Design of RF Window for 42 GHz, 200kW Gyrotron

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***Abstract-* This paper describes the design of RF window for 42 GHz, 200 kW high power gyrotron. The simulation of RF window for 42 GHz gyrotron has been carried out using the Ansoft HFSS and CST microwave studio. In 42 GHz gyrotron double disc of diameter 85 mm and thickness 3.2 mm sapphire window and spacing (Coolant FC-75) of discs 2.5 mm has been used in the simulation. The return loss (S11) and insertion loss (S21) of the 42 GHz gyrotron window have been found -47.3 dB and -0.04 dB respectively. The return loss and insertion loss of the S-band single disc sapphire window have been found -27.3 dB and -0.07 dB respectively at cylindrical waveguide length 33 mm. The simulated result has been also validated through experimental results for S-band sapphire window.**

***Index Terms*- RF window, Sapphire, FC-75 Coolant, Return loss, Gyrotron**

I. INTRODUCTION

The Gyrotron is a high power microwave tube, which emits coherent radiation at approximately the electron cyclotron frequency or its harmonics. Gyrotron is widely used in Plasma fusions, ECRH heating, Industrial heating and Material processing. The need for high power, high frequency rf sources for the magnetic fusion research experiments has provided much of the impetus for the development of present day gyro oscillators. From the last three decades gyrotron oscillators have played a key role in magnetic fusion experiments. Magnetic confined plasma fusion is the most important application of gyrotron oscillator as a high power, high frequency rf source [1]. A 42 GHz, 200kW (CW) gyrotron is being developed for electron cyclotron resonance plasma heating for an Indian TOKAMAK system. RF window is a critical component of all high power microwave tubes and is used on the output section of the device for the transport of microwave power from vacuum to external pressurized atmosphere. The rf window is a passive component that must be transparent to microwaves and hold ultra high vacuum. It must be fabricated from a low-loss material. The desired features of an ideal window are minimum reflection, minimum insertion loss, and high power handling capability, wide bandwidth, excellent mechanical strength, high thermal shock resistance and vacuum tightness [2]. The wave-guide type microwave windows are generally preferred for high power microwave tubes due to their higher capacity for handling high peak and average rf power. The other functional advantages are broad bandwidth and easy impedance matching with the rest of the transmission line.

The specifications of the window under consideration for the gyrotron of 200 kW average power operating at frequency 42 GHz are VSWR $\leq$ 1.2 and Insertion loss $\leq$ 0.1 dB. In 42 GHz gyrotron double disc sapphire window and coolant FC-75 between discs have been used and temperature of coolant is 25^0C. The advantage of the double disc window cooling is most effective. The double disc windows from BeO, SiC, and PACVD diamond material have been also studied. The double disc face cooled structure causes power loss in two discs [3]. In addition, loss in the coolant also has to be taken into account. However, as far as cooling of dielectric is concerned this design is the most effective. Once the thickness of the coolant is confirmed, the flow rate can be decided based on the heat transfer requirements.

II. DESGIN OF RF WINDOW

The schematic diagram of S-band single disc sapphire window is shown in Fig.1. The electrical design parameters for the window are thickness, diameter, length of the wave guide and dielectric constant of the disc [4]. The window diameter 85 mm, disc thickness 3.2 mm, length of the circular waveguide is 33mm and rectangular wave guide (WR-284) have been used for the design of S-band single disc window. The material of disc is sapphire and dielectric constant (ε_r) of the sapphire is 9.41, loss tangent is 5.4×10^{-5} is measured. The S-band single disc sapphire window has been designed and developed. The design of single disc S-band window has been carried out using Ansoft HFSS and CST Microwave studio. The design has been validated with experimental results. The same electrical design approach has been used for the design of 42 GHz gyrotron window. In 42 GHz gyrotron double discs D1 and D2 of diameter 85 mm and thickness 3.2 mm sapphire window and spacing (Coolant FC-75) of discs 2.5 mm have been used in the simulation. The sapphire base window has been used in 42 GHz gyrotron. The spacing between discs is Coolant FC-75, and dielectric constant of FC-75 is 1.8 and loss tangent (tanδ) is 26×10^{-4}. Thickness of window is given by

$$t = 0.55\ D\ \sqrt{\omega/\sigma_t} \qquad (1)$$

Where D is the diameter of the window, ω is loading strength and σ_t tangle strength.

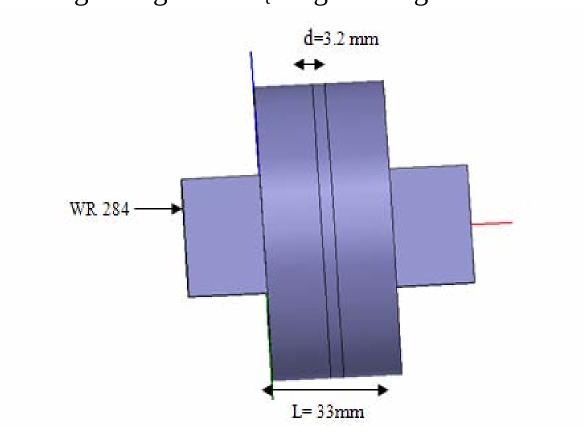

Fig.1 HFSS model of S-band single disc window

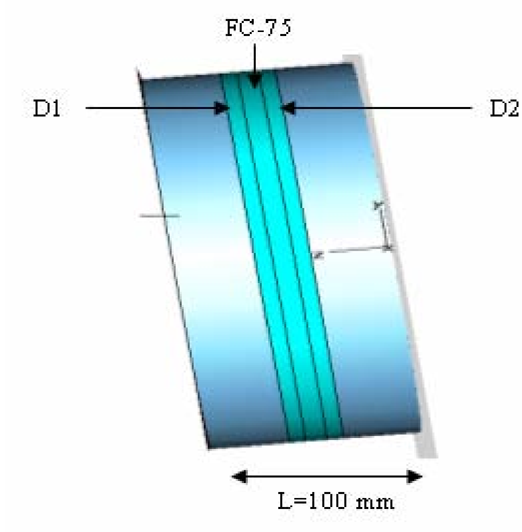

Fig.2 CST model of double disc sapphire window for 42 GHz gyrotron

III. RESULTS AND DICSUSSION

Ansoft HFSS and CST Microwave studio 3-D electromagnetic simulators have been used [5, 6] for the simulation of the S-band and 42 GHz gyrotron window. Fig. 2 shows the schematic model of double disc 42 GHz gyrotron sapphire window. The return loss performance of the S-band single disc sapphire window shown in Fig.3. The rf window play an important role in efficiently coupling the microwave power out from the system with minimum reflection. It is required to have a window with VSWR < 1.20 (return loss < -20 dB).

The return loss performance of the double disc 42 GHz sapphire window shown in Fig.4. The return loss (S11) and insertion loss (S21) of the 42 GHz gyrotron window have been found -47.3 dB and -0.04 dB respectively. The 20 dB bandwidth achieved 0.9GHz. The spacing of discs (Coolant FC-75) disc diameter is 85mm and disc thickness is 3.2mm have been optimized using CST software. Table 1 shows the comparison of results of 42 GHz window using different software.

Table 1 Comparison of results using different software for 42 GHz double discs gyrotron window

Software	Frequency (GHz)	Return loss(dB)	-20 dB bandwidth
HFSS	42.0	-35.0	0.9 GHz
CST	42.0	-39.4	0.7 GHz

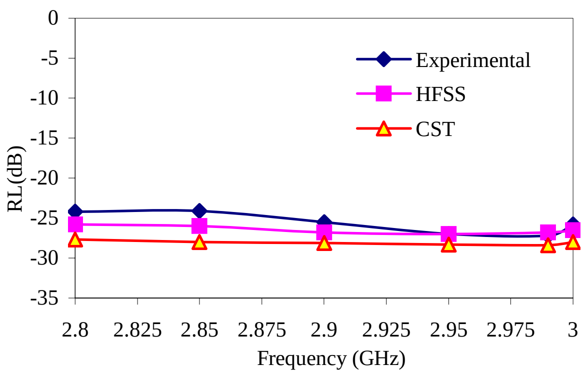

Fig.3 Comparison of simulated and experimental results of S-band window

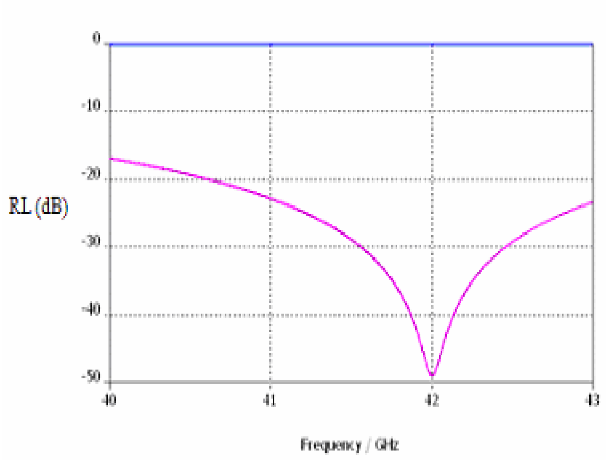

Fig. 4 Return loss performance of the double disc 42 GHz sapphire window using CST

III. CONCLUSION

Sapphire is a viable dielectric material for high power microwave window. The design of S-band single disc window has been carried out using Ansoft HFSS and CST software and validation with experimental results. The design of 42 GHz gyrotron double disc window has been carried out using Ansoft HFSS and CST microwave studio. The disc diameter 85 mm, disc thickness 3.2 mm, the spacing of discs (Coolant FC-75) is 2.5 mm and circular waveguide length 100 mm for 42 GHz gyrotron window have been optimized.

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