A Broadband Quasi-Optical Collection System for the JET Heterodyne Radiometer

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A multi-channel, fixed frequency heterodyne radiometer, operating inthe radiation frequency range 73GHz to 127GHz, is used for electroncyclotron emission measurements on the JET tokamak {1}. In a tokamak,the spatial variation of the magnetic field in the plasma provides the means by which spatially resolved measurements of theeission can be made {2}. To obtain well localised measurements, it isnecessary to minimise the volume over which the measured emission is averaged. The spatial resolution along the line of sight is determined by the spectral resolution of the radiometer which, in the case of the JET radiometer, is 500 MHz. This corresponds to a spatial resolution of ≈20.mm. The spatial resolution transverse to the line of sight is determined by the antenna pattern of the collection system. At present a waveguide system is used and this has a spot size of ≈20 mm at the plasma centre. A quasi-optical system which will be used to improve this is under construction and is described in this paper.

The quasi-optical system has been designed to satisfy certain criteria. It must operate over a wide bandwidth; the bandwidth of the radiometer has been increased to cover 73GHz to 139GHz. It must transmit two orthogonal, linear polarisations with minimal cross-polar scattering because the radiometer measures the intensity of both polarisations independently. The double vacuum window through which the plasma is viewed has a diameter of ≈65mm which means that the beam radius, at the vacuum window, has to be ≈16.mm. In addition, the beam has to couple efficiently to oversized waveguide which is used to transport the radiation along a tortuous path, ≈40m long to the radiometer.

Figure 1 shows schematically the quasi-optical collection system. Radiation from the plasma is reflected by the two off-axis mirrors and, after passing through the vacuum window, arrives at the first aperture of a 'back-to-back' corrugated horn {3}. After traversing the horn,the radiation, in a fundamental Gaussian beam, is coupled into oversized waveguide.

The 'back-to-back' horn is formed by two corrugated tapers connected by a short section of corrugated circular guide. The fundamental Gaussian component of the incident field excites the HE11 mode which propagates down the horn structure. The short circular guide, acting as a mode filter, ensures that only the HE11 mode can propagate through the horn and defines the antenna pattern of both the receive and transmit ends. As the back-to-back horn is axially symmetric it transmits orthogonal polarisations of the incident field identically. The antenna pattern of such a horn has been measured and satisfactorily approximates a fundamental Gaussian beam. Side lobes in the antenna pattern were not observed above the noise floor of the measurement which was 24dB below the power in the central peak. Cross-polar mode conversion was also not detectable at this level.

To meet the requirement of a small waist at the vacuum window, the 'back-to-back' horn is mounted directly behind the window and the collection mirrors in the vacuum vessel. The mirrors are limited in size by adjacent components. The smallest waist that can be produced in the plasma is 40mm, at a distance of 2.5m from the paraboloidal collection mirror.The cross-polar power loss and the higher order mode loss for each mirror has been reduced as far as possible. The combined power loss due to these effects is estimated to be less than -24dB for each mirror.

The quartz discs, which form the vacuum window, are tilted to reduce channel fringing in each window and in the gap between them. They are tilted at equal and opposite angles so that the beam remains on axis after traversing the window. Residual channel fringing will occur in each window and may cause the transmission of the double vacuum window to be strongly frequency dependent. Methods are being explored to reduce this effect (see Hughes et al this conference).

Two different ways of coupling the quasi-optical beam into the oversized waveguide are being examined. The first is to illuminate the mouth of the waveguide directly from the scalar feed. Coupling in this case {4} may be poor, ≈0.6, but it can be applied with minimal technical problems in this situation. The second technique is to focus the beam to form a waist at the mouth of the guide using a third mirror {5} as shown in Figure 1. Coupling should be higher in this case, ≥0.9, across the whole bandwidth. However, limited access may prevent the use of this arrangement.

Experiments are in progress to determine the best method for coupling the beam to the oversized waveguide and to verify the performance of the system as a whole.

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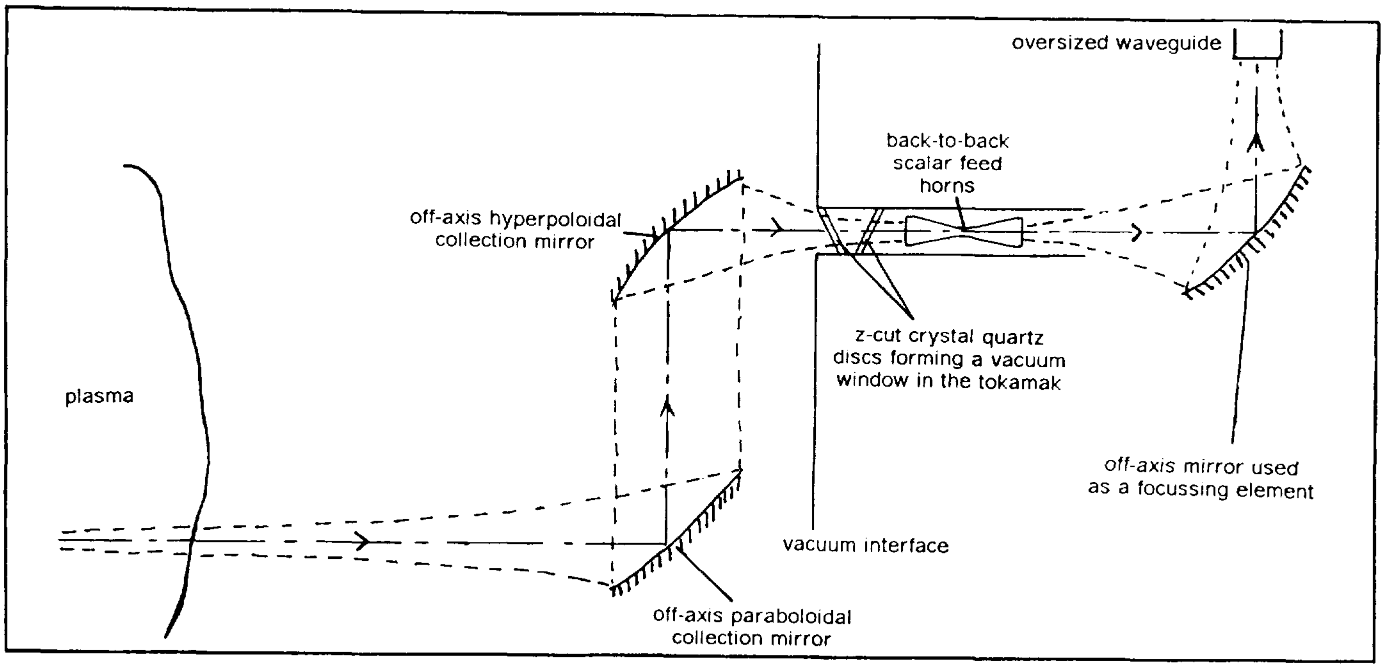

Figure 1: The Collection System for the JET Electron Cyclotron Emission Radiometer