§11. Application of Millimeter Wave Technology to Plasmas

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The objective is to discuss an ongoing R&D of heating technology by millimeter wave at the domestic institutions and the related international progress with collaborators who engage in the study using gyrotrons, klystrons, free-electron lasers, and REBs. In the workshop, we focused the program with special subject and reviewed to increase the mutual understanding.

In the present workshop, the subject on a remote steering antenna (Fig.1) as topics was discussed. Drs. W. Kasparek, K. Sakamoto and K. Ohkubo lectured from the viewpoint of low and high power tests and theoretical consideration on the subject.

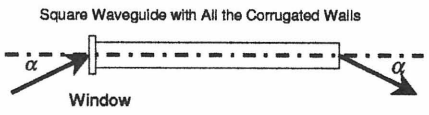

Fig. 1: The remote steering antenna

W. Kasparek reported "Activities at IPF in High-Power Millimeter Wave Transmission for Electron Cyclotron Heating Systems". At the Institut fuer Plasmaforschung, University of Stuttgart, research on high-power millimetre wave transmission is going on. Several transmission systems have been built, which are used for electron cyclotron heating (ECRH) of the stellarator W7-AS and the tokamak ASDEX-Upgrade at IPP Garching. New developments include the quasi-optical 140 GHz/10 MW system built up for the new stellarator W7-X as well as investigations of a remote steering antenna for ECRH and ECCD on ITER. The talk gave an overview on these activities and concentrated on the new developments. The philosophy of the quasi-optical transmission system for W7-X was given, and the design of the multi-beam waveguides and the mirrors was described. For ITER, calculations and experiments on a remote steering antenna based on imaging properties of square corrugated waveguides was discussed in detail.

K. Sakamoto reported "High Power Experiment of Remote Steerable Launcher". High power radiation experiments of a remote steering launcher for a 170GHz electron cyclotron heating and current drive system was carried out. The remote steering launcher consists of a 4.5 m corrugated square waveguide (45×45 mm^2) and a movable mirror which was placed at inlet side of the waveguide. The rf beam radiation in the steering direction was performed at the steering angle of 0-10deg. The radiation field pattern was the clear gaussian-like distribution at 0-10deg, which agreed well with the result from the low power experiments and the calculations. Up to now, the rf transmission of 0.5MW-0.2sec was successfully demonstrated in the range of the steering angle, 0-10deg without breakdown in vacuum. The calorimetric measurement showed that the rf transmission loss in the launcher was less than 2 %.

K.Ohkubo presented "Analysis of Hybrid Modes in a Square Corrugated Waveguide for a Remote Steering Antenna". By using two scalar eigenfunctions, electric and magnetic fields in the rectangular (or square) corrugated waveguide are analyzed. In a rectangular corrugated waveguide, the boundary conditions on two corrugated and two smooth walls can be satisfied to excite the hybrid mode. In a highly oversized waveguide where the wavelength of dominant mode is close to that in vacuum, two smooth walls can be exchanged with the corrugated walls because the boundary condition at this walls is satisfied approximately. The replacement is possible due to almost no penetration of the electromagnetic fields into the gap of the replaced walls when the direction of main electric field is parallel to the gap of replaced walls. This characteristic enables us to rotate the polarization of the hybrid mode in the oversized square waveguide with all four corrugated walls and is applicable to the remote steering antenna for electron cyclotron heating in the ITER.

The discussion in the workshop is fruitful and continuation of the workshop was reconfirmed.

Reference

1) K.Ohkubo: IRMMW **22**,(2001) 1709.