CHAPTER 1:

Thermal Simulation of RF Window for Klystron Specifications

1. Introduction

An RF window, or resonant cavity, is a component that transmits radio frequency (RF) power from a vacuum into a transmission line. RF windows are used in many RF devices, including linear accelerators, industrial screening, and national laboratories. They are designed to: Maximize RF power transmission, minimize loss over the desired frequency range, achieve low insertion loss, excellent VSWR, and minimize reflection.

RF windows are typically made of high-grade ceramic and housed in a length of waveguide. They must also be able to withstand high power, mechanical, and thermal stresses, and be leak tight.

For RF linear accelerators, klystron is the main source of RF energy. Radiofrequency (RF) microwave window is a critical component of klystron.

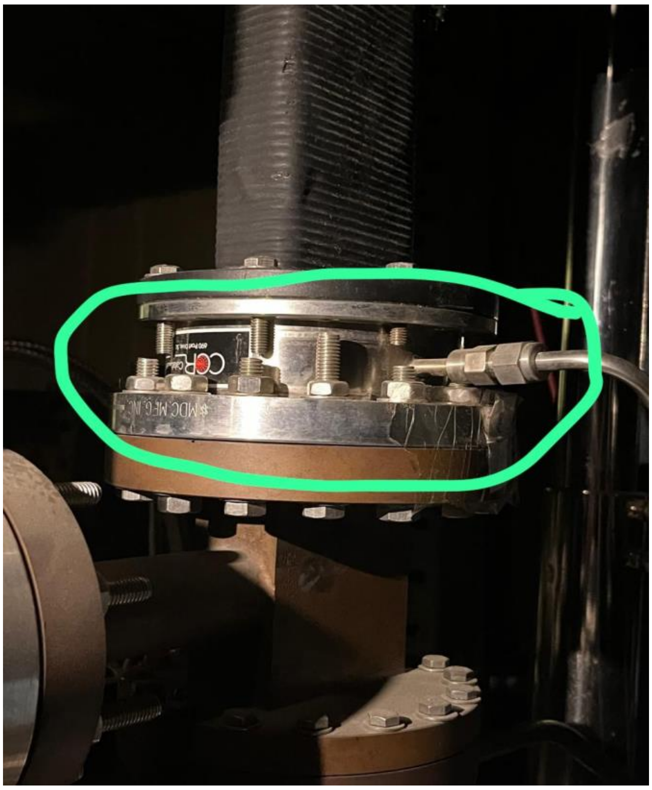


Fig. 1.1 RF window
Source: EBC Kharghar

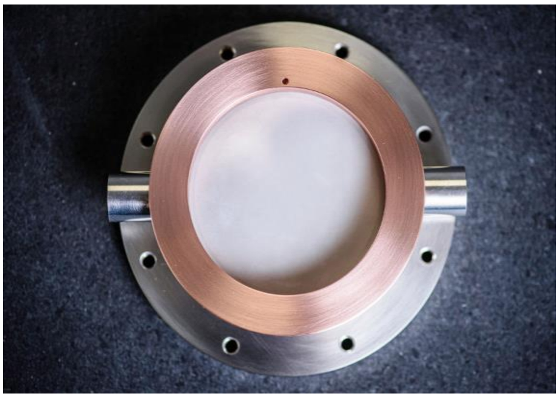


Fig. 1.2 RF window
Source:
https://images.app.goo.gl/DF8KZitPMbrpXvig7

2.Objectives

• Execute thermal simulations to assess the temperature distribution on the RF window.

• Refine the RF window design for two designated klystron configurations: o Case: 5.5 MW peak power and 25 kW average power.

3. Klystron Specifications

Case:

• Peak Power: 5.5 MW

• Average Power: 25 kW

• Pulse Duration: 20 microseconds

• Pulse Repetition Frequency (PRF): 300 Hz

4. Simulation Methodology Software and Tools

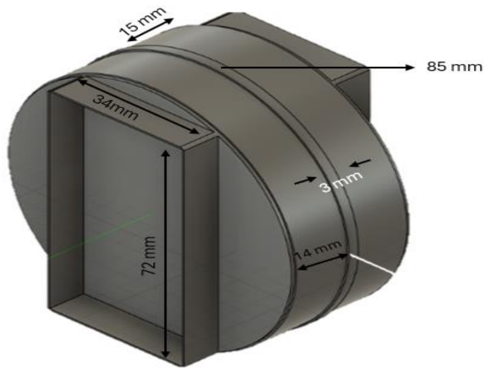
• Utilization of Finite Element Analysis (FEA) software for thermal simulations. (Workbench'24 of Ansys Student Version)

• Access to ANSYS material properties database to ensure precise simulation inputs.

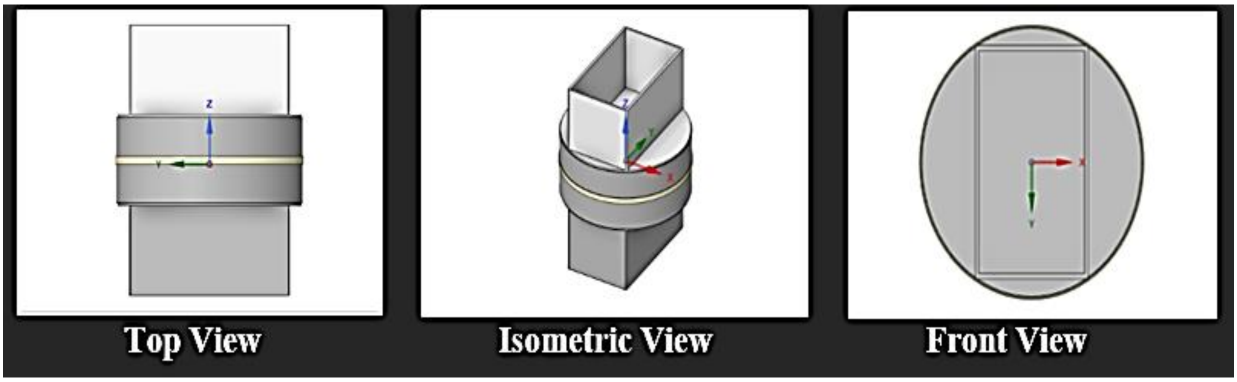
Simulation Steps

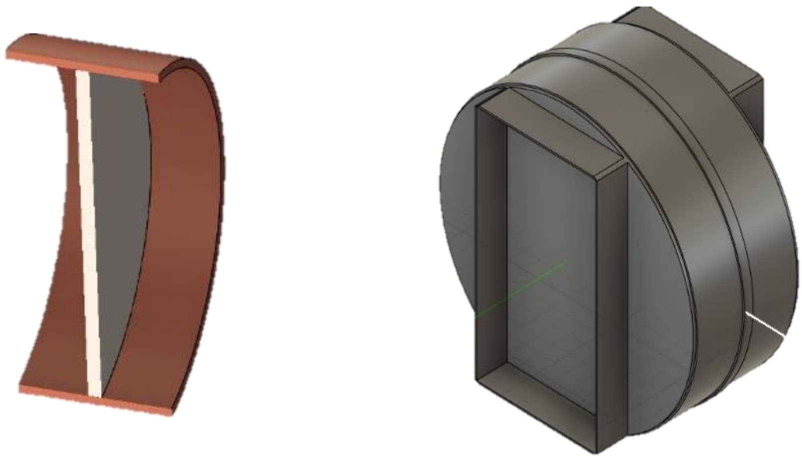
1. Define the geometry of the RF window.
2. Assign material properties based on the selected materials.
3. Apply thermal loads in accordance with power specifications.
4. Conduct thermal simulations to determine temperature distribution.
5. Optimize the design predicated on simulation results.

Geometry specifications

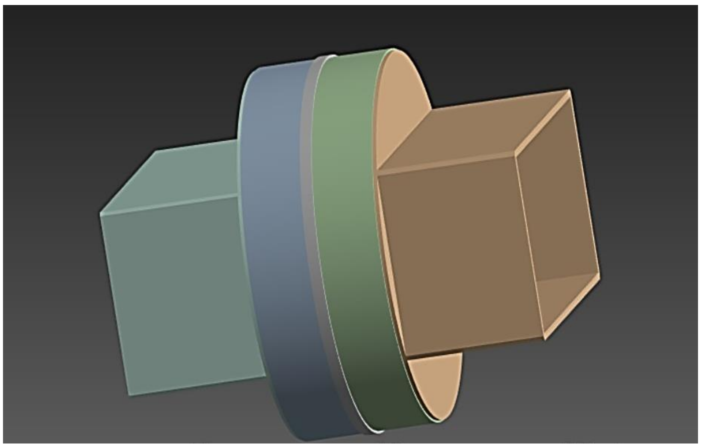


Cross Section of RF Window





3D Model of RF Window



AutoCAD Fusion Model

5. Thermal Analysis

Case : 5.5 MW Peak Power and 25 kW Average Power

Thermal Load Calculation

- The peak power correlates to a transient thermal load.
- The average power indicates prolonged heating effects.
- Thermal load distribution is considered across the RF window surface.

Results

- **Temperature Distribution**: The apex temperature is located at the centre of the RF window, tapering towards the periphery.
- **Thermal Stresses**: Significant thermal stresses emerge, particularly around the window's edges due to thermal gradients.

6. Optimization

Material Selection

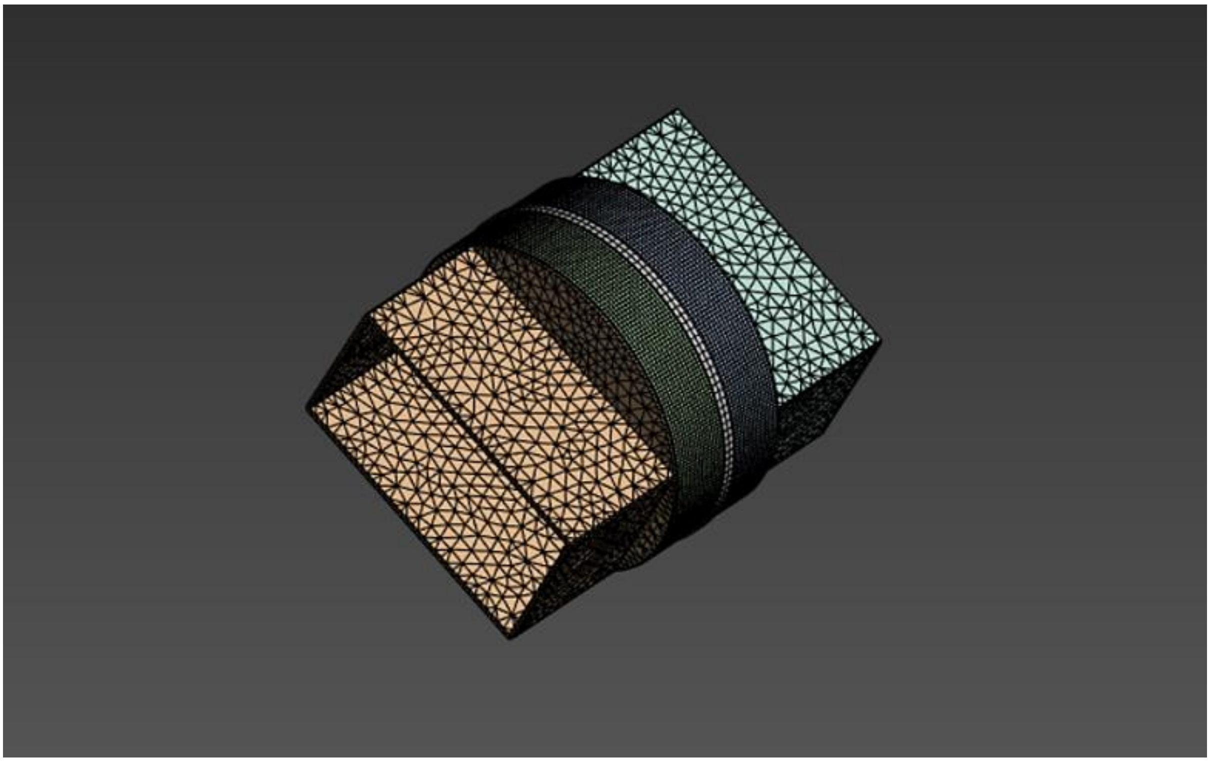
- Preference for materials with high thermal conductivity and low thermal expansion coefficients.
- Potential materials encompass high-grade ceramics and specialized glass.

Geometric Optimization

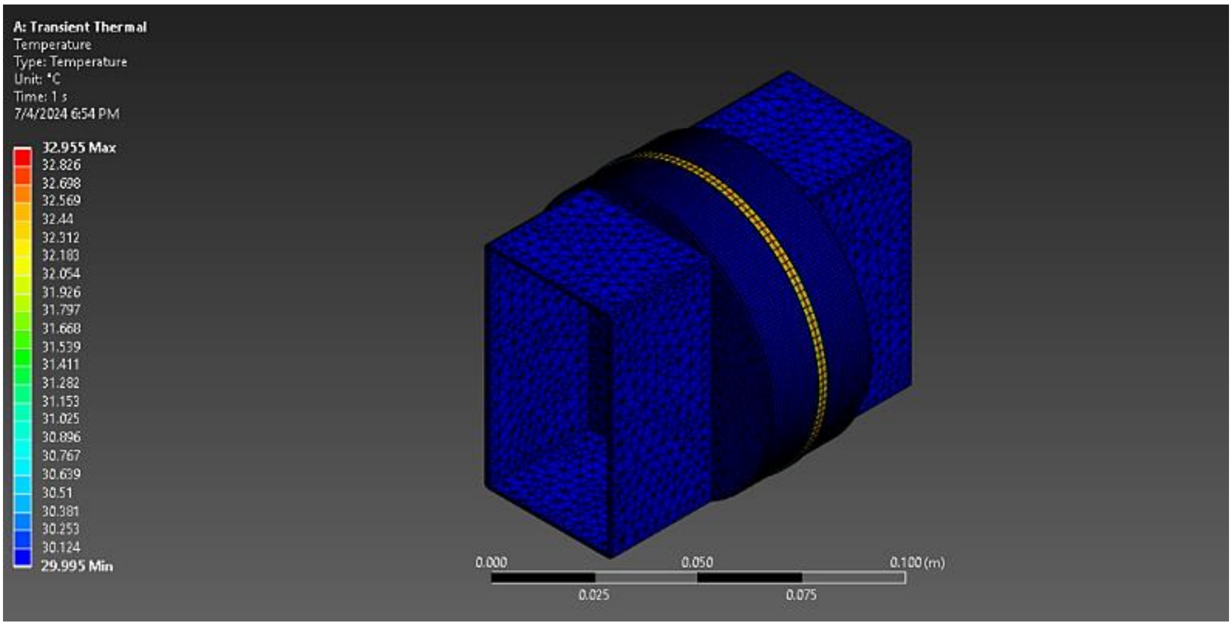
- Incorporation of cooling channels or heat sinks to dissipate excess heat.

7. Results and Discussion

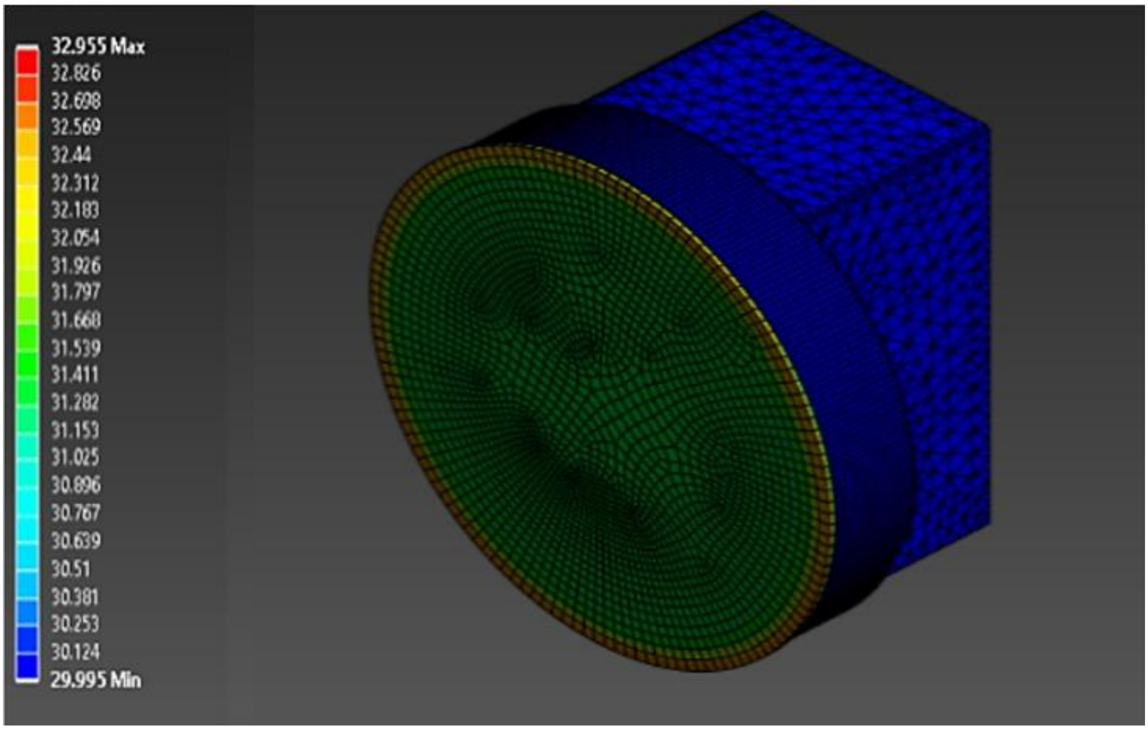
The mesh is generated of the element size of 0.002m.



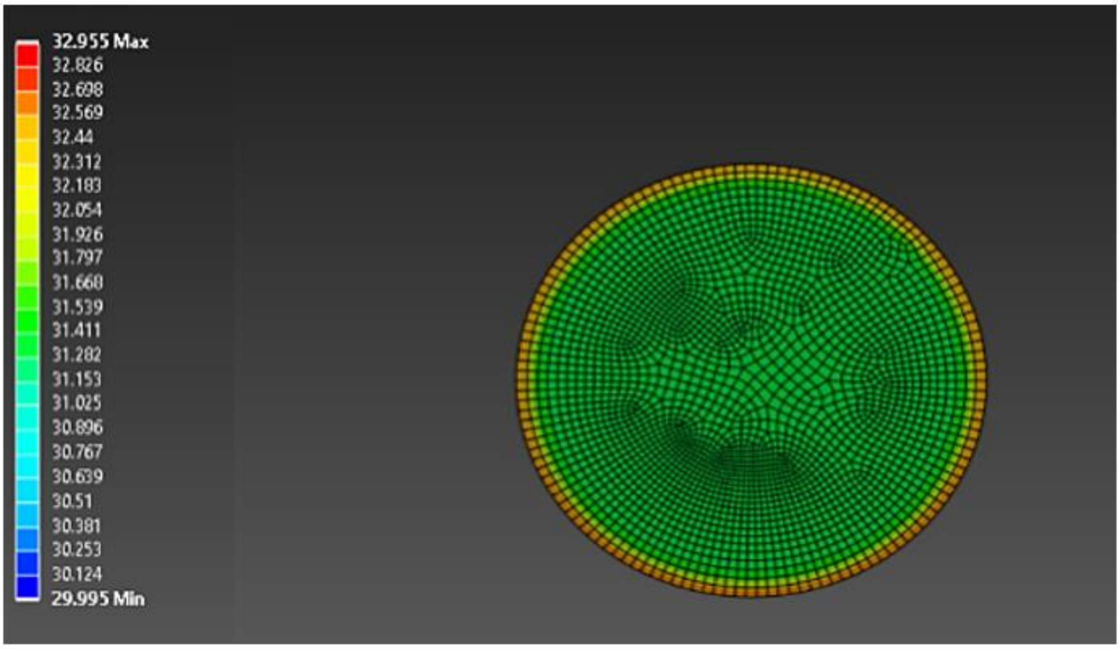
Meshed Structure



Temperature Distribution of the CAD model



Section View of Temperature Distribution



Temperature Distribution over the Assembly

Maximum Temperature obtained from the thermal analysis is 32.955°C which is within the allowable limit.

8. Conclusion

The RF window design ensures that the window can endure the specified thermal loads, thereby guaranteeing reliable operation under the given conditions.

9. References

- Klystron product catalogue
- Ansys documentation
- Fusion documentation
- Frank P. Incropera and David P. Dewitt, Fundamental of Heat and Mass Transfer, Chapter- 8