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ABSTRACT

A multichannel instrument to measure oblique ECE has been recently installed at JET. The diagnostic has been designed to investigate features in the ECE spectra taken at different toroidal angles (0º, ~10º, ~22º), related with the deviations of the electron velocity distribution from the Maxwellian behavior, both in the near-thermal and in the superthermal energy range. Instrumental accuracy was assessed from live system measurements using in- and ex- vessel thermal sources at different temperatures and also the attenuation of the transmission lines has been evaluated. Data look promising for providing an absolute calibration of this instrument for the first time.

1. INTRODUCTION

A multiple channel Electron Cyclotron Emission (ECE) diagnostic has been recently installed at JET [1]. The instrument has been designed to investigate features in the ECE spectra taken at the different angles, related with deviations of the electron velocity distribution from the Maxwellian behavior, both in the near-thermal [2] and in the superthermal energy range [3].

This diagnostic allows simultaneous analysis of the ECE spectra along three lines of sight (at 0º, ~10º, ~22º, to the poloidal plane). The spectra are analyzed with a multichannel Martin-Puplett Interferometer (MPI), designed with Gaussian beam optics as a set of confocal telescopes with elliptical mirrors [4]. The shared movable arm is a rotating wheel-shaped spiral rooftop reflector [5] with four 90º sectors, allowing a time resolution up to ~5 ms per interferogram (corresponding in plasma measurement to a single temperature profile) and 40mm path scan, resulting in 7.5GHz as single line equivalent best spectral resolution. The band of interest (75-800GHz) is well covered since 256 samples/interferogram set the upper bandwidth limit well above 900GHz.

An Inconel antenna at radial coordinate R_{ant}~4.1 m collects the perpendicular ECE signal while a quasi optical antenna [6] at radial R_{ant}~4.3 m collects the signal at ~10º and ~22º from the poloidal plane. Both antennas are located close to the equatorial plane on the low field side but in two different JET octants. The radiation from oblique antennas is delivered to the MPIs through a pair of ~60m copper circular smooth waveguides with 17 mitre bends whereas radiation from the perpendicular antenna is delivered with an aluminium rectangular oversized waveguide. A mechanical switch before each input port of the instrument allows to collect radiation from either the plasma or a blackbody source nearby for local measurements (Ex-Vessel).

Since the ECE radiation observed outside the poloidal plane is elliptically polarized, each oblique line of sight feeds two different interferometers with linear orthogonal polarizations (mostly X-mode, mostly O-mode).

This paper discusses the instrument performances and the first results of the in-vessel spectral calibration of the whole system carried out in June-August 2010. Data analysis has just begun at the time of writing.

2. PERFORMANCES

2.1. SENSITIVITY

After a recently refurbishment with a new set of optical mirrors (to make easier any periodical realignment) and of rooftop mirrors (to increase sensitivity to incoherent radiation) the instrument achieved its final configuration. A Signal-to-Noise (S/N) ratio has been estimated in Ex-Vessel configuration and in plasma measurements with ohmic/heating phase. In the Ex-Vessel measurements the *signal* was defined as the peak-to-valley amplitude of the Zero Path Difference feature (ZPD) while measuring a blackbody (BB) source at 873 K whereas the *noise* was defined as the standard deviation of the signal obtained by closing the movable arm of the interferometer with Eccosorb®. In the case of plasma measurements the signal was defined in the same way for the Pulse No:'s 77908 (@13.5s, ohmic phase) and 78006 (@9.85s, heating phase with NBI+ICRH) while the noise is assessed from the first and the last phase of a discharge where no plasma signal is present [7]. Table 1 shows the order of magnitude of the S/N ratios for all channels; the local results are normalized to 1keV.

Figure 1 shows the spectrum of BB source at 873 K measured in local configuration with the perpendicular channel after 2.5×10^5 revolutions of the wheel (i.e. 1.9 hours integration time at 2200 rpm) and with 9.6GHz equivalent spectral resolution. Many oxygen and water absorption lines due to the air in the ~5m long transmission lines are apparent in several features of the spectrum.

2.2. IN-VESSEL CALIBRATION

In June-August, during the 2010 JET shutdown, an absolute calibration of the instrument has been done. A BB hot source (Fig.2) built by CCFE was positioned in the Torus in front of the antennas. A few different angular positions were used for the oblique antenna. The BB support hosted also a shutter for switching between hot and cold source in less than a minute. The shutter moves vertically about 300mm from the hot surface. It is made of thin aluminium plates covered with low emissivity film on the side facing the hot source, to reduce heating. The other side is covered with Tessalating TeraHertz RAM™ [8]. The temperature of the antenna facing surface is usually below 50ºC. The temperature of BB and the shutter are registered with thermocouples.

Table 2 shows the total integration time for all channels. The mirror speed was close to 2200 rpm (~ 7ms for 1 interferogram).

All data were stored on disk (about 1TB) for off-line processing.

The integration time with the raised shutter is lower than that with the hot source. We plan to compare it with the signal measured from the vacuum vessel at room temperature (during shutdown) and use the latter as cold reference if the comparison is satisfactory.

2.3. WG ATTENUATION

A fast way to estimate waveguide attenuation is comparing the amplitude of ZPD (e.g. peak-to-valley amplitude) obtained from in-vessel measurements with the slope of the ZPD-vs-Blackbody temperature line obtained from ex-vessel calibrations. The in-vessel signal is the difference between the measurements from the BB source at 873 K (T_{HOT}) and that with the shutter raised (room temperature reference, T_{COLD}). Concerning the ex-vessel acquisitions, a set of measurements with different temperatures (77-473-673-873 K) has been acquired with the BB source in local configuration. Assuming that the spectrum of the source observed by the instrument is approximately the same (the difference between the two BB sources being small for the precision of this estimate), the difference between the two measurements is introduced by the WGs and the antennas.

The WG attenuation L is:

$$L = \frac{\left(T_{HOT} - T_{COLD}\right)_{remote}}{\Delta ZPD_{remote}}$$

where α is the slope of the ZPD-vs-Blackbody temperature line

$$= \frac{\Delta ZPD_{local}}{\left(T_{HOT} - T_{COLD}\right)_{local}} \tag{1}$$

if T_{COLD} is the temperature where ΔZPD is zero and ΔZPD is the peak-to-valley amplitude (*remote* In-Vessel and *local* Ex-Vessel).

Table 3 shows the preliminary results for perpendicular and 10's channels only.

CONCLUSIONS

The oblique ECE instrument in its final configuration has been characterized with a defined S/N ratio and spectral resolution capabilities. A preliminary analysis of data acquired in the course of absolute calibration allowed to detect clearly the signal from the in-vessel BB source and to estimate the losses of the WGs+antennas system. Data look promising for providing an absolute calibration of this instrument for the first time.

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Channel	S/N Local	S/N Ohmic plasma (77908 @13.5s)	S/N Heated Plasma (78006@9.85s)
Perpend.	~8•10^4	~7•10	~2•10^2
10-O	~8•10^4	~2•10^2	~3•10^2
20-O	~9•10^4	~4•10	~5•10^2
20-X	~6•10^4	~1•10^2	~4•10^2
10-X	~5•10^4	~7•10	~2•10^2

Table 1: Local Signal-to-Noise ratio (extrapolation in keV).

Antenna	Hot BB	Shutter	Vessel
Perpendicular	85.41	22.38	80.13
10	85.75	55.37	68.21
20	78.65	54.09	68.21

Table 3: WG attenuation.

Channel	L ± σ	L [dB]
Perpendicular	79.4 ± 4.1	19
10-O	94.7 ± 5.2	19.8
10-X	93.8 ± 5.0	19.7

Table 2: Integration time in hours.

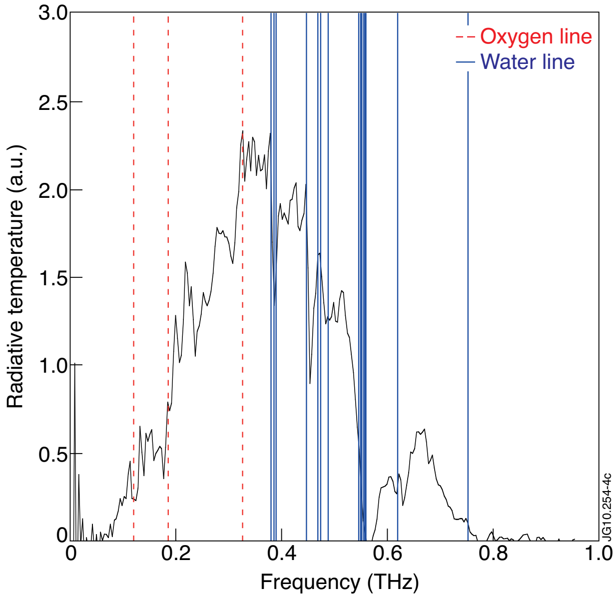

Figure 1: Spectra of hot BB source measured with perpendicular channel. A few water and oxygen lines are shown.

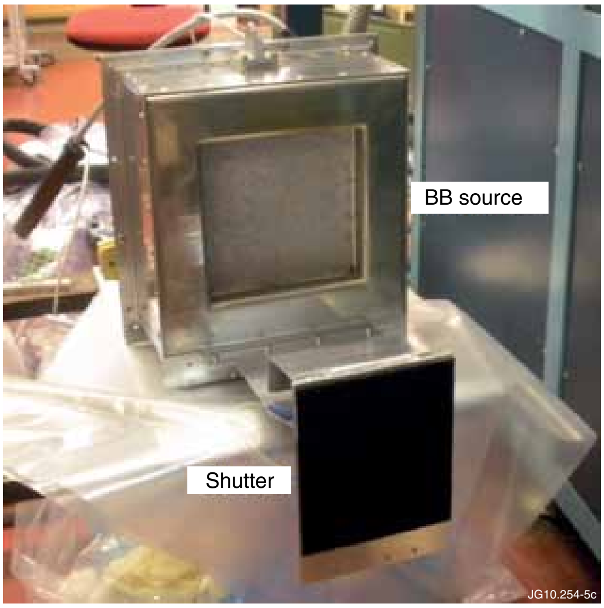

Figure 2: Hot blackbody source built by CCFE, used in the Vessel.

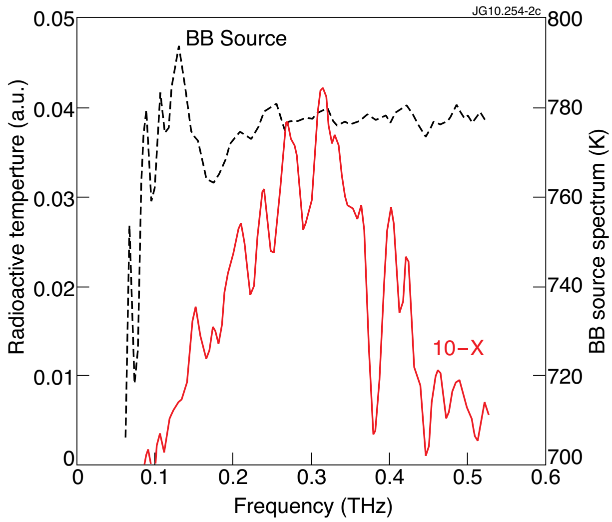

Figure 3: Spectra of hot BB source: nominal (dashed) and measured with 10-X (solid) channel.

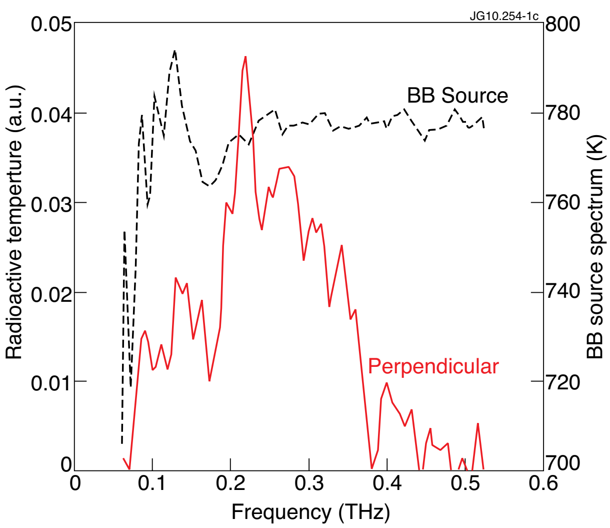

Figure 4: Spectra of hot BB source: nominal (dashed) and measured with perpendicular channel (solid).

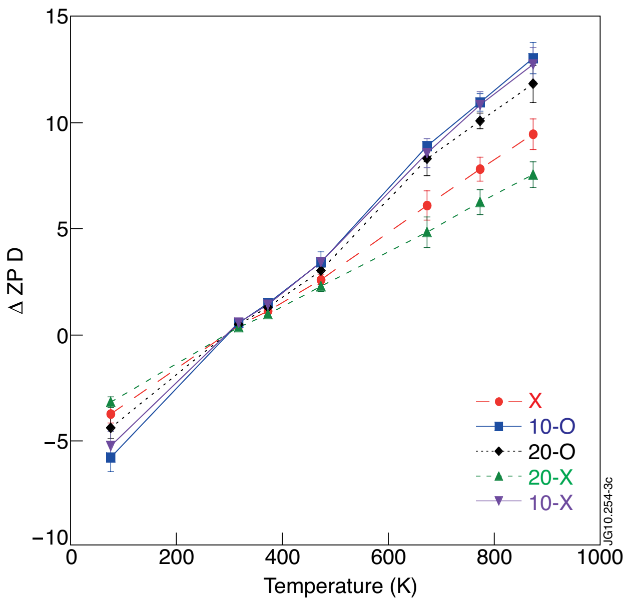

Figure 5: ZPD (peak-to-valley) amplitude versus BB temperature (ex-Vessel measurements). The slope is a as defined in (1).