§25. Development of Vacuum Corrugated 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 FY2010, a new power monitor including its miter bend block for 60.3 mm inner diameter waveguide system are designed and fabricated for 170 GHz which is under consideration for use on JT-60 SA. 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 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[1]. Newly developed method is to take burn patterns of the waveguide ends by adding 1 m waveguide one bye one. These burn patterns are used to retrieve the power ratio and phase differences of undesired modes to a main 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. Fig.1 a) show original burn patterns taken at the end of 8 to 12 meters waveguide. Each pattern is taken by adding 1 m waveguide one bye one from 8 m waveguide that is coupled to the gyrotron output. In order to digitize in space of the original data these pattern is segmented in 32 32 mesh(Fig.1b)). FIg.1c) and d) show the calculated pattern at each corresponding measured point assuming optimal mode mixture and phase differences of three higher modes (HE_{21}, HE_{12} and HE_{31}) other than main mode. Here, Fig.1 c) are 3-D display and d) are contour display with 16 16 mesh. The optimal power fraction of the modes were, in this case, $HE_{21,co}$ 4%, $EH_{12,cross}$ 3%, $EH_{12,co}$ 1%、HE_{31} 0.2%. The dependence of the stability or confidence of the retrieved power fraction on the mesh number, fineness of the gray scale and number or distances of burn patterns taken are under study.

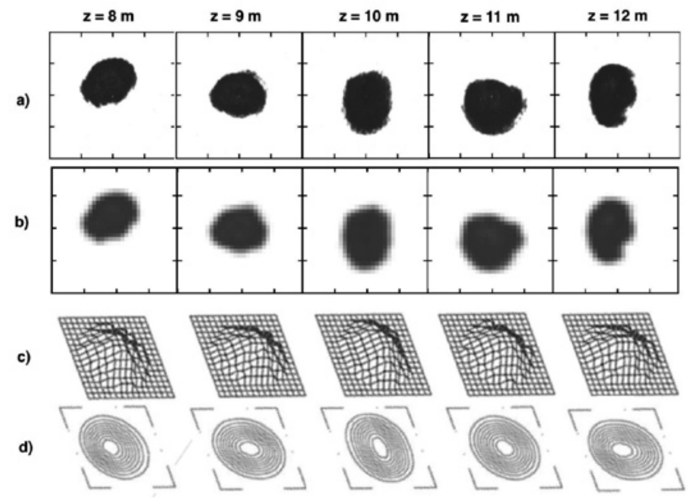

Fig. 1: a) Burn pattern taken at several waveguide ends at 8 to 12 by 1m away from the waveguide coupling point from gyrotron. b) Digitized pattern with 32x32 mesh of above original pattern. c) 3D display of the retrieved patterns for optimal ratios and phase differences assuming given three modes (HE_{21}, EH_{12} and HE_{31}) other than the main mode (HE_{11}). d) Contour plots of c).

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