

## Commissioning a microwave based Collective Thomson Scattering (CTS) Diagnostic on ASDEX-Upgrade.

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Introduction: The fast ion collective Thomson scattering (CTS) diagnostic installed on ASDEX Upgrade (CTS-AUG) uses mm-waves generated by the newly installed 1 MW dual frequency gyrotron as probing radiation at 105 GHz [1]. The CTS-AUG makes use of one of the ECRH launching systems (gyrotron, transmission line and antenna) as a receiver. The scattered radiation will be intersected by a moveable mirror in the transmission line and redirected to the CTS receiver. It measures back-scattered radiation with a heterodyne receiver having 50 channels to resolve the 1-D velocity distribution of the confined fast ions. The physics feasibility of such a microwave based system has already been described in Refs 1 and 3. The presentation will briefly review the commissioning activities carried out to date which will implicitly describe the prerequisites of a microwave based CTS system.

Receiver tests: The details of the detection system of the CTS on AUG are described in Ref 4. The receiver is equipped with 3 sets of IF amplifier pairs (70 – 80 dB amplification for each frequency band) that need to be robust against gain compression. Gain compression is the reduction in differential or slope gain caused by nonlinearity of the transfer characteristic of the amplifying device. This nonlinearity may be caused by heat due to power dissipation, or by overdriving the active device beyond its linear region. Using a programmable IF source, tests have been carried out to study the IF amplifier characteristics.

In situ transmission line alignment and beam quality: Careful design, construction, alignment and quality assurance of the of the CTS transmission section and its coupling to the ECRH transmission line are important not only to achieve low loss transmission, but also to provide good spatial localisation of the measurement and accurate definition of the location of the movable measurement volume and resolved velocity direction. The first

phase of the alignment process is achieved using a diode laser and mirrors mounted on the quasi optical mirrors. The second phase is alignment using microwaves where a 110 GHz Gunn oscillator is installed in the fundamental waveguide portion of the receiver out through the horn into the transmission line. To measure the beam pattern at different locations in the transmission, a compact 2D scanning rig (micro-rig) equipped with a sniffer probe connected to 110GHz detector diode has been constructed at Risø. This valuable tool enables us to not only to improve the alignment, but also verify the beam quality. A technique has been developed and tested using a two way laser and the micro-rig where each beam segment is aligned. Starting from the horn, the piecewise alignment is done between two components. The two-way laser is used as a reference that connects the geometrical centres of the two mirrors. The laser is then removed and the micro-rig measures the beam pattern in between. The mirror angles are adjusted to match the beam pattern maximum to the laser reference. Figure 1 (right) shows the set-up and two examples of alignment sections; between the second polarizer and the coupling mirror (#1), and between the coupling mirror and the wave guide (#2). To the left of Figure 1 are the beam pattern measurements after the mirrors have been modified to match the laser reference marked by red crosses on the figures. The transmission throughput of the entire transmission (except the in-vessel section) was improved to about 85-90% which is close to the expected theoretical estimates, taking into account the losses in the mitre bends in 70 m of wave guide transmission line. The beam pattern measured at the end of the waveguide transmission line in the torus hall was nearly circular and had no side lobes. Tests have shown that the most sensitive part of the MOU transmission line is the receiver horn position and the mirror coupling the beam to the waveguide shown in Figure 1. To study the effect of the receiver beam in the tokamak by misalignment and astigmatism inside the MOU, the beam pattern was measured inside the ASDEX Upgrade vacuum vessel at different antenna angles using the micro-rig. The measured beam in the vacuum vessel shows no side lobes for all extreme antenna angles settings and the beam width agree well with calculations. After each scan, the sniffer probe mounted on the micro-rig is then moved to the position that corresponds to the peak value of the radiation. A high precision calibrated arm, supplied and operated by IPP engineers, measures the waveguide's global coordinate position, essentially measuring the coordinates of the receiver beam centre at a given distance from the steerable mirror. At each antenna setting, two beam centres were measured at different distances from the steerable mirror, thus creating a vector. A direct comparison of the distance between the microwave and laser

line as a function of the distance from the steerable mirror is shown in Error! Reference source not found. for five extreme antenna angle settings. At the antenna angle corresponding to the blue curve, the measurements were repeated for case when the beam was misaligned and distorted. The beam patterns are shown in the graph inset. The results are shown in the blue dotted and dashed line. These results show that the difference between the microwaves and the laser is less than 2 cm for all antenna angle settings even for marginal cases of misalignment and astigmatism in the MOU. The polarization properties (ellipticity, angle of ellipticity and phase direction) as a function of polarizer settings has been also measured at the end of the transmission line using a device constructed at Risø consisting of an orthogonal pair of fundamental wave guide detector.

ECRH gyrotron study/tailoring: In addition to the gyrotron frequency and polarization, two essential properties need to be studied when using gyrotrons for CTS experiments. The first is the frequency dynamical behavior at different operating scenarios and the second is the mode purity. To block out the gyrotron main line, the CTS-AUG system is equipped with two notch filters each with about 60 dB attenuation and 200 MHz bandwidth. There is a tradeoff between a narrow notch filter to access more information of the bulk ions and the frequency chirp due to thermal effect of the gyrotron resonator and space charge effects during beam voltage ramp-up. Therefore it is essential that the frequency behaviour of the gyrotron is well understood under different operating conditions. A large frequency drift during the measurements will make the CTS analysis more difficult. Experiments to measure the gyrotron frequency of the Odyssey #2 were done where stray radiation was collected from a pick-off horn/waveguide installed in MOU box. The signal was heterodyning down using a harmonic mixer/oscilloscope set-up. Results have shown a frequency drift for every ramp phase of more than 400 MHz and there is strong evidence of an efficient cooling of the resonator. The second prerequisite is mode purity. A gyrotron spectrum free of spurious modes is essential in the CTS experiments. Any spurious modes that appear outside the notch, even 100 dB down from the main gyro line, will corrupt the CTS signal. Experiments have been carried out to measure stray radiation launched power into the main load and into the ASDEX upgrade vacuum vessel. The stray radiation is measured by the CTS receiver and results show no spurious modes.

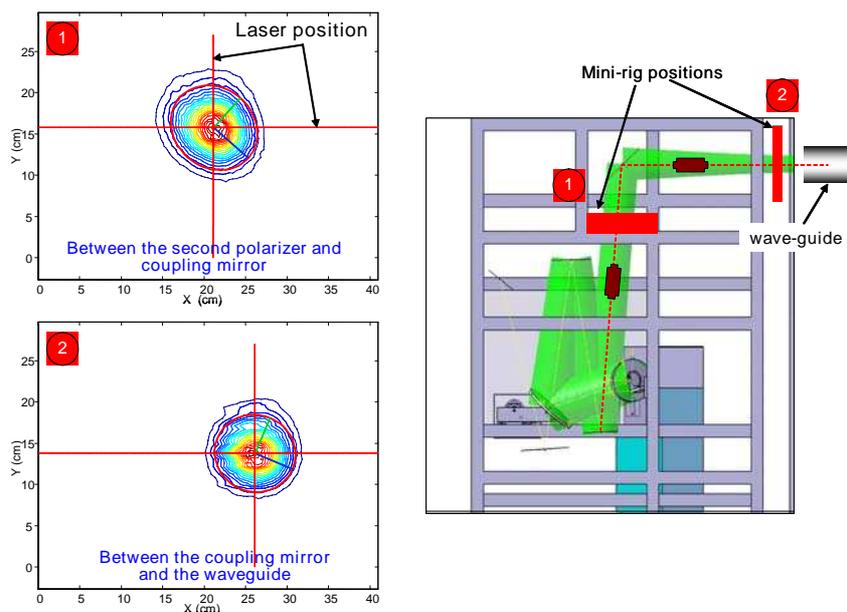


Figure 1. The piecewise alignment process. The left two graphs show the beam pattern measured at the corresponding sections in the ECRH MOU box transmission line shown on the right. The cross hairs are the laser reference position from the two-way laser that connects the geometrical centers of two mirrors.

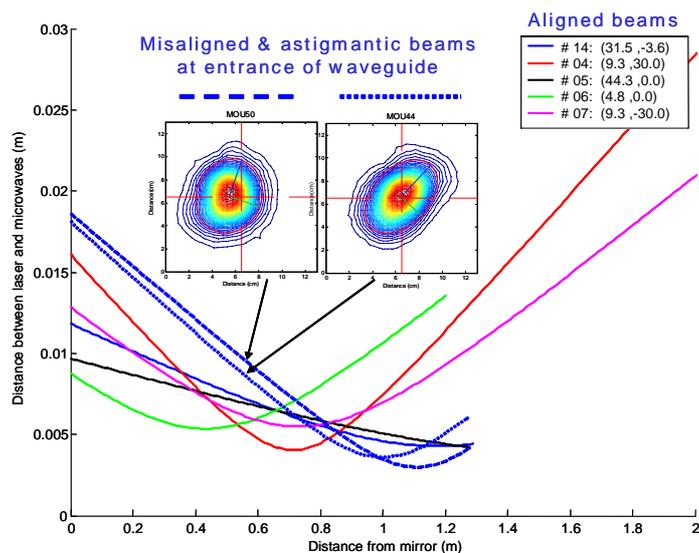


Figure 2. The distance between the measured laser and the microwave line as a function of distance from the steerable mirror. The line colors corresponds to different antenna settings. The solid lines are “aligned” cases. The insets are the “misaligned” beam pattern entering the waveguide at the MOU. The dashed line is the case where the beam at the waveguide in MOU is misaligned by 0.5 cm. The dotted is the case one of the CTS mirrors causing a slight beam astigmatism.

References

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