**JET Far Infrared (FIR) Interferometer/Polarimeter Diagnostic System – 40 years of lessons learned**

A.Boboc1 and JET Contributors\*

*1 UKAEA-CCFE, Culham Science Centre, Abingdon, OX14 3DB, UK*

The first-generation burning plasma devices such as ITER, STEP or DEMO will operate in a very challenging environment for diagnostic systems that can be found only to a certain extent in some of the existing fusion devices around the world. Some of these conditions are high ambient temperatures, strong electro-dynamic forces due to high magnetic fields, long pulse lengths and uninterrupted periods of operation and, most notably, very low or zero access to some parts of diagnostics. With that in mind one must develop a system with enough redundancy and robustness to survive the reactor-relevant plasma conditions for many years to come.

Originally designed for five years of plasma operations, the JET Far Infrared (FIR) interferometer/polarimeter diagnostic system is still operating at its full capabilities nearly forty years later and in ITER relevant conditions, albeit with significantly lower neutron fluences and for several D-T campaigns. The original design changed substantially over the years, just to give two examples: the introduction of the divertor significantly reduced access and the number of laser beams; D-T readiness required double vacuum windows that greatly reducing the laser signal level through plasma to 5% but the diagnostic still worked, due to the excellent dynamic range of the detectors.

On JET, complete alignment of the FIR system is required only once in a decade, like the timescale for fusion reactor maintenance shutdowns. The FIR system operates as a hybrid interferometer and polarimeter system, nearly automated, with state of the art electronics for phase counting, improved redundancy in both optical hardware (multiple lasers) and data acquisition and control, real-time integration of measurements with the JET plant (active plasma control and additional heating system interlocks) but also with other physics diagnostics& systems and magnetic reconstruction codes such as EFIT++ are just some of the upgrades and optimisations done in many years.

One notable completed enhancement was the integration and use for polarimetry for real-time plasma density control and machine protection in a fusion plant for the first time. This is being replicated in most of the current FIR developments. Also, during the latest D-T campaign on JET the FIR system was the single point failure device for density control on JET with nearly 100% reliability 16hrs/day, 5 days a week. This presentation will discuss invaluable lessons learned designing, operating, optimising, and enhancing such a complex system and how these can these used for developing the new class of laser-based diagnostics for the next generation reactor grade machines.

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**\*See the author list of ‘Overview of JET results for optimising ITER operation’ by J. Mailloux et al 2022 Nucl. Fusion 62 042026**