§15. Development of CW High Power Transmission Line Component

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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, 77 GHz and one 154 GHz 1MW gyrotrons, total injected power of ECRH into LHD exceeded 5.4 MW in FY2014. Five 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. 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. Miter bend blocks for 63.5 and 60.3 mm inner diameter corrugated waveguide systems are designed and fabricated for 28, 70, 170 GHz. Those for 70 and 170 GHz systems includes power monitor sub-waveguide embedded in the reflecting mirrors. One of them is already applied successfully in Heliotron-J and the other is under high-power test in JT-60SA.

A set of new antenna system for 77 GHz and 154 GHz is added at 2-O port and two corrugated waveguide lines which had been connected to 9.5U port are extended to be connected fully utilizing the method developed under this collaboration.

A new type power power/polarization monitor which can pick-up both P and S components simultaneously has been developed and installed on the active transmission system of ECRH system in LHD, as one of the applications of such development this fiscal year.

Demonstration of real-time power/polarization monitor

The polarization detection is enabled by separating picked-up wave to P and S-components and heterodyne detected by harmonic mixers for both polarization with common local oscillator composed of voltage controlled oscillator (VCO). The IF signals from both polarizations are directly digitized by a 2-channel Fast A/D converter with FPGA[1]. The data is Fourier transformed to deduce each intensity and phase difference between them. The block diagram of the detection scheme is shown in Fig.1.

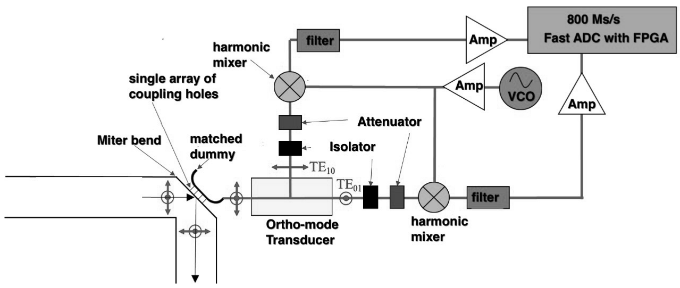

Fig. 1: Schematic diagram of a developed polarization monitor.

The capability of separating P and S component and deducing the phase difference between them so as finally derive the polarization state of the transmitted to wave inside the corrugated waveguide is demonstrated in the polarization scan in the high power transmission line in LHD at the frequency of 77 GHz. in Fig. 2.

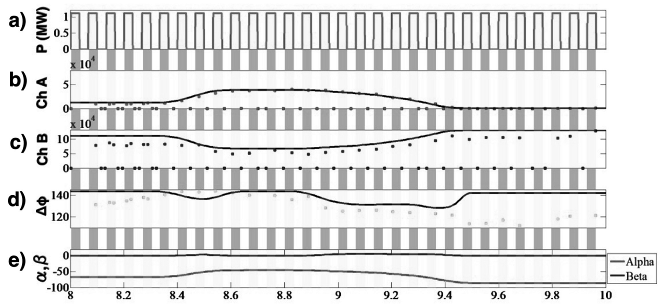

Fig. 2: Example of detected signals from polarization monitor during polarization scan experiment. a) Power monitored. The power is 100% modulated with 15 Hz. b),c) Detected intensity of P- and S- linear components (dots) and those expected from the polarization change as indicated in e). d) Phase difference between S- and P- linear polarization components (dots) and that expected from the polarization change as indicated in e). e) α and β expected from the movement of the polarizers using the analytical model. The direction of linear polarization is scanned (α scan with β =0) for this shot. The intensity and phase differences in b),c) and d) are analyzed from FFT the data of the time span of 2^{16} points taken by a fast A/D converter with 800 Ms/s. Time interval of each time span is determined by the data transfer rate between A/D converter and the time for FFT analysis in the workstation.

1) R. Makino, S. Kubo, K. Kobayashi, S. Kobayashi, T. Shimozuma, Y. Yoshimura, H. Igami, H. Takahashi and T. Mutoh, REVIEW OF SCIENTIFIC INSTRUMENTS **85** (2014) 11D831.