§2. Field Reconstruction in the Corrugated Waveguide Based on Mode-Content Analysis

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A mode-content analysis is extensively performed for high power electromagnetic waves propagating in the corrugated waveguide of the LHD ECH system[1]. The flow of the mode-content analysis is overviewed as follows. At first, a target plate, which is set at a position several tens of centimeters apart from the open edge of the corrugated waveguide, is irradiated by high power millimeter waves. The temperature rise of the target plate is recorded by an IR camera with high precision at several target positions. Then, the phase information is retrieved by the phase retrieval method[2]. Once the information of the amplitude and phase at the exit of the waveguide is determined, the mode content can be analyzed by an orthogonal-mode expansion in the corrugated waveguide[1].

As a next step, we can reconstruct the electric field in the waveguide up to its entrance using the obtained expansion coefficients and the phase factor of each constituent mode. The obtained information will be useful to determine the cause of the misalignment between the electromagnetic wave and the corrugated waveguide. The configuration is shown in Fig.1. At the waveguide

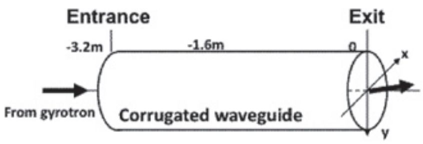

Fig. 1: Configuration of the field reconstruction.

exit (z=0), the phase can be retrieved by the phase retrieval method. Such amplitude $A(x, y, 0)$ and phase $\varphi(x, y, 0)$ can be expanded by the orthogonal functions in the waveguide as,

$$A(x, y, 0)e^{j\varphi(x,y,0)} = \sum_{n=1}^{N} C_n e^{j\varphi_n} \phi_n(x, y), \qquad (1)$$

where C_n is the amplitude and φ_n is the phase of a mode n. On the contrary, the electromagnetic field at the arbitrary position, z, in the waveguide can be reconstructed using the expansion coefficients of each eigenmode, $C_n e^{j\varphi_n}$, and the propagation phase factor, $e^{(-j\beta_n z)}$, where β_n is the propagation constant of the mode n in the z-direction.

Figure 2 shows an example of the contour plots of the amplitude in a) and phase profiles in b) of the reconstructed field. The peak position in the amplitude profile at $z = -1.6$m moves slightly in the $-y$-direction. This is due to the existence of the unwanted mode, HE_{21} (odd-mode). The phase profile, however, keeps almost uniform along the waveguide axis.

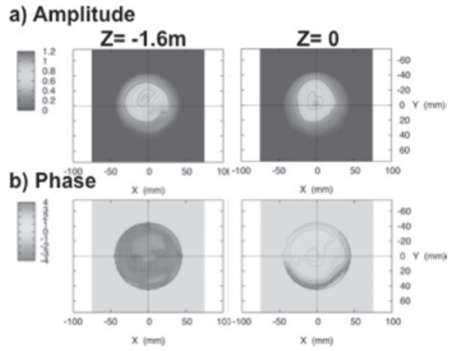

Fig. 2: The reconstructed a) amplitude and b) phase.

In general, the n-th moment in the x-direction weighted by the intensity $A(x, y, z)^2$ can be defined as,

$$< x^n > (z) = \int x^n A^2(x, y, z)\mathrm{d}x\mathrm{d}y / \int A^2(x, y, z)\mathrm{d}x\mathrm{d}y. \qquad (2)$$

As a representative of the power density center, the first moment was calculated. The results are shown in Fig. 3.

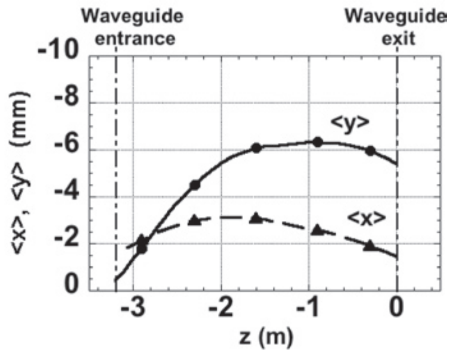

Fig. 3: The first moment of the intensity profiles shown in Fig.2

Because the beat wavelength between the main mode HE_{11} and HE_{21}, which is the most dominant mode among the unwanted modes, is about 9.8m, the calculated result shows the periodic change of the first moment $< y >$ whose period coincides with about a beat wavelength. This suggests that the burn-pattern measurement should be performed, for example, at several positions separated by less than a quarter beat wavelength between the main mode and unwanted modes.

1) T. Shimozuma, *at al.*, Proceedings on 33rd International Conference on Infrared, Millimeter, and Terahertz Waves, 2008, R5D38.

2) M. A. Shapiro, T. S. Chu, D. R. Denison et al., Fusion Eng. and Design, Vol. 53, 2001, pp537-544.