PRELIMINARY DESIGN OF RF COUPLER FOR 650MHZ SUPERCONDUCTING CAVITY

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Abstract

A probe type coaxial coupler with doorknob transition in WR1500 at 650MHz has been designed for its application in a test facility for qualification of dressed superconducting RF cavities in order to qualify them before their assembly into a cryomodule. In this paper we present the results of RF simulation of the complete coupler and discuss the engineering issues in realization of such coupler. A proof-of- process test model for the coupler is designed and preparation of engineering drawings for fabrication is taken up. Major components like windows, doorknob transition and copper coated bellow assemblies will be fabricated and tested for their quality. A coupler test stand will also be built to qualify the couplers.

INTRODUCTION

At RRCAT, Indore we have two electron synchrotron sources namely Indus-1 and Indus-2, with normal conducting RF cavities for acceleration. Development of superconducting niobium cavities and associated RF technologies has been taken up at the centre, considering its importance for future accelerator programmes. An interest is generated for investigating the design and development of high power RF input couplers for superconducting accelerating cavities. As the name suggests an input coupler is needed for transporting RF power into the RF cavity and to work as a barrier for ultra high vacuum towards the cavity. Couplers are critical components of SRF accelerators and the cost is often comparable to that of cavities. The window failure causes contamination to the Niobium cavities and the recovery is time consuming and expensive.

BASIC CONFIGURATION

A probe type coupler has been considered for this 650MHz SRF cavity, that includes a WR1500 waveguide to coaxial doorknob type transition and coaxial portion. We have considered two designs for placement of RF windows. In one of the design the doorknob transition has an integrated cylindrical RF window in the half height waveguide and the other window is placed in coaxial portion with full height waveguide. The other Design incorporates both RF windows in coaxial section itself. The whole coupler is divided into three temperature zones and bellows on both outer and inner conductors are placed to allow for the thermal expansion-contraction during temperature cycles. The inner conductor bellow allows the movement of the probe position inside the cavity with the help of a linear motion transmission mechanism lying inside the inner conductor and operated behind the door knob. Fig.1 and 2 shows the two basic configurations discussed above.

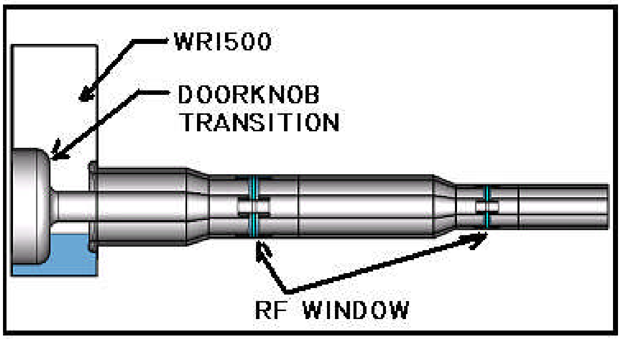

Figure 1: Two flat windows placed in Coaxial section

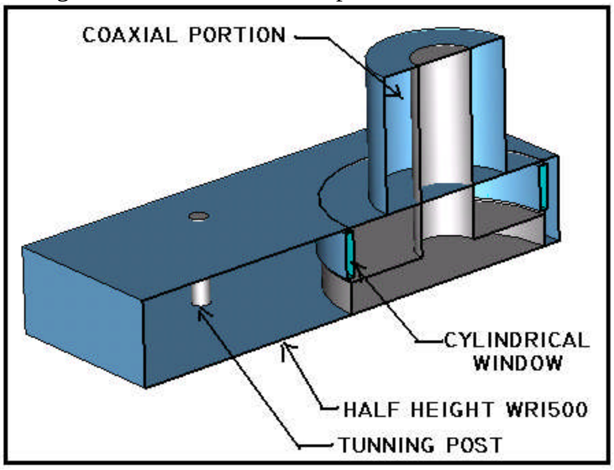

Figure 2: Cylindrical window in half height WR1800 with tuning post and Chamfered at short wall corners.

POWER COUPLER DESIGN

So far the electromagnetic simulation of the coupling system from coupling region to the electromagnetic transmission system/source is concerned there is no or little difference whether normal conducting or superconducting system is in consideration. It is a single frequency device and a coupling corresponding to $Q_{ext}=10^6$ is easy to obtain. The coupling to the cavity needs to be determined to minimize the power requirements and to ensure optimum performance for a given beam current. the numerical tools become essential to determine the coupling in situations of high beam currents or strong coupling demand. The coupling match between the cavity and the coupler is estimated using codes or analytically. The most important parameter the $Q(Q_{ext})$ of the coupled system provides a direct correlation between Q_{ext} and the cavity voltage, the beam power and the shunt impedance.

$$Q_{ext} = 1/2\ V^2_{acc} /(R/Q)P_{beam}$$

RF impedance matching is accomplished by means of a careful geometrical design and selection of materials. to avoid waste of power by reflection or by additive dissipation. To effect Q_{ext} tuning of the coupler, a transmission mechanism which moves the middle part of the coupler axially and thus changes the inner conductor antenna end position, has been incorporated.

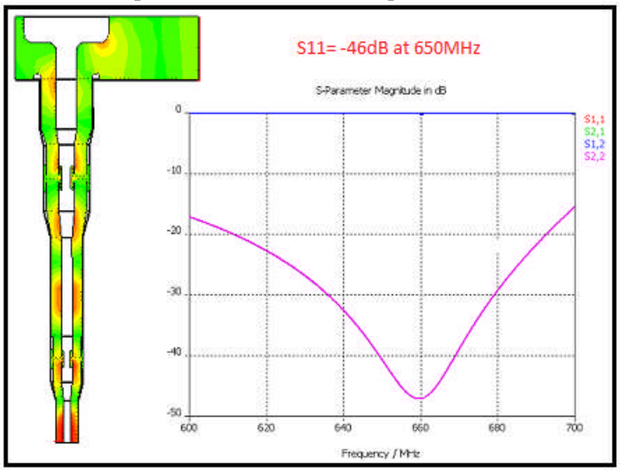

Figure 3. Simulation Results of full Coupler

The geometrical dimensions of doorknob transition from waveguide to coaxial transition are optimized to reduce the return and insertion losses for both the cases, with and without cylindrical window. Some good multipaction studies and scaling laws for coaxial lines done by P.Ylae-Oijal et.all has been referred to for selecting the coaxial line size, bigger coaxial diameter and higher impedance. Then coating the critical surfaces like ceramic with titanium or titanium nitride is envisaged so that the secondary electron emission coefficient changes from 8 to approximately 1. Similarly enough cleaning and extensive conditioning is anticipated to cut down multipaction further. Finally additional field, electrical bias on inner conductor or magnetic bias on waveguide shall be done to drive away the resonant condition. The real challenge in

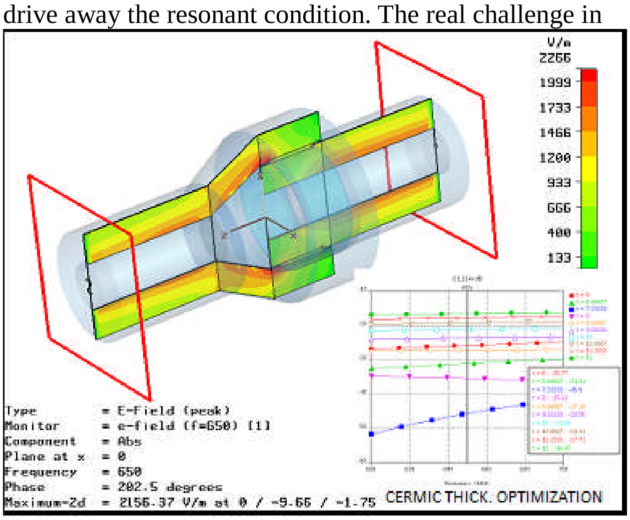

Figure 4. Window Ceramic thickness optimization

coupler design lies in transporting 10s of kW of RF power down into a 4.2K environment with minimal heat input into the helium bath. There is also a stringent control over the static and dynamic thermal losses to the cavity and helium bath. In addition to this very small amount of heat usually 100s of mW power is allowed to transfer from room temperature side to cryogenic side. The next big problem has been the realization of a ceramic window to sustain higher power level and thermal cycling for longer period of time. Development of such reliable windows is an engineering challenge. The window can fail by excessive heating because of power lost in transmission and adequate removal of heat is not provided. This actually leads to increase in tensile forces in the ceramic above its tensile strength and failure occurs. Also if mechanical strength of the window is weak, a thermal variation specially in situation of waveguide arcing, may fail the joints. Therefore the choice of material for construction of windows and other parts has carefully taken into account the thermal loads and other electrical and mechanical properties. Ultra pure Alumina ceramic (purity 99.7%, loss tangent $\leq 1 \times 10^{-4}$, conductivity 30W/m-K, flexural tensile strength 330MPa), OFHC copper, austenitic stainless steel AISI316L are the basic construction material. All inner surface of waveguide, coaxial outer conductor and outer

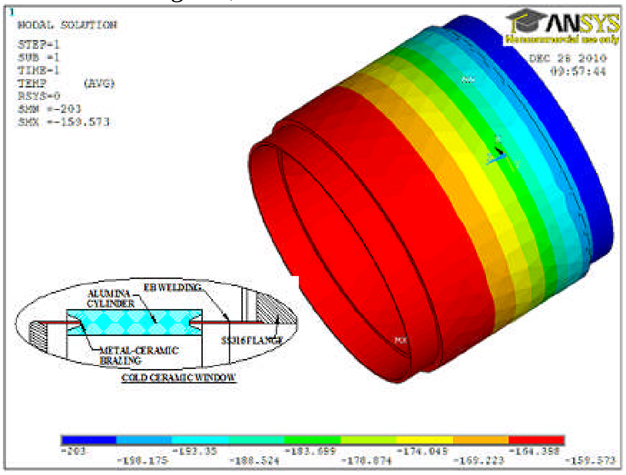

Figure 5. Cold window Ceramic temperature profile

bellows and outer surfaces of doorknob, coaxial inner conductor and inner bellows respectively are a few skin depth copper plated. Copper plating quality is of highest standard and a special set up is being established to electroplate the bellows with strict process control to achieve good thickness uniformity all over.

SUMMARY

The attempt is to develop the technology for SRF high power couplers. Different ceramic windows will be fabricated in first stage followed by fabrication of two couplers and the test stand with all necessary diagnostics arc detector, electron monitor etc. and vacuum system for high power testing.

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