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Recent results of the collective Thomson scattering diagnostic at TEXTOR

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The technique of collective Thomson scattering (CTS) is versatile and has the potential of determining several important plasma parameters. The CTS diagnostic installed at TEXTOR is primarily aimed at diagnosing the dynamics of confined fast ions, and results of first measurements of the CTS diagnostic at TEXTOR have been reported [1, 2]. These results include temporally and spatially resolved measurements of the 1D velocity distribution function of the confined fast ions, which is obtained by observing the scattered radiation resulting from the interaction between microscopic collective fluctuations in the plasma and injected powerful mm-wave radiation. On TEXTOR, the probing radiation is generated by a 200 kW, 110 GHz gyrotron. The transmission lines for the probe and receiver are fully quasi-optical [3]. This contribution gives an overview of the recent experiments of the CTS diagnostic at TEXTOR, while detailed results have been or will be reported elsewhere.

Resonant magnetic perturbations (RMP) have been proposed and are being used for controlling edge localized mode (ELM) activity by changing the magnetic field in the plasma edge. This may prove to be an important technique for future fusion machines. However, it is not yet clear how RMPs affect the confinement of fast ions. On TEXTOR, we have an excellent opportunity to investigate this, since the RMPs can be generated by the dynamic ergodic divertor (DED) [4], and the fast ion dynamics can be diagnosed by the CTS diagnostic. The first part of an experimental campaign on this topic has been performed, and it will be followed up shortly. The experiments and preliminary data analysis are presented in these proceedings in "*Confinement of fast ions during applied resonant magnetic perturbations in TEXTOR using collective Thomson scattering diagnostic*" by Moseev et al.

In a different set of experiments, the fast ion confinement during sawtooth oscillations has been measured in the centre of co-current NBI heated TEXTOR plasmas. The fast ion distribution was investigated both in the projection close to perpendicular and also close to parallel to the magnetic field. Investigations seek to determine whether an anisotropy is occurring in the fast ion velocity distribution and/or in the redistribution of the fast ions. Studies of possible pitch angle scattering of fast ions during the sawtooth collapse are also performed. The final results and conclusions of this study will soon be reported elsewhere.

The TEXTOR CTS diagnostic receiver has also been involved in studies of a new scattering phenomenon. During NTM suppression experiments on TEXTOR, it was observed that when ECRH is applied and a rotating island is present in the plasma, strong signals showed up in the FOM radiometer viewing the plasma along the beam line of the gyrotron (in-line ECE) [5]. In order to further study this unexpected scattering phenomenon, the Risø DTU CTS receiver was modified to detect frequencies in the range of 136 - 144 GHz, which is the frequency range of the FOM in-line system. In this way, the origin of the strong signals has been investigated by the use of both receiver systems. The high frequency resolution of the CTS receiver system was sufficient to reveal detailed structures in the detected signal as presented in Figure 1. In this case, the island passing frequency is around 200 Hz, and the present time window shows ten island passages. At each passage of an island, several characteristic frequencies appear. The experiments and detailed studies of this strong scattering phenomenon are reported in [6].

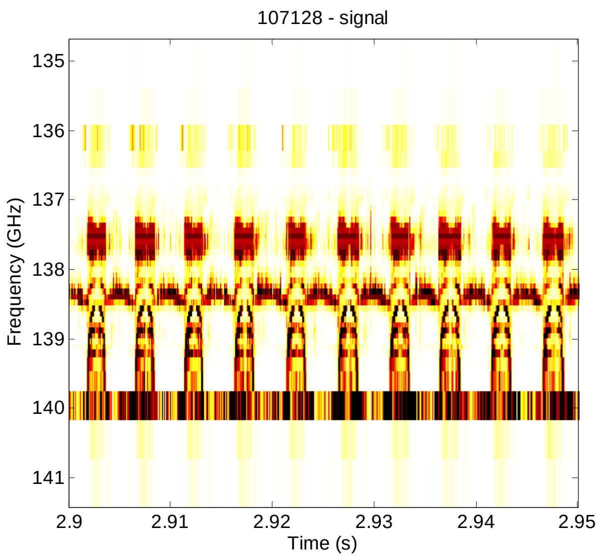

Figure 1 Measured spectrum during ten magnetic islands passages.

Recently, the issues of fuelling and fuelling diagnostics have been receiving increasing attention. For the diagnostics currently in the ITER baseline design it is not clear if the fuel ion ratio can be determined within $\rho < 0.3$ [7]. Since the fuel ion ratio is in the high priority group of measurements for machine protection and basic control, it is of great interest to the community to develop alternative diagnostics capable of measuring the deuterium-tritium ratio. An EFDA task has been launched to investigate alternative approaches to fuel ion ratio diagnostics, and one of the diagnostics included in the study is a CTS based system. The technique of CTS also offers the possibility of measuring the fuel ion ratio, since at scattering geometries resolving the direction perpendicular to the magnetic field, the bulk ion feature of the CTS spectrum is modulated by ion Bernstein waves. Ion Bernstein waves are hot plasma waves that are strongly damped when the propagation is not perpendicular to **B**, while perpendicular (or within 1-2° off perpendicular) to **B** the effect on the CTS spectrum is dominant [8]. The spectrum of the ion Bernstein waves is determined by the cyclotron frequencies and their harmonics of the different ion species in the plasma. Furthermore, since the weights of the different contributions are related to the densities of the given species, it is in principle possible to infer an isotope or fuel ion ratio from the CTS spectrum. Therefore, efforts to develop a proof-of-principle CTS fuel ion ratio diagnostic have been initiated. A fundamental requirement of a CTS fuel ion ratio diagnostic is to demonstrate that the CTS spectrum indeed contains information about the ion Bernstein waves under realistic plasma conditions, and furthermore that it is sensitive to changes in the isotope content. In Figure 2, we present the modeled spectral power density for a scattering geometry resolving an angle of 88° to **B**.

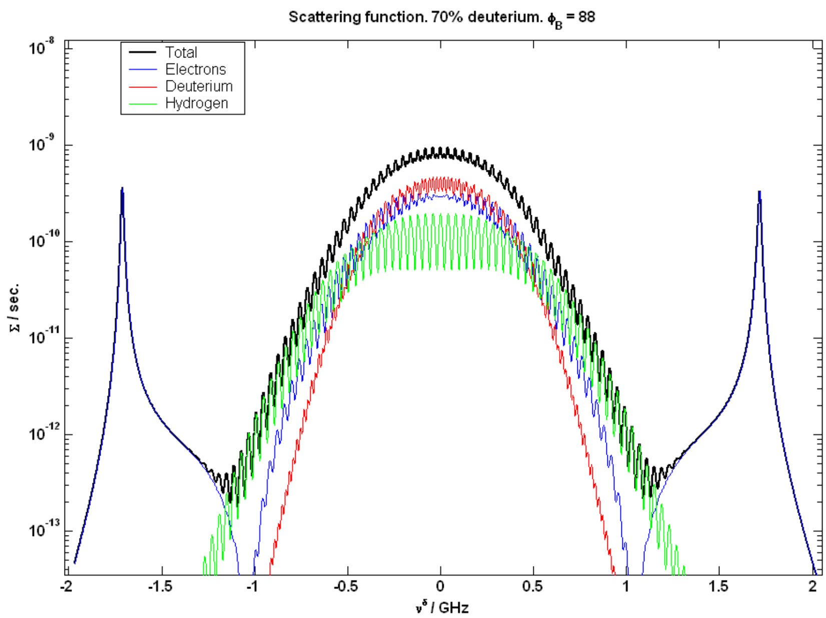

Figure 2 The modeled CTS scattering function for a geometry of $\angle(\mathbf{k}^{\delta}, \mathbf{B}) = 88^{\circ}$ in TEXTOR. The bulk part of the CTS spectrum is sensitive to ion Bernstein waves, which are seen as modulations between approximately -1 and +1 GHz. The two large peaks in the vicinity of the spectrum are due to the fast magneto-sonic wave.

In Figure 3, calculations of the ion Bernstein wave modulations of the CTS spectrum are shown for two different H/D-ratios in TEXTOR. It is clear that the spectrum should be sensitive to changes in the isotope ratio. While the spectrum generally is dependent on many plasma parameters, the sensitivity to the isotope ratio is significant.

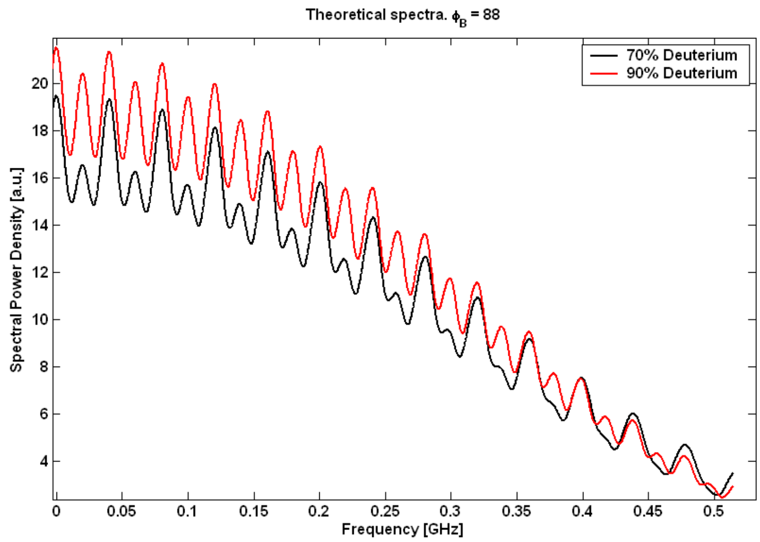

Figure 3 The modeled CTS scattering functions for a geometry of $\angle(\mathbf{k}^{\delta}, \mathbf{B}) = 88^{\circ}$ and two different H/D ratios in TEXTOR.

When demonstrated and fully developed, a dedicated CTS based fuel ion ratio diagnostic for ITER could determine the D/T-ratio over the full plasma radius with a spatial resolution of a/10 and a temporal resolution of 100 ms. The first proof-of-principle measurements of ion Bernstein waves by using CTS on TEXTOR will be reported soon.

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