§4. 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 be applied to JT-60SA and ITER ECRH system, with individual waveguide and corrugation parameters. We have developed general design and fabrication method of miter bend. The miter bend blocks for 63.5 and 60.3 mm inner diameter corrugated waveguide systems are designed and fabricated for QUEST 28 GHz, Heliotron-J 70 GHz, and JT-60SA 110/140GHz systems.

The low loss polarizer mirror set is designed for QUEST 28 GHz system and the polarization setting program routinely utilized in LHD is extended incorporated with the QUEST antenna and transmission configuration.

The development of 28 GHz polarizer miter bend and extension of polarization setting program

New polarizers with optimized groove shape and minimized ohmic loss are designed and fabricated for QUEST 28 GHz 1MW system[1)]. In order to realize optimum heating and current drive the optimum injection the polarization which is dependent on the plasma parameters and injection angle and peripheral plasma density. The program which determine the combination of the setting angles of $\lambda/4$ and $\lambda/8$ polarizers was developed utilizing a similar program routinely used for LHD. The original program used for LHD needs the configuration of the transmission line. Here configuration includes the relative setting angle of miter bends, antenna mirrors and injection angle as well as positions and characteristics of $\lambda/4$ and $\lambda/8$ polarizer. In Figure 1 are shown the realized polarization state defined by α (angle of long axis of polarization ellipse relative to mid-plane of Quest) and β (ellipticity $= \tan\beta$, $\pm$ defines right/left rotation seen from propagation direction) for the polarizer setting angles of (ϕ_1, ϕ_2)

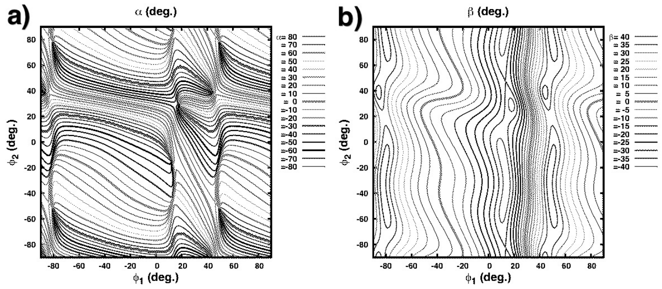

Fig. 1: a)α and b) β contour plot on (ϕ_1,ϕ_2), here ϕ_1 and ϕ_2 are setting angles of $\lambda/8$ and $\lambda/4$ polarizer, respectively.

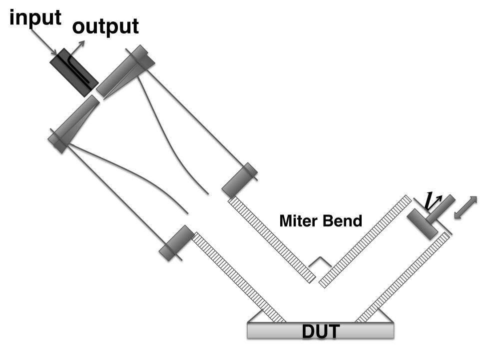

Fig. 2: Schematic diagram of a miter bend cavity.

Development of cavity type loss measurement system of miter bend

The losses of a miter bend of corrugated waveguide include polarization dependent ohmic loss, mode conversion loss. The precise estimation and separation of ohmic loss and mode conversion loss are generally hard to measure, since they are so small in one reflection and normally below estimation error. Quasi-optical cavity has been utilized to estimate the ohmic loss of mirror surface. An new idea is to form a cavity with the miter bend itself and estimate losses by the cavity quality factor through scanning the input frequency or the cavity length as shown in Fig. 2. Utilizing the difference of the propagation constant of eigen modes in a corrugated waveguide, Ohmic loss of each mode and even mode conversion coefficient can be estimated by this method using flat mirror as DUT. Furthermore, if corrugated polarizer plate is used as DUT, polarization dependent losses would also be measured.

1) Ii, T., *et al.*: Rev. Sci. Instrum. **86** (2015) 023502. and Tsujimura, T. I. *et al.*: NIFS Annual Report 2015-2016.