§4. Development of a Forced Air-cooled Brewster Windows for High-power CW Millimeter Waves

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High power over 1MW and CW (Continuous Waves) millimeter wave injection is required for electron cyclotron heating in LHD. One of the critical issues is to realize a vacuum barrier window. From a viewpoint of high power windows, the Brewster window has a lot of merits. It has an effectively large area and the power density of an injected RF beam can be reduced by several times. Being different from normally-injected resonant windows, the thickness of the Brewster window can be selected freely from the RF wavelength and determined from the aspect of mechanical designs. The window with an elliptical shape also has less internal stresses and smaller deformation than that of a circular shape with the same surface area.

We have been adopted a low loss silicon nitride composite (SN-287 Kyocera) for a material of gyrotron output windows. For the silicon nitride composite with a permittivity of 7.92, the Brewster angle θ_B is 70.4 degrees.

Figure 1 shows a dependence of the millimeter wave incident angle on the reflection coefficient, when the disk thickness is changed on the assumption of a plane wave approximation. The reflection from the window disappears around the Brewster angle regardless with the disk thickness. The reflection coefficient also become zero when the thickness corresponds to the multiples of half wave length in the material. If we choose multiples of half wave length as the disk thickness, the reflection coefficient looks to remain low over the wide range of the incident angle.

We fabricated a 320 x 120mm^2, 2.53mm thickness racetrack disk of the silicon nitride composite for a 0.5MW CW window. Since the material has very low thermal expansion coefficient, we first designed and assembled a prototype Brewster window using normal silicon nitride (SN-220 Kyocera) to check the structure of brazing and welding. Figure 2 is a photograph of the prototype window itself. The peripheral of the racetrack disk can be water-cooled. To transmit millimeter waves the corrugated wave guide sections are prepared at the both sides of the disk. At the atmospheric side of the wave guide nozzles for air-cooling are perforated on the wall. The number of the nozzle holes is optimized to be nine with the diameter of 1mm, and air is blew on the disk unidirectionally. This structure was determined from the experimental results using a simulated heat source.

Hereafter we have a plan to test this cooling structure of the window at first by means of the simulated heat source instead of the millimeter waves power, and ultimately real millimeter wave power.

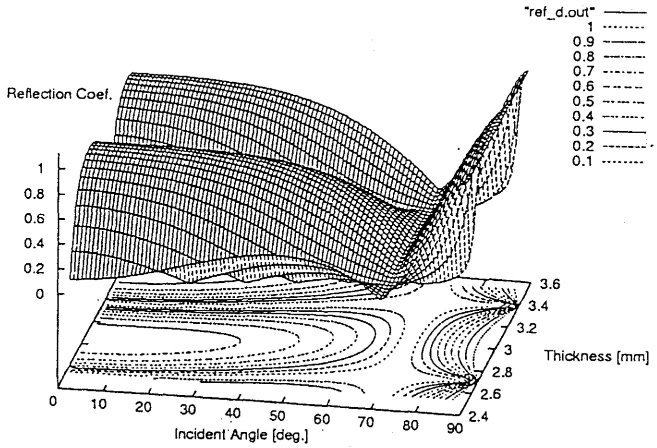

Fig. 1 Calculated results of the dependence of reflection coefficient on the incident angle of the millimeter wave when the disk thickness is changed. The frequency of the wave is 84GHz, and its electric vector is in the incident plane.

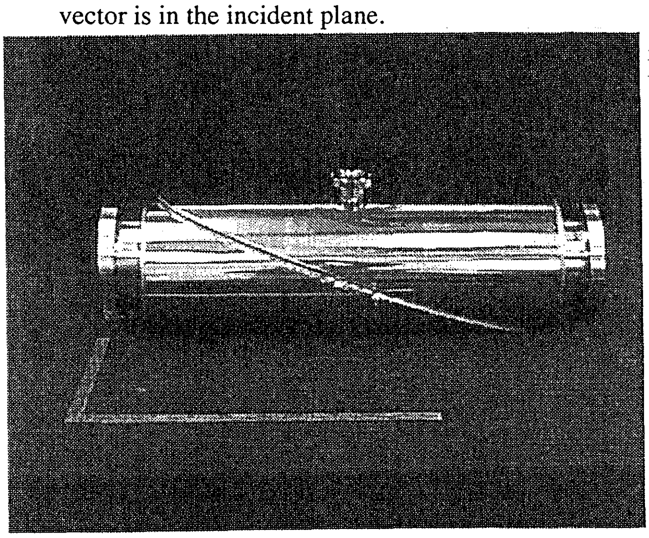

Fig. 2 Photograph of a prototype Brewster window. Total length is about 60cm.