

§15. 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, 77 GHz and one 154 GHz 1MW gyrotrons, total injected power of ECRH into LHD exceeded 4.6 MW in FY2013. 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. 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.

Development of Real-Time power/polarization monitor

These power monitors are basically for the use of one particular linear polarization which is determined by the relation between the coupling holes and aligning side of the sub-waveguide embedded in the miter bend mirror. A new type of power/polarization monitor is started to be developed from the necessity to monitor and control the polarization state of the injected power to optimize the heating efficiency in LHD.

Once the high power real time polarization monitor had been realized in LHD system¹⁾. In that system, two independent sub-waveguides with two different coupling hole array are used to pick up the independent components in P and S linear polarizations in the high power corrugated waveguide side. The picked up P and S components are compared with each other to deduce the power ratio and phase difference those determine the polarization state in the corrugated waveguide. Microwave components of fundamental waveguide are used to analyze the phase difference and power ratio of each

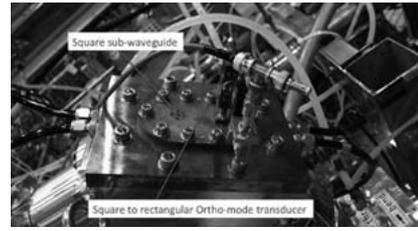


Fig. 1: Modified 1-row multi-hole power square sub-waveguide coupler

picked-up components. In order to realize the two row multi-holes in the central region of the miter bend mirror, small row of holes with $(2m+1)\lambda_g/4$ distance each other are placed in two rows. Due to the recent high power operation of the transmission line, we found a trace of arcing between the row of holes and furthermore after long pulse operation the part is damaged mainly due to a low cooling capability.

New design adapts a square cross-section sub-waveguide to pick-up and transmit both P and S polarization component simultaneously with one row of coupling holes. These two components are separated by a ortho-mode transducer which is also developed in LHD. The capability of separating P and S component is demonstrated in the polarization scan in the high power transmission line in LHD at the frequency of 77 GHz. The new system installed on one of the miter bend of 77 GHz high-power transmission line is shown in Fig. 1. Analyzing the polarization need to detect the power ratio and phase difference between P and S components. The combination of scalar horn antenna and down converting the linear independent modes by harmonic mixers and IQ demodulator are already realized in the low power²⁾ systems, but due to the limitation of the circuit used, uncertainty in the sign of the phase difference remained. In order to resolve this point and moreover, for the future extension, a set of fast digitizers with the sampling rate of 1 GHz and field programmable gate array (FPGA) is applied for the IF signal process after the harmonic mixers as shown in Fig. 2. Preliminary test using the real high power system shows that this method, picking-up two polarization in squared waveguide and analyzing phase and power difference of P and S polarization is promising.

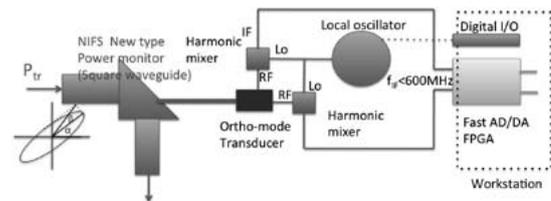


Fig. 2: Block diagram of the polarization monitor

- 1) T. Notake *et al.* Review of Scientific Instruments, **76** (2005) 023504.
- 2) T. Shimosuma *et al.* Journal of Microwave Power and Electromagnetic Energy, Vol. **43** (2009) 60.