§3. 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 MW in FY2009. Three corrugated 3.5 inch waveguide transmission lines have been already evacuated using several developed components so far. In FY2009, a new power monitor working at more than 1 MW power level and corrugated waveguide switch with cooling channel are developed and used without any problem up to 1.6 MW, 0.5 s.

Improvement of the power monitor for more than 1 MW power level

The power monitor with in-situ sub rectangular waveguide in the miter bend reflector has been developed and used in the LHD transmission system. An aluminum plate had been traditionally used for the reflector, due to it's machinability. During more than 1 MW operation, one of the aluminum plate got a damage due to a thermal stress. The coupling holes that connects the surface of the mirror to the in-situ sub- rectangular waveguide are placed near the reflector mirror center where the power density is highest, but the cooling channel can not be made near by from the structural limitation. The material of this reflector was replaced by a copper as shown in Fig. 1. The loss power at the surface is decreased due to its higher electrical conductivity and the cooling efficiency is increased due to its higher thermal conductivity. The new power monitor is now gives reliable signal under the transmission power of more than 1 MW, 1 s may be due to the much reduced temperature rise near the coupling holes.

Design and fabrication of an evacuated corrugated waveguide switch for high-power and CW operation

A corrugated waveguide switch is composed of a moving block and its vacuum chamber with three waveguide ports. The moving block is formed by the jointed straight waveguide section and miter bend section. This moving block slides inside the chamber back and forth to connect straight ports or perpendicular ports. In order to use this switch under high power and long pulse condition, the chamber should be evacuated and the moving block have to be cooled by water, in particular, the miter bend reflector inside the vacuum chamber.

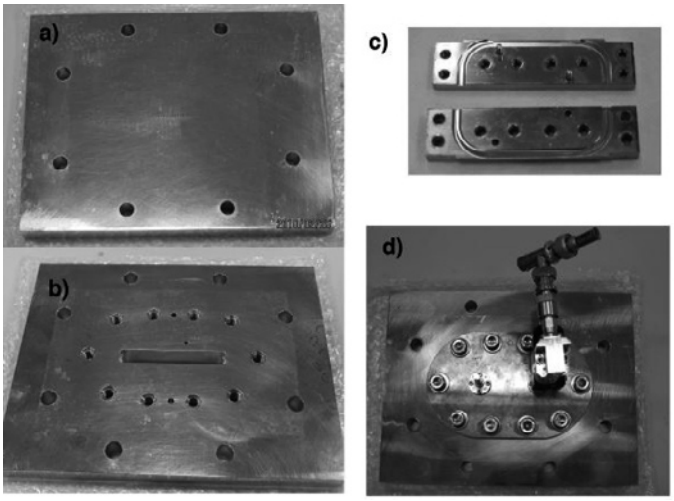

Fig. 1: Photos of the improved power monitor, a) surface with multi hole array at center, b) backside with insert trench for sub-waveguide of the miter bend reflector, c) waeguide inserts and d) the outlook assembled as a power monitor.

Such waveguide switch is needed in the transmission line in LHD, especially when the gyrotron is under long pulse conditioning but also routinely used for the plasma experiment. When the transmission line is connected to LHD, the straight section of the moving block is normally used and the loss of this straight block is negligible small. While the transmission line is connected to the dummy load, the miter bend section of the moving block is used, and the reflecting mirror of the miter bend have to be cooled in the vacuum condition. The moving block itself is machined from aluminum and the miter bend reflector is made by copper-stainless steel jointed plate with copper side as a reflector. In order to introduce inlet and outlet of the water cooling channels to the moving miter bend reflector, co-axial stainless pipe are used. This switch can be remotely driven by a pneumatic valve and an actuator. O-rings are used to seal this water-pipe and the actuator rod. The vacuum level in the waveguide switch reached as low as 1×10^{-3} Pa. This waveguide switch worked well without any problems for both straight and miter bend sides up to the power level of 1 MW, 5 s or 0.3 MW few minutes operation.