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Progress on the Fast Ion Millimetre Wave CTS Diagnostics on TEXTOR and ASDEX Upgrade and status of the CTS design for ITER

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Introduction

One of the biggest challenges in burning plasmas is the understanding of the effects of confined highly non-thermal populations of fast ions originating from fusion processes, ion cyclotron heating, and neutral beam injection. These ions carry a considerable amount of free energy that can be a benefit, but also have undesirable consequences to the plasma. The fast ion collective Thomson scattering (CTS) diagnostic has unique capability of performing spatially, temporarily, and directionally resolved measurements of the fast ion velocity distribution in a given direction determined by the chosen scattering geometry. Currently, two CTS systems are installed, one on TEXTOR (CTS-TEX) in FZ Jülich and another on ASDEX Upgrade (CTS-AUG) in IPP Garching. Detailed description of the systems and their hardware can be found in Ref. 1. Experimental results obtained by the upgraded CTS-TEX have already been reported [2], while the CTS-AUG is ready for operation.

This paper presents progress of the CTS diagnostic systems on the TEXTOR and ASDEX Upgrade tokamaks and preliminary mock-up experiments to support the present design of a fast ion CTS system for ITER (CTS-ITER).

The CTS-TEX and CTS-AUG activities

By utilizing millimetre waves, the collective Thomson scattering diagnostic measures the spectral distribution of resulting radiation from a gyrotron beam passing through the plasma while scattering off collective fluctuations. Important information on the fast ion velocity distribution can be obtained from the scattered spectra.

One of the key parts of the CTS diagnostic system is the mm-wave transmission line, which consists of quasi-optical mirrors, scalar horns, waveguides and polarizing wave-plates. As a first step, a first order alignment of the quasi-optical components is performed using a diode laser. During the machining process of the CTS quasi-optical mirrors, small holes are drilled at the position where the microwave beam centre is incident. Small optical quality metallic pins are inserted in the holes. These are used as reflection points in the first order adjustment throughout the transmission line. However, the microwaves and the laser are not necessarily fully co-linear. Special attention must be paid to misalignment issues, which will decrease the total power of the signal being transmitted by the antenna. This may also generate unwanted high order modes and standing waves in the transmission line. The higher order modes will distort the shape of the transmitted microwave beam, which is initially Gaussian, and create sidelobes. Therefore, it is important to check the beam properties of the transmitted signal in the different sections of the transmission line. For these purposes, two devices: a two-way laser and a mini-rig were constructed at Risø. The mini-rig is a modified standard *XY* plotter, which is equipped with a microwave receiver unit consisting of a sniffer probe, Schottky diode and amplifier. The diode laser is used as a reference to centre points of the adjacent quasi-optical components. The mini-rig is placed in the given beam line section perpendicular to the beam propagation to scan/map out the beam shape/radiation pattern.

Both devices have been successfully used on the CTS systems at ASDEX Upgrade and TEXTOR. In particular, for the CTS-AUG, each beam section was referenced by the two-way laser and then at each section the beam profiles were measured by the mini-rig. Figure 1 illustrates examples of three of the six steps of the CTS alignment process performed using this technique at ASDEX Upgrade. The figure shows the components of the CTS transmission line in the AUG Matching Optics Unit (MOU) #2, namely the CTS horn, the two CTS quasi-optical mirrors, the MOU #2 polarizing plates, coupling mirror, and the waveguide. Radiation is launched through the horn by a Gunn oscillator. The alignment process starts between the horn and the first CTS mirror. The mirror angles are adjusted to match the maximum beam emission to the laser reference. The step marked by 3 was performed at the torus hall and the total throughput after alignment was found to be ~ 85 - 90%

A similar alignment procedure was performed at TEXTOR, and at the end of the alignment procedure the mini-rig was placed inside the tokamak and the beam profile was measured at different spatial locations for a number of launch angles of the CTS mirror 1 (Fig. 2).

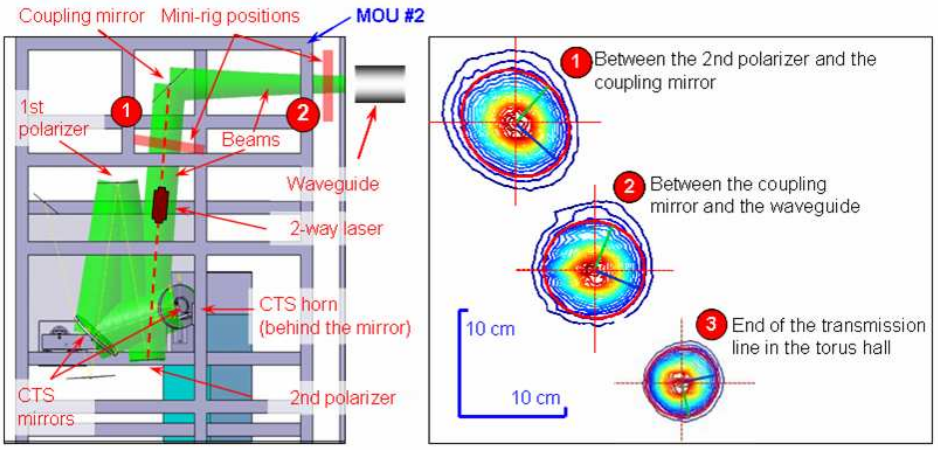

Figure 1. Alignment of the CTS-AUG transmission line by the two-way laser and the mini-rig.

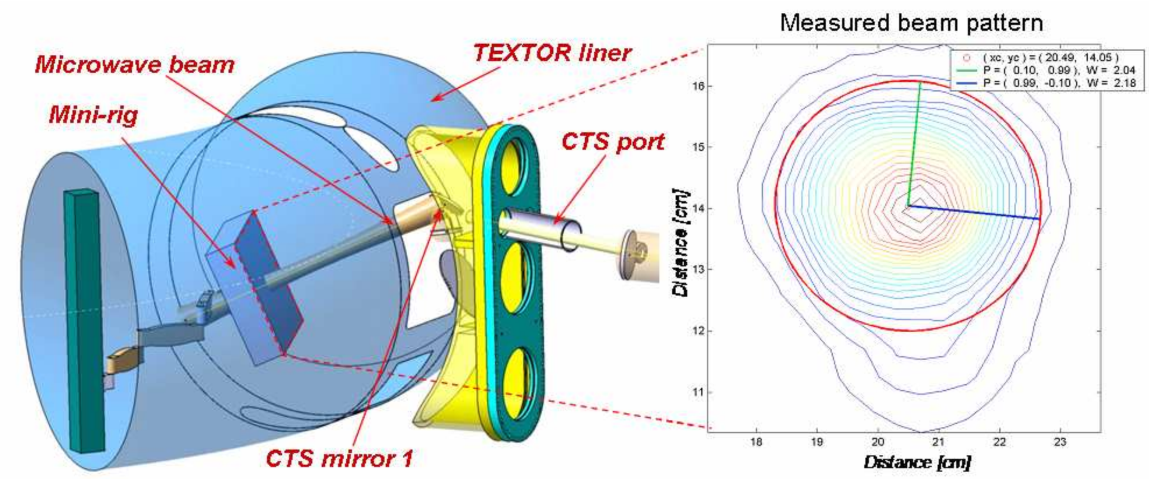

Figure 2. Alignment of the CTS-TEX transmission line.

CTS-ITER preliminary mock-up experiments

Preliminary design of the CTS-ITER system can be found in Ref. 3. The CTS diagnostic for ITER consists of two systems each with a separate ECRH launcher: high field side – forward scattering (HFS-FS) and low field side – back scattering (LFS-BS) systems that measure the fast ion distribution in the direction parallel and perpendicular to the magnetic field, respectively. The front-end components of the HFS-FS system will be mounted on the vacuum vessel behind the blanket modules. It consists of two quasi-optical mirrors, which collect the scattered radiation from the plasma between the blanket modules. The radiation is then coupled to 10 horns, which are distributed toroidally, each representing a different radial position of scattering volumes in the plasma. To ensure sufficient CTS signal, cut-outs in the lower blanket module are needed in the design. To study the radiation pattern between the blankets, a simplified mock-up of the HFS CTS receiver has been constructed at Risø (Fig. 3).

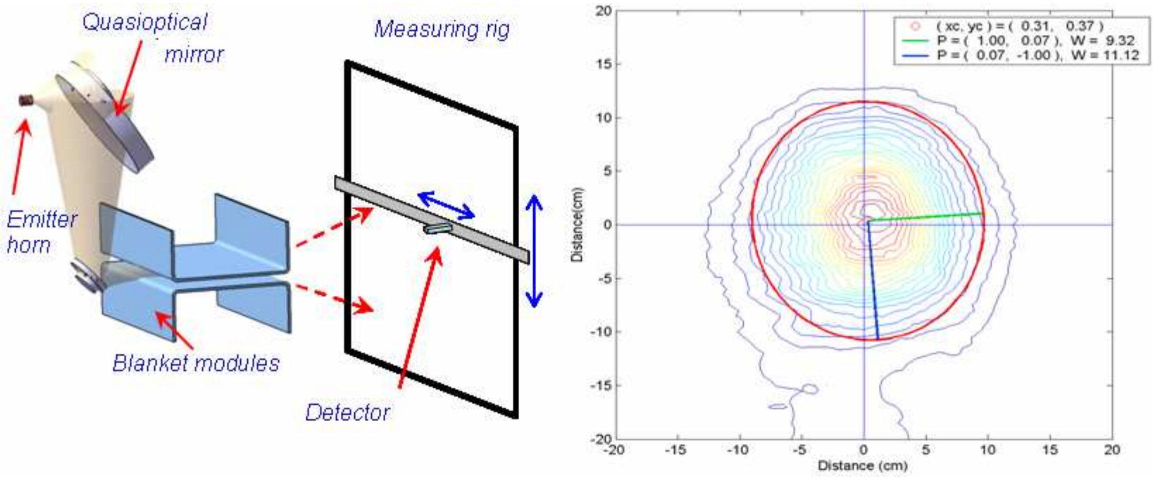

Figure 3. Sketch of the CTS-ITER mock-up to study the properties of the beam transmitted through the gap between blankets, and an example of the measured radiation pattern.

The mock-up experiments have confirmed that the minimum size of the gap in the vertical plane must be no smaller than 30 mm in order to satisfy the measurement criteria of confined fusion alphas, which supports the conclusion from the full wave calculations reported in the ITER feasibility study of CTS on ITER [4]. The mock-up experiments have also established the required horizontal dimensions of the blanket cut-out of 300 mm to accommodate the beam without interference. Moreover, the agreement between the experimentally measured and theoretically found dependence of the beam opening angle [4] on the vertical gap size has been confirmed.

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