§2. Propagating Mode Analysis and Field Reconstruction in the Corrugated Waveguides of ECH System

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New method are proposed to analyze mode contents of high power electromagnetic waves that are propagating through corrugated waveguide in the electron cyclotron resonance heating (ECH) system for nuclear fusion devices. The method was applied to a 168GHz transmission line of the ECH system in Large Helical Device (LHD) to evaluate the waveguide misalignment. Mode contents of the propagating wave could be well obtained, and the wave field in the waveguide was reconstructed by using the information of each mode.

ECH is one of the most powerful heating methods for plasma heating and current drive in fusion-oriented plasma devices. The high power millimeter-waves for ECH are usually transmitted by over-sized circular corrugated waveguides. The length of such transmission lines becomes longer and longer due to the huge size of plasma confinement devices. In the over-sized corrugated waveguides, tilt and offset of the waveguide axis easily cause conversion of the transmitted mode of HE_{11} to unwanted modes. Improvement of transmission efficiency is essential in view not only of increase of usable power but reduction of heat load to the millimeter-wave components.

We already proposed an alignment method of transmission lines based on infrared (IR) images on a target irradiated by high power millimeter-waves[1)]. As a next step, it is important to identify propagating mode contents in the corrugated waveguides for clarifying what kind of misalignment induces such mode conversion.

In the process of designing phase correcting mirrors and performing waveguide alignment, the phase retrieval method was successfully used to reconstruct the phase information of the radiated waves by using only measured intensity profiles at several positions[2)]. By using the phase retrieval method, we can find the complex amplitude at radiating edge of the corrugated waveguide. It can be decomposed by the eigen modes in the corrugated waveguide. The expansion coefficients by the eigen modes give the mode contents of the corresponding eigen modes.

This method was applied to the 168 GHz transmission line in the ECH system of LHD. Figure 1 shows measured amplitude and retrieved phase at the radiating edge of the circular corrugated waveguide. This information was used for mode-contents analysis. Figure 2 shows the mode contents for the orthogonal even- and odd-modes in the corrugated waveguide. HE_{11} main propagating mode dominates 89 % and the other spurious modes are HE_{21}/1.1 %, HE_{12}/0.9 % (even-mode) and HE_{21}/5.4 % (odd-mode). These results suggest that there is a mismatch between the incident angle of millimeter-waves and waveguide axis and/or tilt of waveguide axis.

On the contrary, the electromagnetic field in the waveguide can be reconstructed by the expansion coefficients of these modes and can be pursued along the guide. This will help to clarify the possible causes of the generation of unwanted modes.

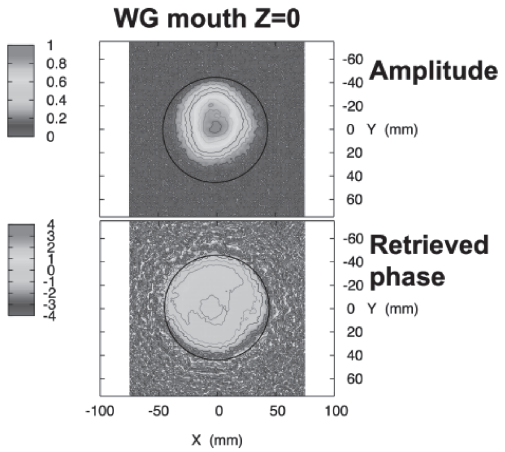

Fig. 1: Measured amplitude and retrieved phase at the radiating edge of the corrugated waveguide.

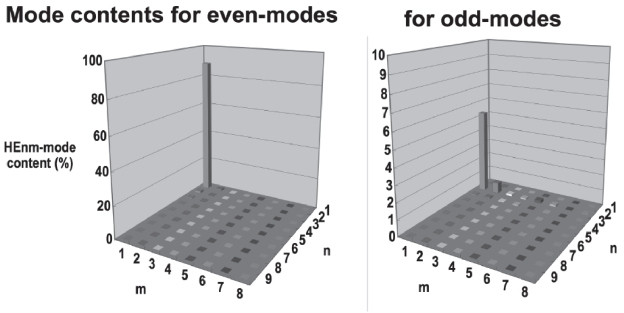

Fig. 2: Results of mode contents analysis for even and odd modes in the corrugated waveguide.

1) T. Shimozuma, H. Idei, M. Shapiro, R. J. Temkin et al., J. of Plasma and Fusion Research Vol.81, No.3, 2005, pp191-196.
2) M. A. Shapiro, T. S. Chu, D. R. Denison et al., Fusion Eng. and Design, Vol. 53, 2001, pp537-544.