Yu. Popov, Europhys. Lett. 99 (2012) 15001

[4] https://www2.euro-fusion.org/erwiki/index.php?title=ER15-ENEA-06

[5] U.Tartari et al, Nucl. Fusion 46 (2006) N.11, pp. 928–940

[6] A.Bruschi et al., Fusion Sci. Technol. Vol. 55 (2009) pp 94-107

[7] W.Bin et al., Fusion Eng. Des. Vol. 84 (2009) pp 451-456

[8] W. Bin, et al., Fusion Eng. Des. (2015), http://dx.doi.org/10.1016/j.fusengdes.2015.05.022

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