§5. Evaluation of Transmission-Line Components Based on Phase Measurements in mm-Wave Frequencies

Idei, H. (Kyushu Univ.), Shapiro, M.A., Temkin, R.J. (MIT), Shimozuma, T., Kubo, S., Yoshimura, Y., Igami, H.

Electron Cyclotron Heating (ECH) using high power millimeter waves is an attractive method for plasma production, auxiliary heating, and current drive in a nuclear fusion research. A Gaussian beam from a high power gyrotron oscillator is coupled into oversized circular corrugated waveguides in the ECH system, which is transmitted to the launcher using the HE_{11} mode of the waveguide. To obtain high transmission efficiency in the waveguide, the beam center-position and tilt in the coupling into the waveguide line should be aligned within tolerable limits to provide coupling into the HE_{11} mode from the Gaussian beam. The offset or tilted injection excites unwanted coupling higher modes, which cause high transmission losses and arcing events in the high power transmission. The analysis of the mode content transmitted in the waveguide is a key issue to study how to attain the high coupling and transmission efficiencies. In last year , an approach to analyze the mode content in the waveguide was proposed for the low power experiments where precise direct phase measurements are available. The mode content of the propagating waveguide-modes was evaluated using the irradiant waveguide modes in the radiated field. In this method, the phase retrieval process was not required. In the high power application, the direct phase measurements are not available. In this study, the mode content is directly retrieved from the amplitude profiles along the propagation.

A Gaussian beam is prepared to inject to a 1m long corrugated waveguide with a diameter of 88.9mm. This injected beam is tilted by 1 degree with respect to the waveguide z-axis in the x-direction. The electric field is in y-direction, in perpendicular to the tilted x-z plane. Here, the wave frequency of the beam is 84 GHz. In the tilted injection, the unwanted modes are excited. The distorted intensity profiles are measured at the several propagation-position along the z-axis. Figure 1 shows the intensity x-y profile measured at z =150 mm. The intensity profile is mainly deformed in the x-direction. The irradiant waveguide mode Φ_{mn} are calculated by the Kirchhoff integral in the paraxial approximation. Figure 2 shows the intensity and phase profiles of the Φ_{21} mode in x-direction at y=0 cut. There is a phase jump in -/+ x direction. The beam center offset comes from the interference between the Φ_{11} and Φ_{21} modes. The beam size is affected by the interference mainly between the Φ_{11} and Φ_{1n} modes. The complex fraction for the Φ_{21} mode in mode expansion is initially assumed for the beam-offset to be explained. The complex fractions of the Φ_{11} , Φ_{21} and Φ_{12} modes are retrieved in an iteration process where the amplitude profile reconstructed from the complex fractions matches with the measured one. Figure 3 shows evolutions of the complex fractions C_{mn} along the iteration in a case of z=150mm. The relative difference ε between the measured and reconstructed amplitude profiles is also plotted in the figure. Figures 4 and 5 show the measured and reconstructed amplitude profiles at z=150 and 200 mm. The reconstructed profiles are well coincided with the measured profiles. The mode content of HE_{mn} is analyzed from the retrieved complex fraction C_{mn}. The mode content retrieved from the measured amplitude profile is 0.67, 0.13 and 0.05 for the Φ_{11} , Φ_{21} and Φ_{12} modes at z=150mm. The obtained mode content has an excellent agreement with the previous mode content analysis using both the measured amplitude and phase profiles. The mode content or complex fraction retrieved from the measured profile at z= 150mm is slightly different for those from the profile at z= 200mm. More various modes in the amplitude profiles along the propagation should be included with consistency in the analyses.

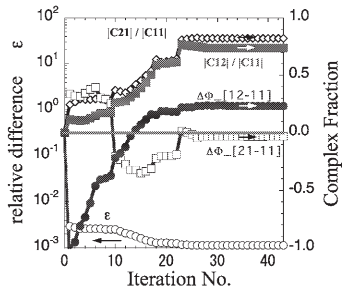


Fig.3. Relative difference and complex fractions in the iteration process.

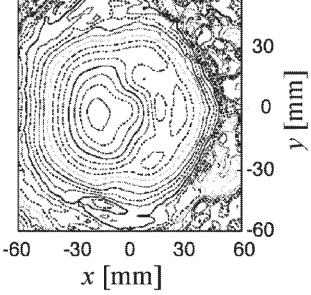


Fig.1. Intensity profile at z= 150mm in the tilted injection.

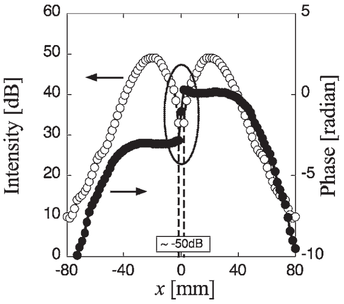
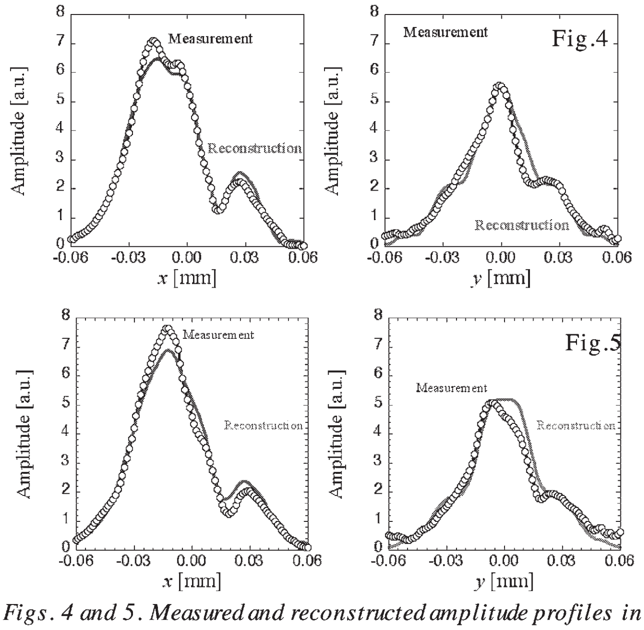


Fig.2. Intensity and phase profiles of an irradiant Φ_{21} WG mode.



Figs. 4 and 5. Measured and reconstructed amplitude profiles in the x- and y-directions at z= 150 and 200 mm.