§18. Development of CW High Power Transmission Line Components

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The development of the high power, and long pulse millimeter wave transmission component is inevitable for the high temperature steady state plasma confinement experiment in the LHD. In order to accommodate high power of the order of 1 MW, long pulse or CW transmission with high reliability, the evacuation of the system and the developments of the corresponding components are necessary. Due to the successful development and the simultaneous operation of the three 1MW, 77 GHz gyrotrons, total injected power of ECRH into LHD exceeded 3.7 MW in FY2010. Three corrugated 3.5 inch waveguide transmission lines have been already evacuated using several developed components so far. These experiences are utilized to develop corrugated waveguide components with other inner diameter.

Design and fabrication of miter bend and power monitor for an evacuated corrugated waveguide of several inner diameters

Evacuated corrugated waveguide system is now widely used and planned to apply JT-60SA and ITER ECRH system, but with several waveguide and corrugation parameters. We have developed general design and fabrication method of miter bend for each system. In FY2011, a new power monitor including its miter bend block for 88.9 mm inner diameter waveguide system are designed and fabricated for 154 GHz which will be used for LHD and the new high power gyrotron will be delivered within FY2011. This design is based on the fabrication and test experiences of 88.9 mm waveguide system which are used without any problems up to 1.8 MW, 1.0 s at 77 GHz in LHD.

Transmission mode analysis using burn pattern

Minimizing the transmission loss of the corrugated waveguide system is important for the stable and reliable transmission of high power millimeter waves as well as transmitting with high efficiency. The optimizing the coupling of the gyrotron output to the corrugated waveguide system is crucial to excite as higher purity of HE_{11} mode as possible. The compact diagnostics of the mode purity and utilizing such diagnostics to optimize the coupling are required. So far, the modes inside the waveguide system has been analyzed utilizing infrared images on the target planes placed at several distances radiated by a high power millimeter wave from the end of waveguide. A special phase retrieval technique was developed for this purpose. These analyses is sensitive to the power fraction away from the central axis which is small in the power density but may be appreciable in total fraction. The method has been further refined from FY2010. A set of linear polarized modes which is more suitable for describing the transmission modes coupled from the gyrotron output, since the gyrotron output is linearly polarized. The method is to deduce the contents of transmission modes from several burn patterns in the waveguide. These burn patterns are used to retrieve the power ratio and phase differences of undesired modes to a main $LP_{01}(HE_{11})$ mode. This method utilizes the linearity and orthogonality of each mode inside the waveguide. The great merit of this method is that the power flux going through each plane can be assumed to be conserved and resultant burn pattern can be reproduced using relatively few modes near fundamental one. Based on the orthogonality of waveguide modes, the amplitude fractions and the phase differences are adjusted to reproduce the observed burn patterns. It is also investigated how resolution of the measured burn pattern affects the accuracy of the deduced mode contents and phase difference. The resolution is one of the key parameters for the observation as well as the analysis. Original observed data is the burn pattern, but due to the inhomogeneity of the paper surface, material or wetness the fine structure are not necessarily reflects the mode amplitude there. Fig. 1 shows the observed burn pattern with artificially degraded resolution and the result of analysis using the analysis. This method is also shown to be applicable to infer the amount of miss alignment at the waveguide inlet by deducing the mode contents and phase differences at the beam-waveguide interface.

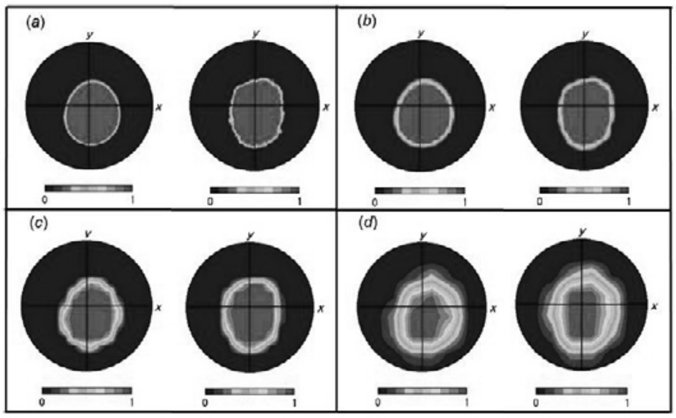

Fig. 1: Optimized theoretical (left) and observed (right) burn patterns with $z=10$ m for various resolution number M. Here, (a) $M = 64$, (b) $M = 32$, (c) $M = 16$ and (d) $M = 8$.