*URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020*

# Electromagnetic Study of Ethylene Glycol and FC-75 for an RF Window

Anshu Sharan Singh* (1) and S.V. Rao[2]
[1]Center of research in microwave tube, IIT BHU Varanasi, India
[1]anshu.rs.ece14@iitbhu.ac.in

## Abstract

In this paper, the reflectivity of coolants is studied to design an RF window to VEDs in the megawatt-class operating regime. Two coolants ethylene glycol (EG) and FC-75 are investigated to design a 10 GHz RF window for megawatt-class operation. EG and FC-75 are employed in between two dielectric discs of aluminum nitride (AlN). Modeling and Electromagnetic study of RF windows with coolants are studied using finite integration technique based 3D simulation tool CST microwave studio. RF propagation characteristics study of RF window (EG) predicts $S_{11}$ of -19 dB and $S_{21}$ of -3 dB while RF window with FC-75 possesses $S_{11}$ of -30 dB and $S_{21}$ of -0.07 dB.

## 1 Introduction

From a particle accelerator to fusion reactor, a vacuum electron device (VED) is needed which generates megawatt of RF power using the high electron mobility in a vacuum [1]. In addition to maintaining vacuum, an RF window provides maximum transmission of RF power with minimum reflections [2]. Design of RF window has been discussed [3] and different variant of RF window has been investigated to improve the bandwidth capabilities [4-5]. Multi disc RF window is designed and developed to achieve wide bandwidth [4]. Similarly Brewster RF window provides wide bandwidth of 50 GHz for gyrotron oscillators [5]. In recent study a multi disc RF window is designed to provide transmission over entire X-band for megawatt class gyro-twystron amplifier [6]. However bandwidth enhancement scheme is not significant for VEDs which are employed for particle accelerators [7].

A hybrid gyrotron amplifier designed to deliver 25 MW of RF power at 10 GHz [8]. A cooling mechanism is required to support high power operation over the long pulse duration [3]. Surface coolant is most effective cooling technique; therefore electromagnetic compatibility of a coolant is needed to investigate. Dielectric properties of ethylene glycol is investigated by R. J. Sengwa in 2003 [9]. In this paper we have studied RF propagation behavior of coolants to design 10 GHz RF window. The design calculation and modeling of RF window is discussed in section 2. EM simulation of double disc RF window is discussed in section 3.

## 2 Modeling and Simulation

RF window with the surface coolants are modelled using CST microwave studio. Copper annealed is chosen to create metallic cylinder and inner discs are created by dielectrics. The material and thickness of disc is chosen to provide zero reflectivity at desired frequency. In similar manner coolants applied for surface cooling of RF window should also possess zero reflectivity. Two coolants FC-75 and Ethylene glycol are applied between the dielectric discs of AlN and Quartz, respectively, with common design goal to achieve the zero reflectivity at 10 GHz. CST model of RF window with EG and FC-75 are shown in Fig.1 (a) and (b) respectively. Dimensions of dielectric discs and coolants are optimized to design 10 GHz RF window as shown in Table 1.

TABLE 1 THEORETICAL DESIGN PARAMETERS OF 10 GHZ RF WINDOW WITH COOLANTS

| Parameters | Values |
|---|---|
| **RF window with Ethylene Glycol** | |
| The thickness of Quartz discs | 3.35 mm |
| the dielectric constant of Quartz | 3.8 |
| The thickness of Ethylene Glycol | 0.9 mm |
| The dielectric constant of Ethylene Glycol | 7 |
| The Loss tangent of Ethylene Glycol | 0.8 |
| **RF window with FC-75** | |
| The thickness of Alumina Nitride discs | 5 mm |
| the dielectric constant of Aluminum nitride | 9.05 |
| The thickness of FC-75 | 6 mm |
| The dielectric constant of FC-75 | 1.85 |
| The Loss tangent of FC-75 | 0.01 |

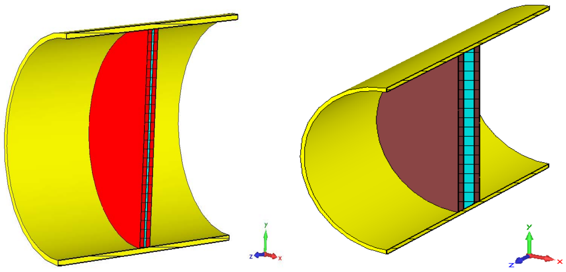

**Figure 1.** CST model of EG and FC-75

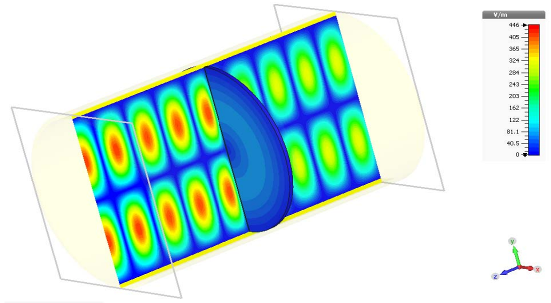

**Figure 2.** RF wave propagation and its absorption in EG double disc RF window

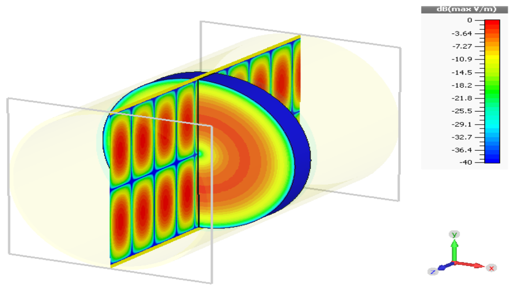

**Figure 3.** RF wave propagation and its absorption in FC-75 double disc RF window

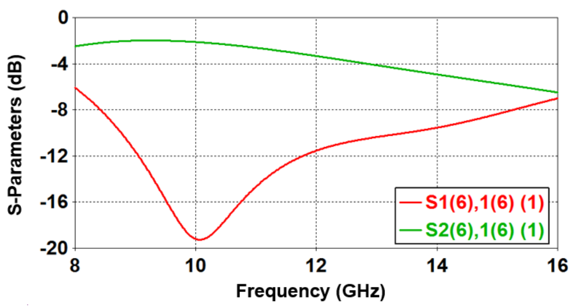


**Figure 4.** S-parameter of EG in double disc RF window.

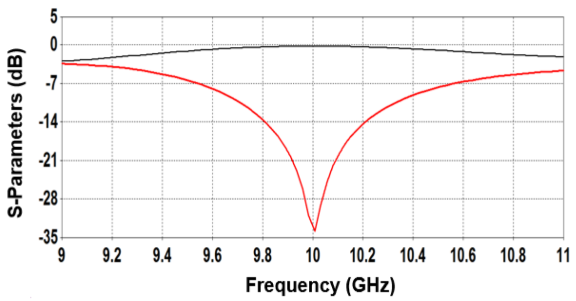


**Figure 5.** S-parameter of FC-75 in double disc RF window.

Despite the thin layer of coolant, the electric field propagation shows the absorption of RF power. Electric field intensity decreases after the propagating through RF window. However, the electric field intensity for FC-75 window is uniform which confirms very little absorption. Further the RF wave propagation characteristics are investigated through scattering parameters. $S_{11}$ of RF window with EG is -19 dB which confirms the negligible reflectivity however its $S_{21}$ is near to -2.5 dB. Unlike EG based RF window, FC-75 RF window possess $S_{11}$ of -30 dB and $S_{21}$ of is near to -0.05 dB.

## 4 Conclusion

Obtained scattering parameters with their electric field confinements confirms that FC-75 have better RF propagation characteristics and Ethylene glycol shows absorptive nature. Since these coolants are widely employed in high power VEDs, therefore the authors would hope that present study on coolants for RF window will help the researchers.

## 5 References


1. A. V. Gaponov-Grekhov and V. L. Granatstein, Eds., Applications of High-Power Microwaves. London, U.K.: Artech House, 1994.

2. M. Thumm, "Development of output windows for high-power long-pulse gyrotrons and EC wave applications", *Int. J. Infrared Millim. Waves*, vol. **19**, pp. 3-14, 1998, DOI: 10.1023/A: 1022514528711.

3. C. J. Edgcombe, Gyrotron Oscillators Their Principles and Practices, New York: 1993.

4. Donaldson, Craig R., Wenlong He, Liang Zhang, and Adrian W. Cross. "A W-band multi-layer microwave window for pulsed operation of gyro-devices." *IEEE Microw. Wireless Compon. Lett.,* **23**, 5, May 2013, pp. 237-239, DOI: 10.1109/LMWC.2013.2251619.

5. G. Gantenbein *et al*., 2014, "First Operation of a Step-Frequency Tunable 1-MW Gyrotron With a Diamond Brewster Angle Output Window," *IEEE Trans. Electron Devices*, **61** (6), pp. 1806-1811, DOI: 10.1109/TED.2013.2294739.

6. A. S. Singh and M. Thottappan, "Design and Simulation of Wide-Band Multi-Disc RF Window for Gyrotron Travelling Wave Amplifiers," URSI Regional Conference on Radio Science (URSI-RCRS 2020), Varanasi, India, 2019 (accepted).

7. V. L. Granatstein and W. Lawson, "Gyro-amplifiers as candidate RF drivers for TeV linear colliders," *IEEE Trans. Plasma Sci.*, 1996, **24**, pp. 648–665, DOI: 10.1109/27.532948.

8. A. S. Singh and M. Thottappan, "RF Coupling and Beam-Wave Interaction Study in a Periodically Loaded X-band 25-MW Gyro-Twystron," *IEEE Trans. Electron Devices*, **65**, 11, Nov. 2018, pp. 5089-5096, doi: 10.1109/TED.2018.2871608.

9. R.J. Sengwa, "A comparative dielectric study of ethylene glycol and propylene glycol at different temperatures,"*Journal of Molecular Liquids, 2003*, **108**, pp. 47-60, DOI: 10.1016/S0167-7322(03)00173-9.