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First scattering results of the Collective Thomson Scattering (CTS) Diagnostic on ASDEX Upgrade..

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Introduction: Fundamentally, in CTS an incident probing beam (e.g. a millimetre wave gyrotron beam) scatters off ion driven collective fluctuations in a plasma. The received scattered radiation emanates from the region where the probe and receiver beam patterns overlap (the scattering volume). The scattered spectrum carries information about the distribution of ion velocity components projected along the fluctuation wave vector wave vector $k^{\delta} = k^{s} - k^{i}$ where k^{s} and k^{i} are the wave vectors of the received scattered radiation and the incident probing beam, respectively. The collective Thomson scattering (CTS) diagnostic installed on ASDEX Upgrade achieved its first results. It uses mm-waves generated by the 1 MW dual frequency gyrotron. The 105 GHz frequency mode is used as the probing radiation where power up to 620 kW can be attained. The near back-scattered radiation is measured by the other ECRH antenna and transmission line located in the same port. The recorded scattered signal is used to infer the 1-D velocity distribution of the confined fast ions in ASDEX Upgrade. A more detailed description of the diagnostic can be found in reference 1. The feasibility study and the summary of the first stages commissioning activities of the CTS at ASDEX upgrade can be found in references 2 and 3 respectively. First ever scattering results showing beam overlap were obtained in the 2007 campaign. The paper presents preliminary scattering results from Ion Cyclotron Resonance Heating (ICRH) that show evidence of frequency up-shift due to the fast ion flow direction. Different scattering geometries will be possible due to the steerable ECRH mirrors installed on ASDEX Upgrade which will enable measurement of the confined fast ion distribution at different spatial locations and different pitch angles.

First Overlap results:

The first overlap experiment in near perpendicular $\angle(k^{\delta}, B) \approx 100°$ scattering geometry in an Ohmic discharge ASDEX Upgrade were carried out. The receiver antenna was swept poloidally across the probe beam twice during the discharge. The gyrotron beam was modulated with on / off time of 2 / 2 ms. The CTS signal is obtained from the difference between the signal during gyrotron on time (scattering + ECE background) and the fit during the gyrotron off periods (ECE background). Figure 1 shows the time traces of centre most channels. The vertical lines are the time points where the receiver antenna position is expected to have maximum overlap from calculations based on prior in-vessel alignment of the antenna and ray-tracing which agree very well. Same experiments were performed for near parallel scattering geometry scattering where $\angle(k^{\delta}, B) \approx 150°$ and the results also show very well agreement of the alignment between experiment and calculation. In this scattering geometry, the k^{δ} is oriented in the same direction as the plasma current and the results show the frequency up-shift due to the fast ion flow direction as expected.

Preliminary results for ICRH heated plasma:

Very preliminary scattered spectra for near perpendicular scattering geometry in an ICRH (minority hydrogen, $R_{2\omega H} \approx$ center) heated plasma on ASDEX Upgrade are shown in Figure 2. The frequency range shown is between 105.4 and 106.5 GHz (gyrotron frequency = 104.95 GHz) which corresponds to approximately 2 – 20 keV for hydrogen. The plasma scenario for coupling ICRH power is still not optimized. However, the increasing Wmhd during the ICRH ramp-up phase suggests some heating is occurring until it decreases again most probably due to the increase in impurities indicated by the Prad increase. The CTS scattered spectra in Figure 2 broadens during the ICRH ramp-up while the density and temperature remain nearly constant. Impurities such as tungsten and carbon, which are the main contributors to the Prad, can distort the spectra and can explain the broadening. However, scattering simulations have shown that due to their higher mass, this should only occur for the portion of the spectra below 0.4 GHz from the main gyrotron frequency. Therefore the scattering at higher frequencies region suggest some indication of hydrogen heating from ICRH. The inference of the fast ion distribution from the scattered spectra is planned.

Commissioning activities to be completed:

The commissioning activity that is yet to be carried out is scenario development to optimize by the electron resonance layer positions w.r.t. the plasma to reduce spurious signal seen on some experiments. The final stage of the commissioning is the inference of the fast ion distribution from scattering spectra and is in progress. The plasma scenario will affect the background ECE level hence the diagnostic error bars in the fast ion distribution which can be improved by a longer integration time which of course will degrade the temporal resolution from the present 4 ms.

List of Figures

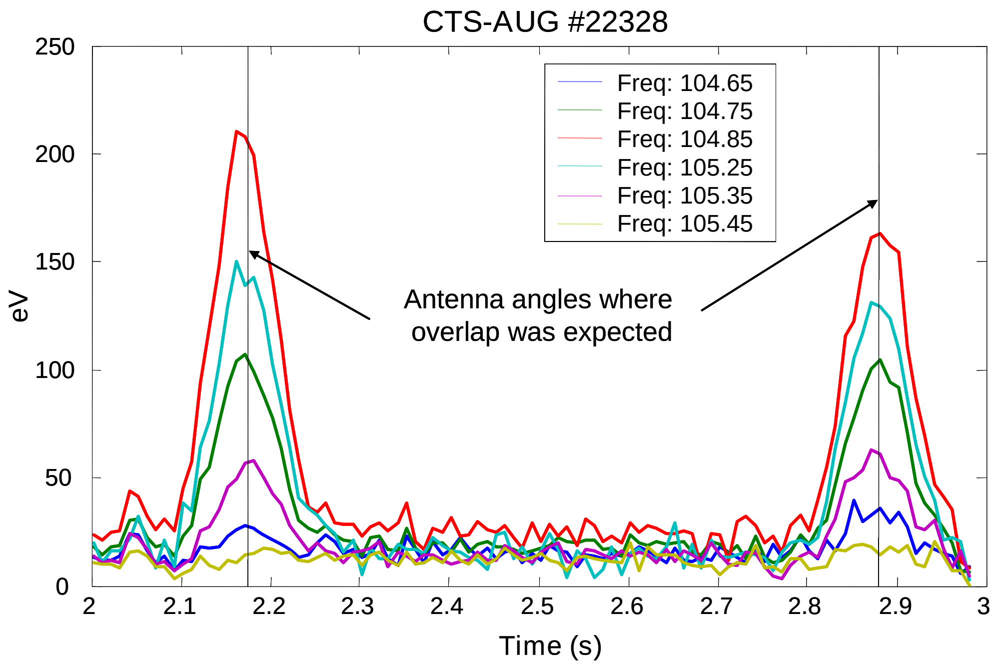

Figure 1. Time traces of the scattered radiation for the center most channels during a double poloidal scan of the receiver beam across the probe beam. The discharge was Ohmic and $\angle(k\delta, B) \approx 100°$. The two vertical lines are the time points where the receiver antenna position is expected to have maximum overlap from calculations based on prior in-vessel alignment of the antenna and ray-tracing. The density during the second poloidal sweep was decreased for comparison. .

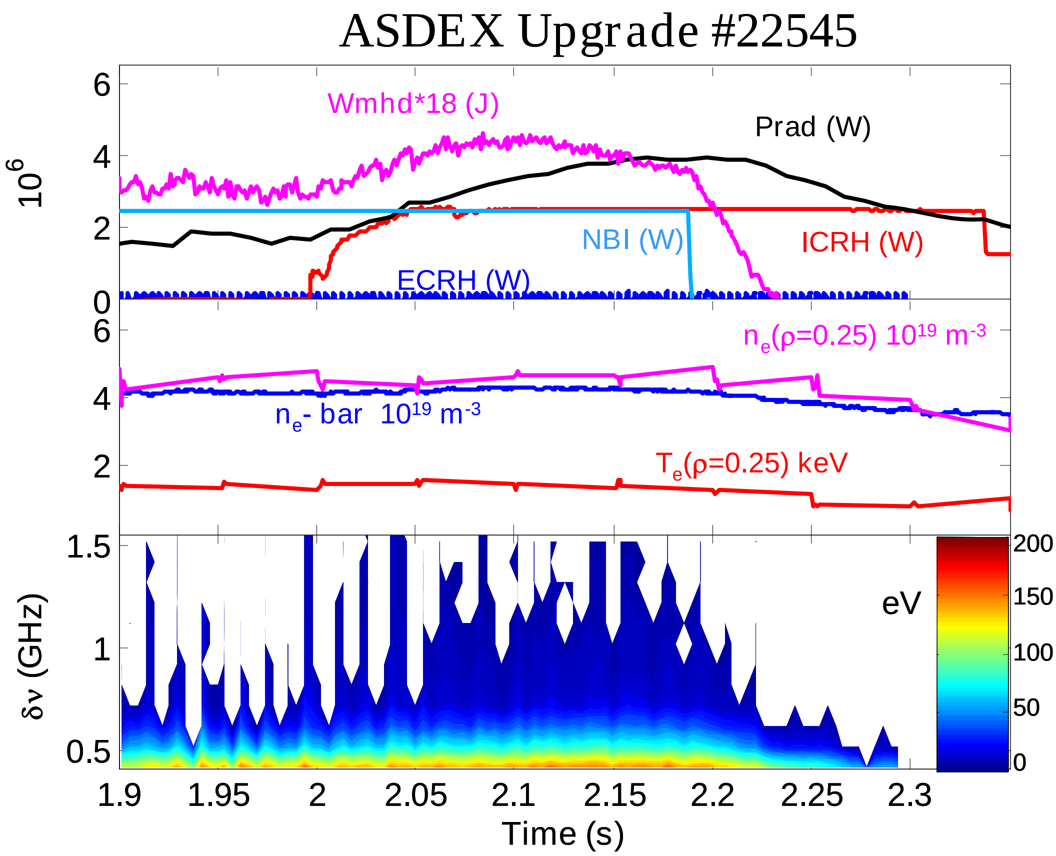

Figure 2. Time traces of the ICRH and Neutral Beam heated ASDEX Upgrade discharge. The top graph shows the traces of the ECRH (blue), ICRH (red), Total radiated power (black), NBI (light blue), and the stored energy from MHD (orange) scaled by 18. The middle graph shows the time trace of the core line integrated density from the interferometer and the density (blue) and temperature (red) at $\rho = 0.25$ from the Thomson scattering. The bottom graph shoes the contour of the CTS scattered spectra for $\angle(k\delta, B) \approx 100°$ and scattering volume located at the plasma center. The high frequency portion of the scattered spectra is plotted (+$\delta\nu$ 0.4 and 1.5 GHz) corresponding to the energy range for Hydrogen of approximately 2 – 20 keV.
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References

1. F. Meo et al, Rev. Sci. Instrum, in press (2008)
2. H. Bindslev, Application for Preferential Support, Fast Ion Collective Thomson Scattering diagnostic at ASDEX Upgrade, January 2002
3. F. Meo et al, Proceedings of the 34th European Physical society Conference on Plasma Physics, Warsaw Poland, July 2 – 6, 2007