EFDA–JET–CP(12)01/10

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** See annex of F. Romanelli et al, "Overview of JET Results",*
(23rd IAEA Fusion Energy Conference, Daejon, Republic of Korea (2010)).

Preprint of Paper to be submitted for publication in Proceedings of the
High Temperature Plasma Diagnostics (HTPD) 2012, Monterey, California, USA.
7th May 2012 - 10th May 2012

ABSTRACT

In preparation for ITER, JET has been upgraded with a new ITER-Like Wall (ILW), whereby the main plasma facing components, previously of carbon, have been replaced by mainly Be in the main chamber and W in the divertor. As part of the many diagnostic enhancements, a new, survey, visible spectroscopy diagnostic has been installed for the characterization of the ILW. An array of eight Lines-Of Sight (LOS) view radially one of the two JET neutral beam shine through areas (W coated CFC tiles) at the inner wall. In addition, one vertical LOS views the solid W tile at the outer divertor. The light emitted from the plasma is coupled to a series of Compact Overview Spectrometers (COS), with overall wavelength range of 380–920nm and to one high resolution Echelle overview spectrometer covering the wavelength range 365-720nm. The new survey diagnostic has been absolutely calibrated in situ by means of a radiometric light source placed inside the JET vessel in front of the whole optical path and operated by remote handling. The diagnostic is operated in every JET discharge, routinely monitoring photon fluxes from intrinsic and extrinsic impurities (e.g. Be, C, W, N and Ne), molecules (e.g. BeD, D_2, ND) and main chamber and divertor recycling (typically D_α, D_β and D_γ). The paper presents a technical description of the diagnostic and first measurements during JET discharges.

I. INTRODUCTION

In preparation for ITER, JET has been upgraded with a new ITER-Like Wall [1, 2] (ILW), whereby the main plasma facing components, previously of Carbon Fibre Composite (CFC), have been replaced by mainly Be in the main chamber and W in the divertor. An extensive upgrade of spectroscopic diagnostics has accompanied the installation of the ILW in order to allow for its characterization in terms of impurity source distributions, erosion rates and migration patterns. As part of the many diagnostic enhancements, a new, survey, visible spectroscopy diagnostic, has been installed to monitor one of the 2 JET Neutral Beam (NB) shine through areas in the main chamber. These are areas of recessed W coated CFC tiles, comprising a portion of the Inner Wall Guard Limiter (IWGL) and the adjacent inner wall tiles. They are the only W main chamber plasma facing components of the new JET main chamber, the remainder being made of Beryllium. An additional, vertical line-of-sight views the solid W tile at the outer divertor. The new diagnostic was installed on JET in 2010, commissioned and calibrated in 2011 and became operational from the first day of the JET experimental campaigns in August 2011. This paper describes the setup of the new diagnostic (known as KS8 in JET) and gives first experimental results.

2. VIEWING GEOMETRY

An array of eight radial Lines-Of Sight (LOS) to the inner wall view the JET neutral beam shine through area at Octant 7 of the tokamak just above the midplane. These tiles are recessed with respect to the other main plasma facing components. The 8 LOS are poloidally and toroidally distributed, with 3 viewing the IWGL and 5 the adjacent inner wall tiles, as shown in the layout of Figure 1. The

LOS spot diameter is 5.2 cm at the inner wall. An additional LOS views the solid W tile at the outer divertor (tile 5) from a vertical port, with spot diameter of 23cm at the divertor target. A poloidal cross section of the KS8 viewing geometry is shown in Figure 2. The final diagnostic alignment was carried out at the JET wall operating temperature of 200°C. The optical head consists of a quartz lens and a fibre holder housing the fibre optics, installed on a bracket bolted in front of a Si-Si window. The plasma light is transferred by 600 μm quartz fibers about 70 m away from the tokamak to a spectrometer room (low radiation and stable temperature area) where the spectrometers are located.

3. SPECTROMETERS AND CCD DETECTORS

In the spectrometer room the plasma light is coupled to 32 Compact Overview Spectrometers (COS) and one high spectral resolution Echelle Overview Spectrometer (EOS). The COS are mini Czerny-Turner spectrometers with fixed grating and medium spectral resolution, 75 mm AvaBench (model AvaSpec-ULS2048L-USB2-RM with USB2/RS-232 interface, from Avantes). The output spectra from the COS systems are imaged onto 2048-pixel CCD detectors (frame transfer). Four COS spectrometers are mapped to each LOS, by splitting the incoming light from a 600 μm fiber into 4×100μm fibers optimized to the spectrometers entrance slit. For 6 LOS the corresponding COS are equipped with 50μm slits, providing medium spectral resolution. One LOS is coupled to a 100μm slit width system for faster time acquisition, while the divertor LOS is coupled to a higher spectral resolution system, with 25 μm slit width. For each LOS, the overall wavelength range covered by the four COS systems is 380–920nm. The wavelength range 380–635nm is covered by 2400 l/mm grating spectrometers (24 COS), while the 620-920nm range is covered with 830 l/mm grating spectrometers (8 COS). For each JET discharge, each COS is individually configurable with respect to triggering, exposure time and number of spectra acquired. The COS are operated at a typical exposure time of 100 ms for survey (minimum exposure time is 2ms). The data acquisition is automatic, in external sync during each JET discharge. One of the KS8 radial LOS is connected to an Echelle overview spectrometer (Spectrelle 20000p, Systematix and GWU Lasertechnik GmbH cooperation, 110mm focal length). The system provides the simultaneous wavelength range of 365-720nm in cross dispersion, with high spectral resolution (resolving power $\lambda/\Delta\lambda \sim 20{,}000$) and high throughput (F-number of 3.6) over ~45,000 spectral channels. The light is imaged onto a back-illuminated ANDOR iXonEM+CCD, 1024×1024, 13μm2 pixel size (model #DU-888E-C00-#BV). The system is typically operated at the maximum time resolution of 120ms (at 10MHz, 14 bit). A mechanical shutter (Uniblitz LS6T2) has been installed and coupled to the externally triggered frame transfer CCD operation in order to correct for the image smearing induced by the vertical frame transfer of the CCD. The data acquisition is automatic, in external sync during each JET discharge, with both the full 2D images and the reconstructed spectra vs wavelength being recorded (typical JET pulse duration is 30s). The EOS system and its applications will be described in greater detail in a separate paper. The data collected by the COS and EOS systems are then transferred to the memory of Personal Computers (PCs) using dedicated data acquisition software written for the

JET computer system. The PCs are controlled automatically by HTTP commands from a central JET UNIX data acquisition computer over Ethernet connections. Data from each JET discharge are acquired on the PCs and are then automatically archived on the main JET data storage system.

4. ABSOLUTE INTENSITY CALIBRATION

The diagnostic has been absolutely calibrated in situ by means of a radiometric light source placed inside the JET vessel in front of the whole optical path and operated by remote handling [3]. A separate 'ex-vessel' calibration was also performed, with the calibration lamp in front of the optical head and separate measurement of the window transmission, employing a green and a red laser and a retro-reflector positioned by remote handling behind the window inside the JET vessel.

5. RESULTS

The KS8 diagnostic has been operating successfully since the first plasma pulse of the JET experimental campaigns with the ILW, which started in August 2011. It operates routinely in every JET discharge, monitoring photon fluxes from intrinsic impurities, such as Be, C and W and injected gases (N and Ne), molecules (e.g. BeD, D2, ND) and main chamber and divertor recycling (typically $D\alpha$, $D\beta$ and $D\gamma$). Examples of COS spectra from JET discharges are shown in Figure 3. An example of EOS spectrum during the limiter phase of a JET discharge is shown in Figure 4. Time traces of photon fluxes of selected impurity lines measured by COS systems along a LOS to the inner wall during a JET discharge are shown in Figure 5.

CONCLUSIONS

As part of the diagnostic enhancements accompanying the study of the Be/W wall, a new survey, visible spectroscopy diagnostic has been installed and commissioned in JET, employing a series of compact overview spectrometers with medium spectral resolution and a high resolution Echelle overview spectrometer. For each plasma discharge the diagnostic allows monitoring of intrinsic and injected impurities influxes (e.g. Be, C, N, W), molecular fluxes (BeD) and plasma recycling from the JET main chamber and outer divertor target.

ACKNOWLEDGMENTS

This work was supported by EURATOM and carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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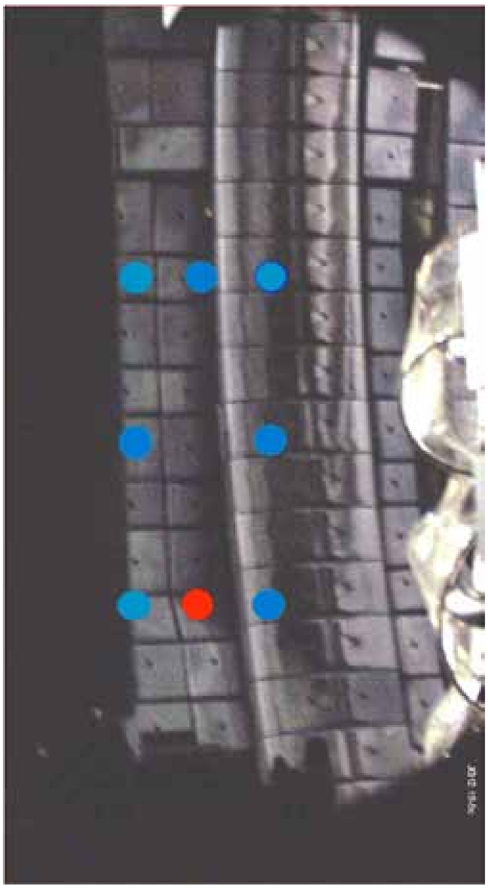

Figure 1: Layout of the 8 radial LOS of the KS8 diagnostic to the JET inner wall neutral beam shine through area (W coated CFC tiles) at Oct 7: 3 LOS viewing the inner wall guard limiter and 5 the inner wall (blue circles represent views coupled to COS, red circle represents a view coupled to EOS).

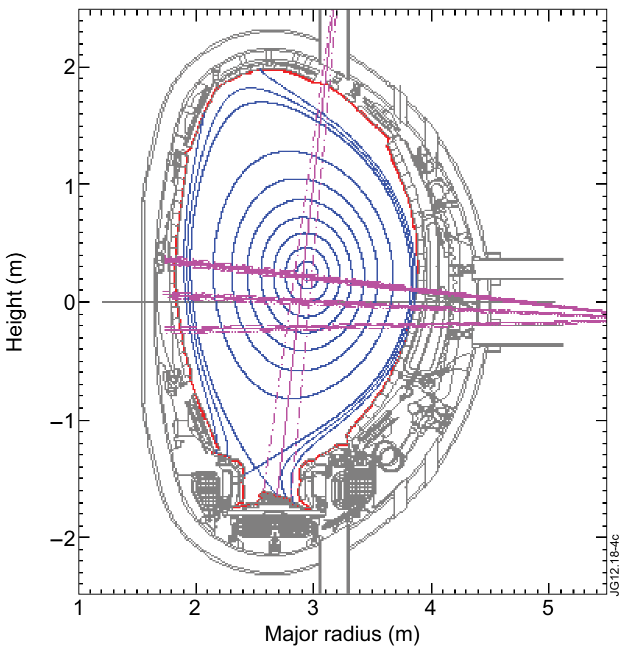

Figure 2: Poloidal cross section of the KS8 viewing geometry.

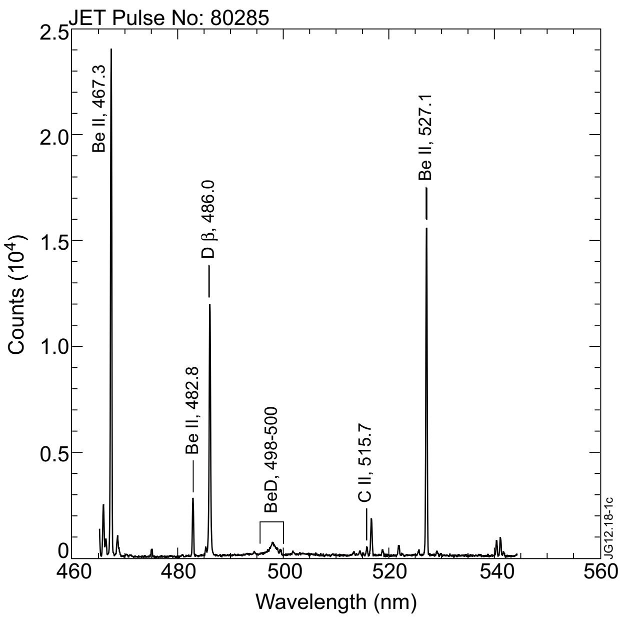

Figure 3: Example of a COS spectrum (inner wall view) from a JET discharge.

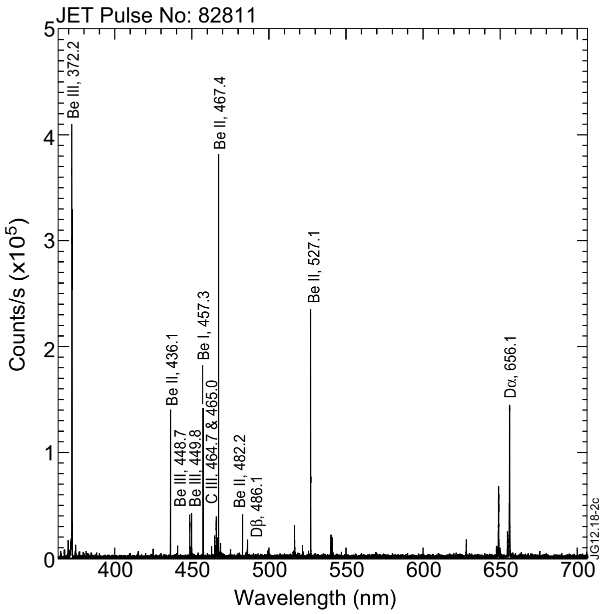

Figure 4: Example of EOS spectrum from the limiter phase of JET Pulse No: 82811 (inner wall view).

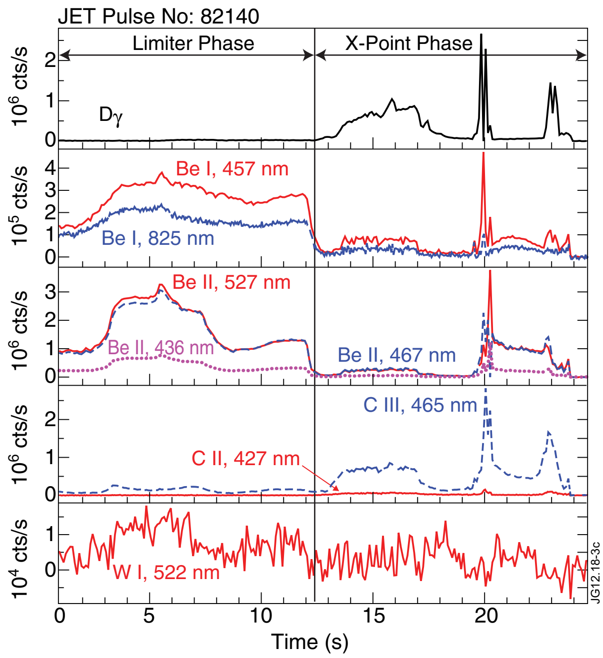

Figure 5: Time traces of line intensities from selected impurities during a JET H-mode discharge, measured by COS systems viewing the inner wall. The transition from limiter to X-point phase is accompanied by a drop in Be emission and an increase in DI and C emission. The WI emission from the recessed tiles is very low and drops below detection level during the X-point phase.