First fast ion measurements by the collective Thomson scattering and ion cyclotron emission diagnostics at Wendelstein 7-X.

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Wendelstein 7-X (W7-X) is an optimized stellarator with five-fold toroidal symmetry. One of its high-level objectives is to demonstrate improved confinement of fast ions in high-beta scenarios.

The Collective Thomson Scattering (CTS) diagnostic is installed at W7-X to measure the projected velocity distribution function of primarily confined fast ions. It is planned as one of the main fast-ion diagnostics at ITER, where it will provide measurements of the fast-ion velocity distribution function across the plasma cross-section [1].

The CTS system at W7-X uses 174 GHz probing radiation and measures scattering spectra within ±1.5 GHz of the probing frequency. Since the optimization of fast-ion confinement should manifest for particles on trapped orbits, measurements should be performed in the min-B cross-section of the stellarator, where their relative density is the highest. CTS is a unique diagnostic that enables measurements at this location [2]. In this contribution, we will, for the first time, present spectra with a significant fast-ion contribution from W7-X.

While CTS measures confined fast ions, the Ion Cyclotron Emission (ICE) diagnostic is sensitive primarily to lost ions and to the waves responsible for their losses [3]. In tokamaks, ICE typically appears as narrow-band emission lines at frequencies corresponding to harmonics of ion cyclotron frequencies at locations where ICE is generated - i.e., where the fast-ion distribution function has sharp gradients. A similar behavior was predicted for W7-X [4]. However, ICE signals at W7-X rarely exhibit this characteristic. Instead, the signals are broadband, corresponding to magnetic field values associated with multiple locations within the plasma, as shown in Figure 1.

The observed emission strongly depends on the magnetic configuration, being pronounced the standard and low-mirror configurations but largely absent in all other configurations, as shown in Table 1 for data from the OP2.1 experimental campaign.

Table 1. Number of experiments with NBI in OP2.1, where ICE was observed.

Magnetic configuration	**Number of experiments with observed ICE**
EIM (standard configuration)	31 out of 32
KJM (high mirror configuration)	0 out of 26
AIM (low mirror configuration)	13 out of 13
ILD (low shear configuration)	0 out of 9
MMG (modified low shear configuration)	0 out of 9

Additionally, low-frequency narrowband activity was observed in a small number of discharges using the ICRF antenna as an ICE detector. This activity occurred at frequencies around 20 MHz, with additional signals observed well above 100 MHz. Notably, these high- and low-frequency activities were not synchronous.

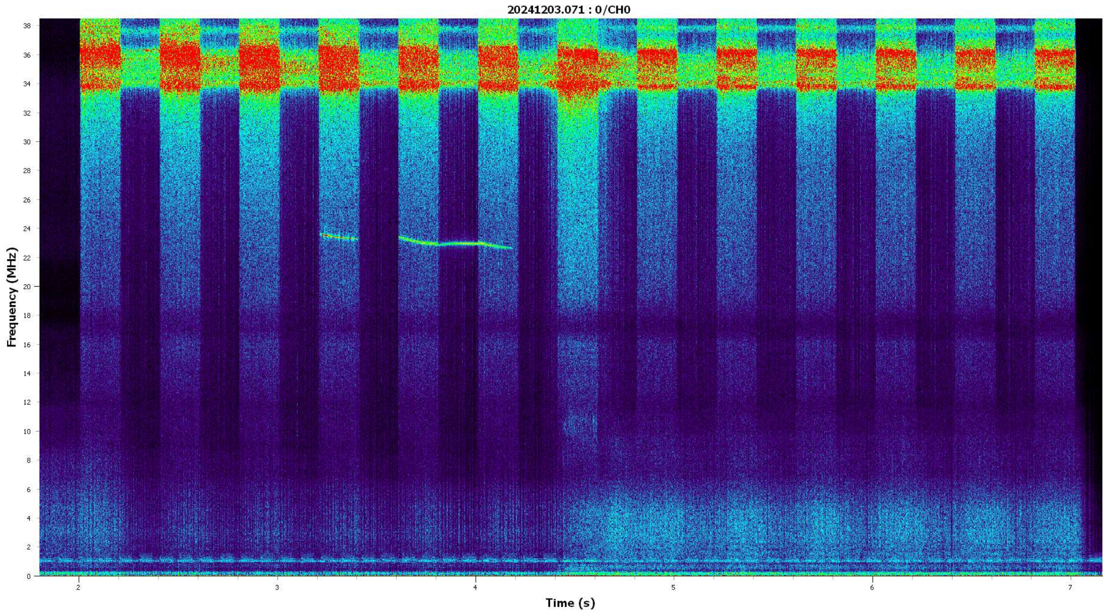

Figure 1. An example of ICE spectrum measured with the ICRF antenna in discharge 20241203.71, demonstrating the low-frequency activity at around 20 MHz and a broadband ICE activity at the fundamental harmonic of ICE at around 35 MHz.

References:

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