DESIGN AND FABRICATION OF INPUT RF COUPLER WINDOWS FOR THE U.S. RARE ISOTOPE ACCELERATOR PROJECT (RIA)

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Abstract

The RIA RF high power coupler window was designed by AMAC to meet the specification requirements for the RIA accelerator project, and is based on AMAC's SNS RF coupler window design. MSU provided the RF specification, and performed the calculations to match the coupler to the SRF cavity. CPI performed the manufacturing optimization, and fabricated two prototype couplers. The prototypes have been high RF power tested by the Jefferson Lab and met or exceeded the requirements of the RIA technical specifications. The RF tests and conditioning are described in a separate presentation in this workshop.

INTRODUCTION

AMAC was awarded a contract to provide two prototype RIA RF input power coupler windows in a very short period, and for this reason it was decided to base the design on the proven SNS AMAC-1 coupler [1]. The main changes were the modification of the antenna and the removal of the water cooling feature. The water is not required due to the lower required RF power level of 10kW CW.

Two window couplers were delivered; high RF power tested, and qualified to meet the RIA technical requirements. The RIA technical requirement are briefly listed in the following:

VSWR: 1.05 or lower at 805 MHz
Maximum radiative heat loss to 2.1K circuit: 1 W
Maximum CW power: 10 kW
External Q of coupler: 2 x 10^{-7}
Operating pressure: $<5 \times 10^{-9}$ torr
Radiation resistance at tip of antenna: 4×10^{8} rads

RIA COUPLER WINDOW DESCRIPTION

It is is a coaxial type of coupler with a planar ceramic window separating the vacuum side from air side. In the HFSS simulation, the loss tangent is taken as 0.0002, and the permittivity value is 9.6.

The RIA accelerating cavity geometry requires a coaxial 805 MHz coupler design with a transition to a standard 3-1/8" transmission line. The window geometry incorporates chokes at the inner and outer conductor. The dissipated power at the window and the antenna are transferred conductively thru the material and removed by air cooling

The vacuum side of the ceramic window is coated with 20-25 Angstrom Titanium Nitride. Figures 1a and 1b show the general assembly drawing and a photo the coupler window.

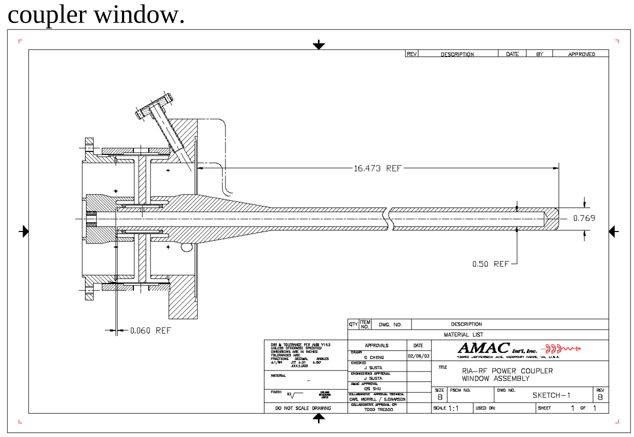

Figure 1a: RIA Coupler Window Assembly.

Figure 1b: Photo of RIA Coupler Window.

RF PARAMETERS

The RF calculations performed for the SNS coupler window, using MAFIA and HFSS programs, and analyzed for their multipacting behavior with a program from the University of Helsinki [2] and are identical for this coupler.

Figures 2, 3 and 4 show the results of the HFSS calculations for the E and H field distribution for the window design for 1KW input power. In Figs 3 and 4, the negative side is the air side of the window.

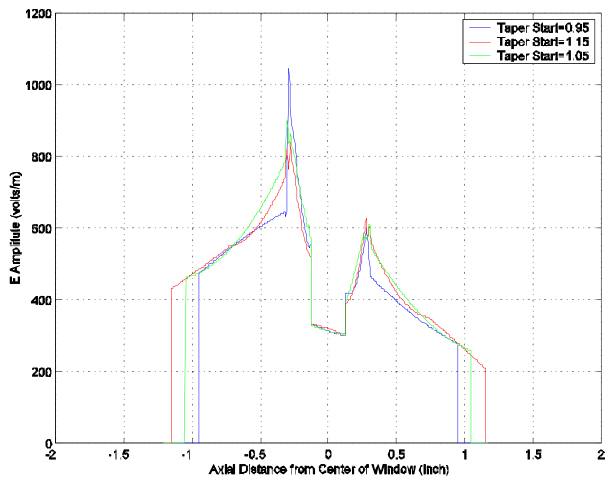

Figure 2: AMAC -1 Electric Field Amplitude along Inner Conductor Surface.

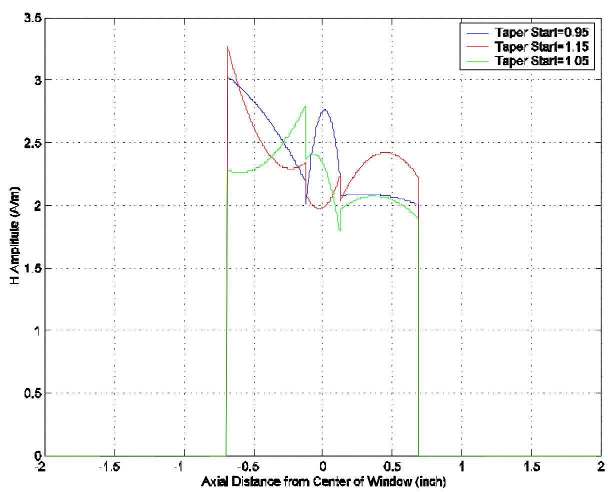

Figure 3: Magnetic Field Amplitude along the Inner Conductor Surface.

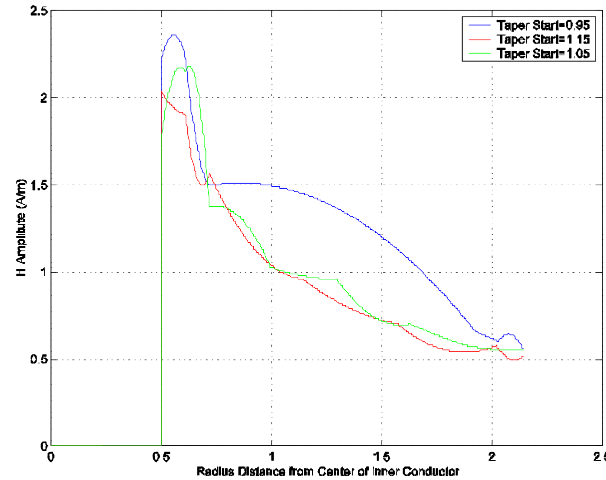

Figure 4: Magnetic Field Amplitude along the Ceramic Window Surface.

Figures 5 and 6 show the MAFIA calculation results for the electric and magnetic fields for 0.5 W incident power. Figure 7 is a contour plot of the dielectric loss in the ceramic. Figures 8(a) and 8(b) show the dielectric loss distribution, and the electric fields at the center plane of the ceramic for 1W incident power.

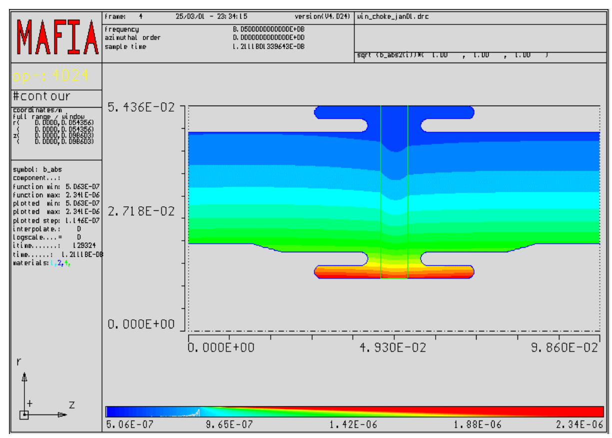

Figure 5: Contour plot of magnetic field in AMAC-1 at 1/2W incident power.

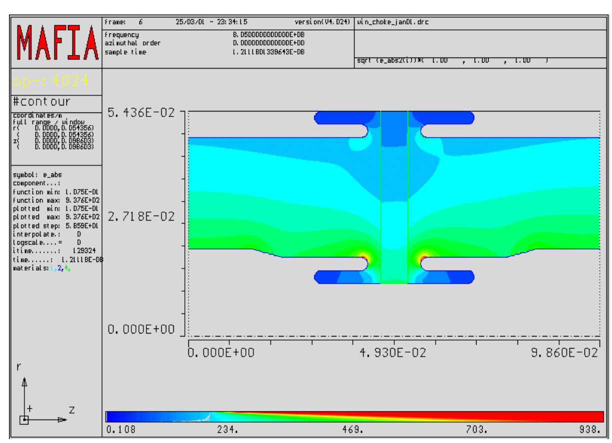

Figure 6: Contour plot of electric field in AMAC -1 at 1/2W incident power.

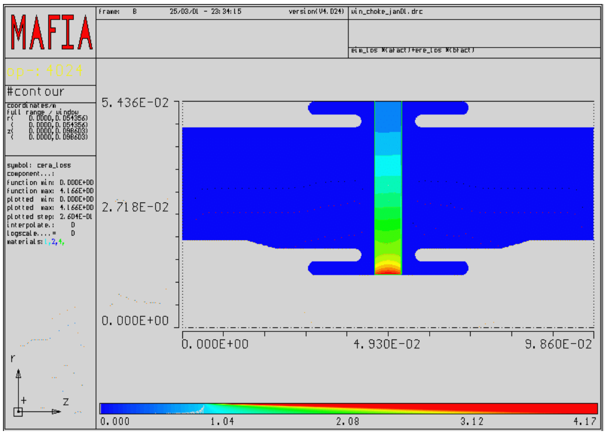

Figure 7: Contour plot of AMAC-1 dielectric losses in the ceramic at 1/2W incident power.

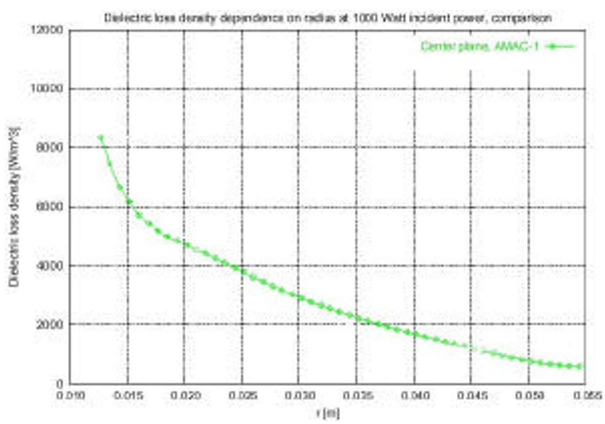

Figure 8a: Radius dependence of dielectric loss at 1000 W incident power for AMAC -1.

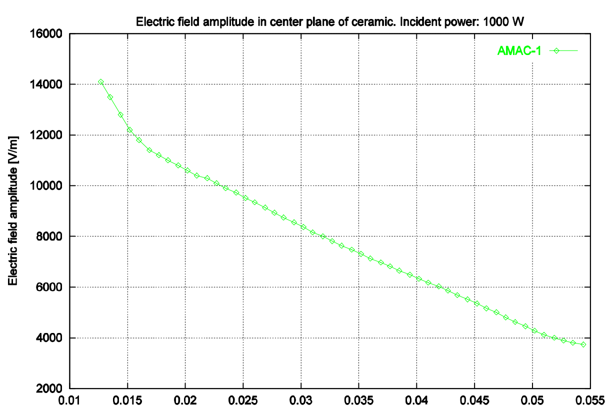

Figure 8b: Radius dependence of electric field at the ceramic center plane of AMAC -1 at 1000 W of incident power.

MULTIPACTING CALCULATION RESULTS

Secondary electron emission data for copper extended to 50eV on the lower energy side was used in the calculations for all copper and copper plated surfaces for the SNS design and apply also to the RIA coupler. The secondary electron emission values for TiN were used for the ceramic window surface.

The calculations were performed at the University of Helsinki with a specially developed program which tracks electron trajectories in various wave reflection conditions and determines their enhancement possibility for different power levels.

These calculations are considered a reliable indication of multipacting occurring due to secondary electron emission on the coupler surfaces in the vacuum region, and are used to validate the coupler geometry in the design stage.

The description and results of the calculations are shown in more detail in another paper [1]

RF TEST RESULTS

The external Q was measured with the cavity as shown in Fig. 9. The coupler windows have been conditioned and successfully RF tested at the Jefferson Laboratory to meet the RIA specifications . All results met or exceeded the specified values and only a mild temperature increase of the window was measured during long periods at full power RF. A separate presentation at this workshop [2] shows the detail test results.

Electron activity (about 20 nA) started to manifest at one coupler during constant RF power tests at 12 kW RF power (20% higher power level than maximum design value).

No bias voltage was applied during all these tests.

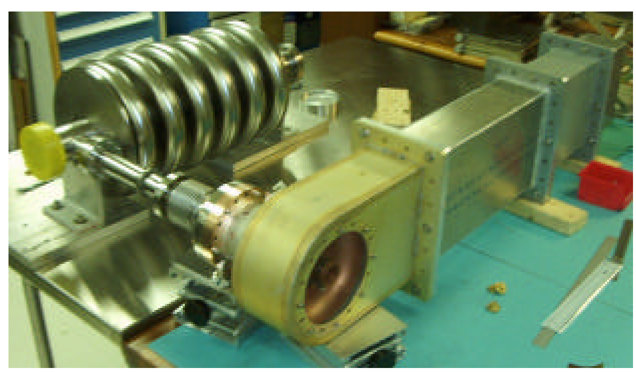

Figure 9: RIA Coupler mounted on SRF Cavity.

REFERENCES

[1] Q.S.Shu, J.Susta, G.Cheng (AMAC), S.Einarson, T.A.Treado, W.C.Guss, M.Tracy (CPI) “Design and Fabrication of Input RF Coupler Windows for the SNS”, High Power Coupler Workshop, Newport News, USA, 2002.

[2] M. Stirbet, T.L. Grimm, J. Popielarski and M..Johnson, “RF conditioning and testing of fundamental power couplers for the RIA project”, this workshop.