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Fast Ion Collective Thomson Scattering Diagnostic for ITER

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Abstract. An integrated detailed design of a Collective Thomson Scattering (CTS) diagnostic system for measuring the distribution of fast ions in ITER has been performed. The system is based on two high power probe beams with a frequency of 60 GHz and two receiver systems. This system is able to fulfill the requirements for measuring the fast ion distribution from 100 keV to 3.5 MeV with a time resolution of 100 ns and a spatial resolution of 1/10 of the minor radius.

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INTRODUCTION

Collective Thomson Scattering (CTS) using millimeter waves measures the frequency distribution of radiation scattered from a gyrotron beam passing through the plasma. From the measured spectrum it is possible to deduce the velocity distribution of fast ions. On the receiver side the CTS diagnostic resembles ece diagnostic, and can be used for ece measurements. Fast ion CTS diagnostics are operational at TEXTOR and installed at ASDEX Upgrade. A detailed integrated design for a fast ion CTS diagnostic on ITER has recently been completed [1]. This system is based on an earlier feasibility study and conceptual design [2]. The feasibility study concluded that a system based on a probe frequency in the 60 GHz range is able to fulfill the requirements for measuring the fast ion distribution from 100 keV to 3.5 MeV with a time resolution of 100 ns and a spatial resolution of 1/10 of the minor radius. The system consists of two launching antennae placed in a port plug on the low field side (LFS) and two receiver systems, one on the LFS for measuring the fast ion velocity component in the direction perpendicular to the magnetic field, and one on the high field side (HFS) for measuring the fast ion velocity component in the direction parallel to the magnetic field. In developing the design, several engineering constraints have to be satisfied. In order to find suitable solutions for the HFS antenna system, a simple mock-up model was constructed in order to estimate the necessary size of the blanket slot, which the receiver beams have to pass. A numerical model has also been pursued; however only approximated solution can be found because the total system is too large for a full wave numerical solution.

FAST ION CTS DIAGNOSTIC

In a fusion plasma there will be fast ions from the fusion processes, and from heating by ICRH and NBI. The fast ions have highly non-thermal population with energies from 0.1-5 MeV, and although their density may be low they may carry 1/3 of the plasma kinetic energy. The fast ions are nearly invisible to scattering, but their wakes in the electron distribution are the dominant cause of microscopic fluctuations at scales larger than the Debye length. By measuring the fluctuation spectrum by collective Thomson scattering it is therefore possible to deduce the fast ion distribution function. With two measuring systems the velocity components can be measured in two directions, i.e. parallel and perpendicular to the magnetic field. The system designed for ITER envisages 2×10 receiver beams giving the fast ion distribution function in 10 positions.

Detailed integrated design

As a first step to the design probe and receiver beams and their overlaps have been calculated. The Gaussian beams are represented by a bundle of rays consisting of 5 independent rays; the beam centre and 4 rays, each at one Gaussian half width from the centre. With these 5 rays the refraction of a Gaussian beam is modelled. Figure 1 shows the beam dimensions of the receiver and probe, respectively.

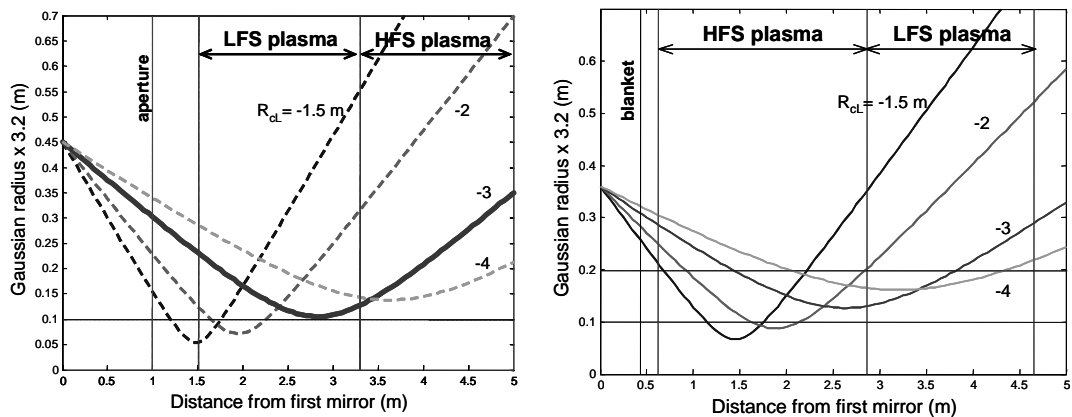


FIGURE 1. Beam diameters as function of distance from mirror for different radii of curvature. Left: For the HFS receiver beam. Right: For the HFS probe beam.

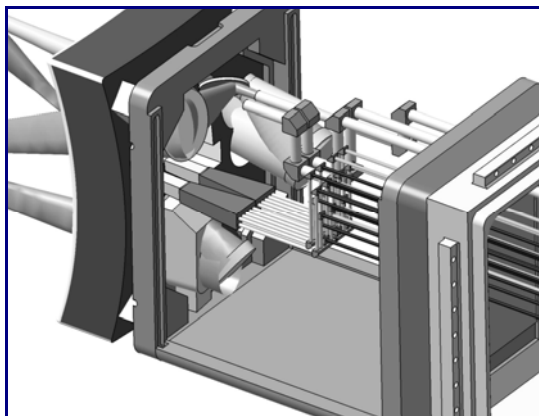


FIGURE 2. View of the CTS system in an ITER port plug.

On the LFS the two probe launchers and the LFS receiver are placed in an ITER port plug (#12) shown in Fig. 2. The blanket is not shown and the plug front plate outer frame has been made transparent.

On the HFS the antenna system consists of two mirrors and up to 10 microwave horns. This system is located behind the blanket modules, with the signal passing from the plasma through a cut-out in a blanket module to the first mirror. The horizontal and vertical dimensions of the first mirror are limited by the space available between the cooling manifolds and the space between blanket module key and the earth-strap mounting block, respectively. The largest integration issue is the size of the vertical gap between the blankets where the receiver is viewing. Presently the vertical gap in the ITER design is 10 mm. According to the feasibility report [2], the vertical gap should be no less than 30 mm in order to satisfy the measurement requirements. With the extra spacing, there is the concern of the extra local increase of neutron flux on two of the 18 TF coils affected. To reduce this effect the 30 mm gap has been reduced to produce a “slot” with the same height. The horizontal dimension of this slot has been chosen to accommodate the full beam diameter of all beams measuring the different locations in the plasma.

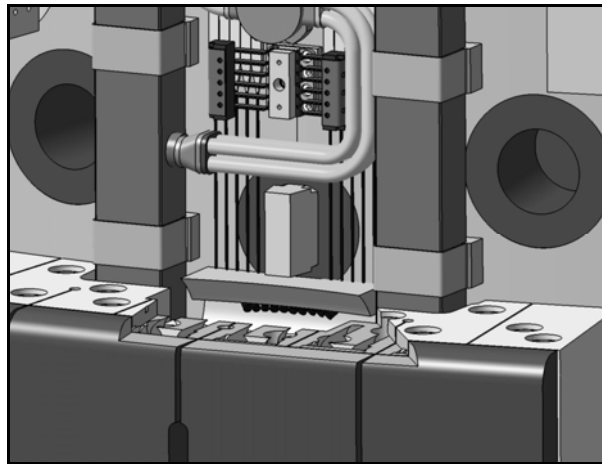


FIGURE 3. View of the high field side CTS receiver system.

The receiver front end on the HFS is shown in Fig.3. For illustrative purposes, the upper blanket and the cooling manifold are not shown. The front end is a complete unit consisting of two mirrors and a series of horn encased beneath the second mirror. The unit is mounted on the vacuum vessel and will be independent from the blanket modules. The unit is cooled by the vacuum vessel wall through conduction. The depth of the unit is about 200 mm. The horns are distributed toroidally, each representing a different toroidal angular view in the plasma. Each horn will be located at the waist of each beam. The distance between the scattered volumes and the first mirror ranges from about 2 to 3 m and the angular range is about 30 degrees. Hence in order to fit 10 horns (the beam waists) a two-mirror approach has been chosen.

Mock-up model

In order to experimentally investigate the effect of the cut-out dimension on the microwave beam propagation, a simplified mock-up of the ITER blanket module and the CTS HFS antenna system was made.

From the practical point of view, we have investigated beam dimensions independently by two separate experiments under the condition that the beams are purely radial, i.e. perpendicular to the blankets' surface. Two sets of mirror pairs for the mock-up system have been designed to reproduce separately the vertical and horizontal properties of one of the beams that measures the centre of the plasma. Figure 4 shows a 3D picture of the simulated transmission lines, the blanket models and examples of measured radiation patterns.

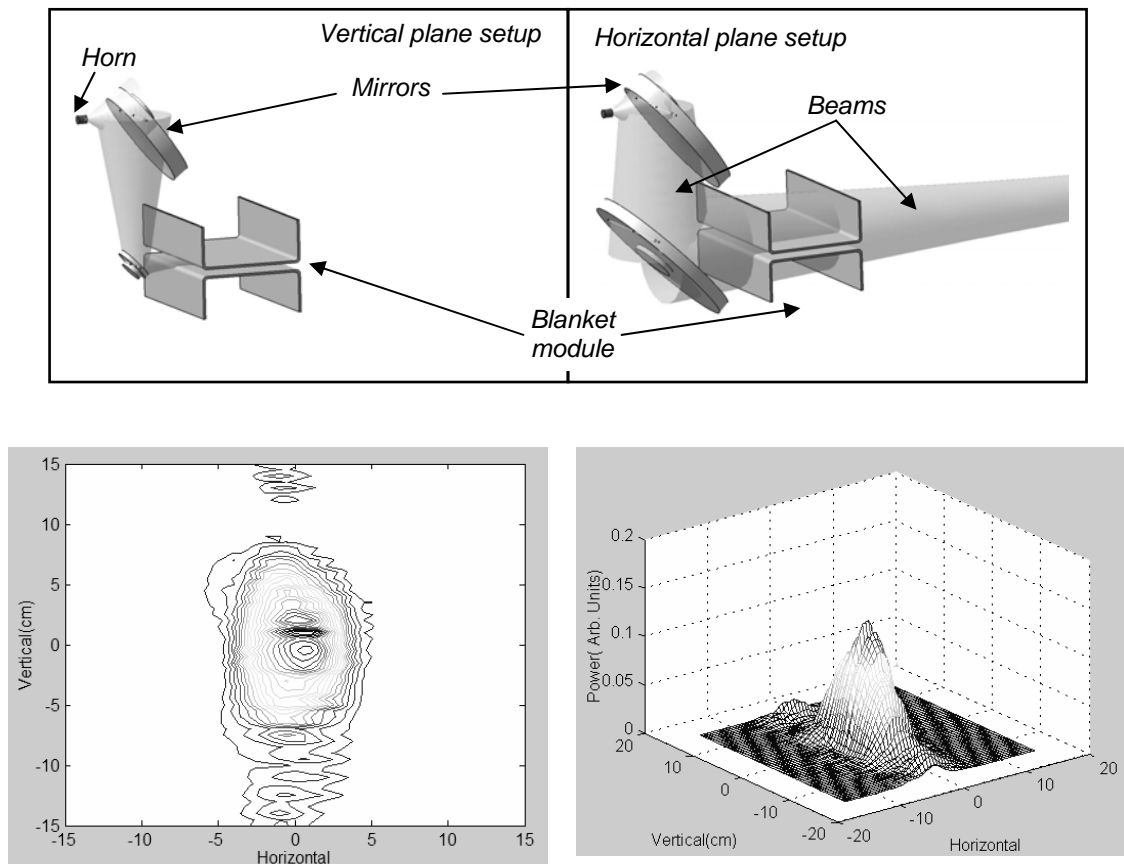


FIGURE 4. Sketch of the Risoe CTS mock-up and examples of measured radiation pattern.

The mock-up experiment has shown that in order to transmit the microwave beam (with the parameters required by the CTS ITER HFS receiver) through the ITER blanket module, the horizontal cut in the lower blanket should be at least the same size as the beam diameter. Therefore, incorporating the Gaussian beams in the HFS receiver CATIA model has concluded that for a series of 10 beams in an angular range (7 – 37 degrees), the cut-out should not be smaller than the one shown in Fig. 3. The experiments have also confirmed the opening angle as a function of vertical gap from the full wave calculations in the feasibility studies. Therefore, we have shown experimentally that a vertical gap of 30 mm is the minimum value whereby the beam diverging angle is small enough to satisfy the measurement criteria concluded from the feasibility report.

Numerical calculations

To support the measurements a finite difference scheme solving the wave equations in the frequency domain, a so-called FDFD was developed. However, the system is very large relative to the wavelength, and an intractably large number of nodes in the finite difference grid is needed for a full 3D simulation. Assuming no variations of the cut-out in the horizontal direction the problem can be decomposed into a series of tractable 2D problems. An example of the total energy flux is shown in Fig. 5 for two cases: The incident Gaussian beam has a beam waist at the right side of the gap entrance. The width of the blanket is reduced. The one to the left has a blanket slit of 6 wavelengths and the one to the right a blanket slit of 2.8 wavelengths. With a slit height of less than 6 wavelengths it seems that the Gaussian beam is strongly distorted.

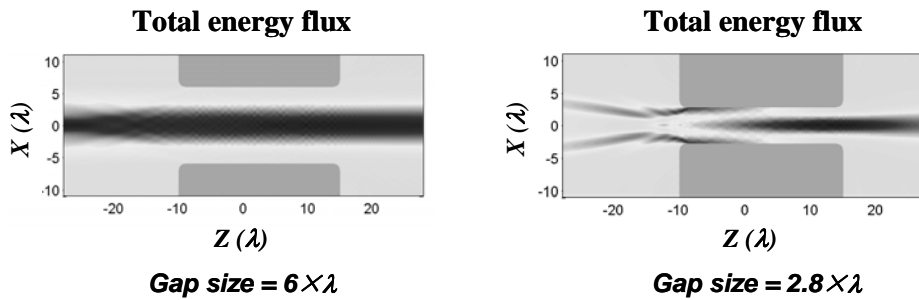


FIGURE 5. An example of the receiver beam passing the blanket slit. Height of slit: Left: 6 wavelengths, Right: 2.8 wavelengths.

CONCLUSION

This paper is a mainly a short review of the work described in [1]: an integrated detailed design of a CTS diagnostic for ITER, which fulfils the ITER specifications for measuring fast ions. The work has shown that it is possible to accommodate an antenna system on the HFS, and that it is possible to transmit an adequate signal to the antennae.

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REFERENCES

1. H. Bindslev, A. W. Larsen, F. Meo, P. K. Michelsen, S. Michelsen, A. H. Nielsen, S. Nimb, E. Tsakadze, Detailed integrated design of the collective Thomson scattering (CTS) system for ITER (EFDA Contract 04-1213)
2. H. Bindslev, F. Meo, S. Korsholm, ITER Fast Ion Collective Thomson Scattering, Feasibility study and Conceptual design of 60 GHz system (EFDA Contract 01.654)