§10. Quasi-Optical Analysis of Output Beam from Remote Steering Antenna

Idei, H. (Kyushu Univ.), Shimozuma, T., Notake, T.
Kubo, S., Zushi, H. (Kyushu Univ.)

A remote steering antenna system is considered as the upper port launcher at International Thermonuclear Experimental Reactor (ITER) for Electron Cyclotron Heating / Current Drive (ECH/ECCD), in order to avoid an installation of plasma-facing movable mirrors. The well-defined Gaussian output beam is required in a steering capability of ± 10.5 degrees. Asymmetric direction antennas in the steering angles of ± 12 degrees have been tested at low and high power levels in relation to the ITER application. A full-scale mock-up of the upper-port launcher is being designed and constructed for the low and high power tests.

A symmetric direction antenna with extended steering capability was prepared to the ECH/ECCD experiments on the TRIAM-1M tokamak in Kyushu University. The TRIAM-1M tokamak has super-conducting magnet coils to generate the high field up to 8T. In the tokamak, there is a long distance between the plasma and the device port, and is not enough space for a mirror array to be installed in the vessel, due to the large bell jar for the magnets. Fundamental ECH and ECCD at the ITER frequency from the low field can be experimentally tested using the developed antenna system in the tokamak. A remote-steering antenna system for a large experimental device is newly being developed under the collaboration between National Institute for Fusion Science (NIFS) and Kyushu University. The output baem of the antenna prepared for the TRIAM-1M experiments is analyzed, based on moment and matching coefficient methods [1]. This work is partly done under the collaboration between NIFS and Kyushu University, to evaluate output beams from remote steering antennas in detail.

Figure 1 shows intensity and phase profiles in the x direction of the E_y component in the output beam at propagation position $z = 65$mm in the 15 degree steering case, which are measured at a low power level. The detector stage or the measuring z axis is rotated in the steering $x-z$ plane corresponding to the incident steering angle. The intensity profile is Gaussian-like beam of $w_x = 11$mm, however, there is a side lobe. The phase profile is parabolic with a phase curvature of $R_x = 218$mm in the main lobe. The phase rapidly changes near the side lobe, therefore, the side lobe part is spread out from the main lobe along the propagation. First this output beam from the antenna is analyzed by the moment theory of quasi-optical beams. Here, the n-th moment is defined with the amplitude distribution $A(x, y)$ as,

$$< x^n >= \int x^n A^2 \mathrm{d}x\mathrm{d}y \ / \int A^2 \mathrm{d}x\mathrm{d}y. \qquad (1)$$

The first moment $< x >$ expresses the beam center position in the x direction. The first moment $< x >$ of the beam in shown Fig.1 is evaluated as 8mm from the intensity profile. The evolution of the beam center position along the propagating can be written in terms of the moment theory by using the phase distribution $\Phi(x, y)$ as the following,

$$< x(z) >=< x(0) > -z\frac{\int A^2(\partial\Phi/\partial x)\mathrm{d}x\mathrm{d}y}{k\int A^2\mathrm{d}x\mathrm{d}y}, \qquad (2)$$

where k is the wave number of the propagating beam. The integrated coefficient of z in Eq.2 expresses a slope of the propagating axis. The tilt angle of the slope is evaluated as -0.2 degrees in this case. The phase profile is flat near the beam center. The beam propagates along the measuring z-axis. The propagating angle of the beam corresponds to the steering angle as designed. Secondly, the Gaussian content of the beam is evaluated from a matching coefficient defined as,

$$\left|\int fg^*\mathrm{d}x\mathrm{d}y\right|^2 \left(\int |f|^2\mathrm{d}x\mathrm{d}y \cdot \int |g|^2\mathrm{d}x\mathrm{d}y\right)^{-1}, \qquad (3)$$

where f and g are the complex amplitudes. Here, the complex amplitudes, f and g, are evaluated from the intensity and phase distributions of the fitted Gaussian beam and of the measured profiles, respectively. The Gaussian content is evaluated as 0.85 for the output beam. The well-defined Gaussian beam with a correct steering angle is obtained, although there is the beam center offset of 8mm. This antenna is successfully used to the ECH/ECCD experiments on the TRIAM-1M tokamak.

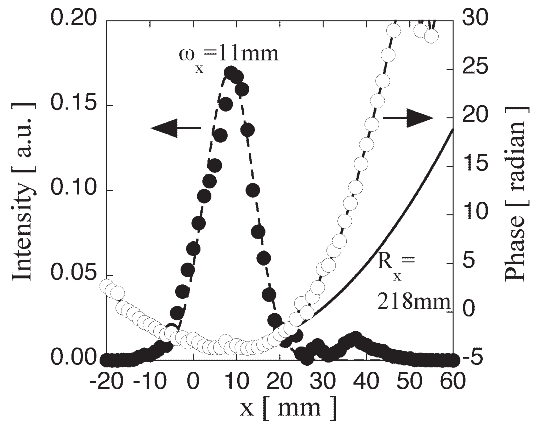

Fig. 1: Intensity and phase profiles in x-direction of the E_y component in the 15 degree steering case.

References

[1]H. Idei. *et al.*, Journal of Plasma and Fusion Research **81** No.3, 186 (2005).