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High Power S-band Window Optimized to Minimize Electric and Magnetic Field on the Surface*

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Abstract: *RF windows are used to separate high and low vacuum regions in high power microwave systems, such as klystrons and RF distribution. RF breakdowns in megawatt environments could damage the window. An S-band RF window was designed to reduce electric and magnetic fields in the waveguide joints and the ceramic.*

Keywords: S-band; RF window; high power.

Introduction

Robust high power operation of RF windows is important for reliability and lifetime of high power RF sources. A variety of innovations and improvements to RF windows have been offered and demonstrated for klystrons operating in S, and X band [1, 2, 3, 4] over the years. The so called Traveling Wave window is of particular interest. Such a window was designed by the authors and built and successfully tested at SLAC for the ILC prototype L-band positron source. A large number of accelerators in the world, including the SLAC linac operate at S-band. Thus this window which should operate comfortably at 65 MW peak power, is of great importance for many accelerators. Particular attention was paid to mitigate the high fields on the ceramic and the metal. Trapped and so-called ghost modes were investigated to assure that such modes are outside klystron bandwidths. This particular design can replace the pair of windows in the current the 5045 klystrons by a single window of this design.

Design Considerations

To minimize the fields on the ceramic, we chose the traveling wave window approach [1, 2]. The basic design requirements of the window and the values achieved in simulation are presented in Table 1.

Table 1. S-Band Window Design Parameters

Parameter	Required	Achieved
Frequency (MHz)	2856	2856
3 dB BW (MHz)	≥ 20	≥ 100
Reflection (S11)	< -20 dB	< -70 dB
Peak Power (MW)	65 MW	65 MW
Peak E on Ceramic (MV/m)	Minimize	1.75
Peak H on Ceramic (KA/m)	Minimize	17
Peak E (MV/m)	Minimize	11
Peak H (KA/m)	Minimize	20

The ceramic is housed in a circular waveguide. We minimized the fields on the metal surfaces by optimizing the shape of the joint between the circular and rectangular waveguide. Figure 1 shows a quadrant of the window.

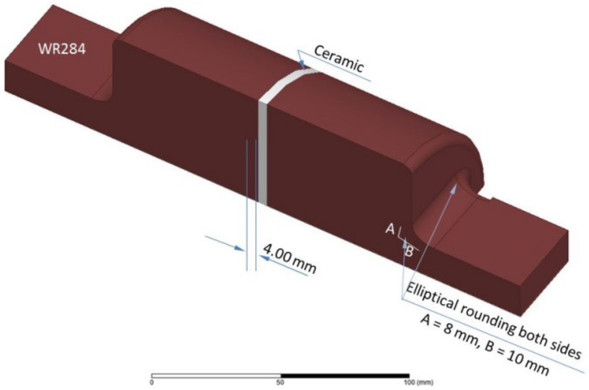

Figure 1. S-band window geometry (one quadrant)

S-band Window Expected Performance

We used the commercial code Cascade [5] for the initial simulations. Cascade uses mode-matching for rapid S parameter analysis and optimization of 2-port passive waveguide components and calculation of frequency and Q of resonators. We then used the 3-D finite-element code HFSS [6] for the final design. Figure 2 shows the reflection vs. frequency for the window with varying thicknesses of the ceramic. For the nominal case of ε = 9.6 and thickness of 4 mm the reflection at 2856 MHz is less than -90 dB and the bandwidth at -20 dB is 50 MHz and more than 100 MHz at -3 dB. The reflection is less than -45 dB at 2856 MHz at ± 0.2 mm from nominal.

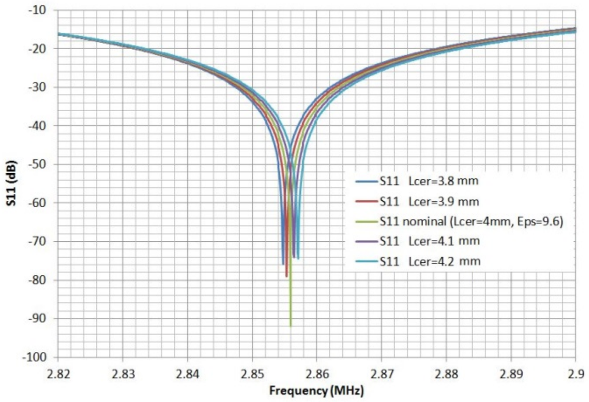

Figure 2. Reflection vs. frequency for varying ceramic thicknesses.

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Figure 3 shows the reflection vs. frequency for the window with varying permittivity of the ceramic. Keeping the ceramic thickness at 4 mm, the ceramic permittivity is varied in ε = 0.2 increments on either side of the nominal. The reflection is less than -35 dB at 2856 MHz in the worst case of ε = 9.6 ± 0.4, which is satisfactory for a practical design.

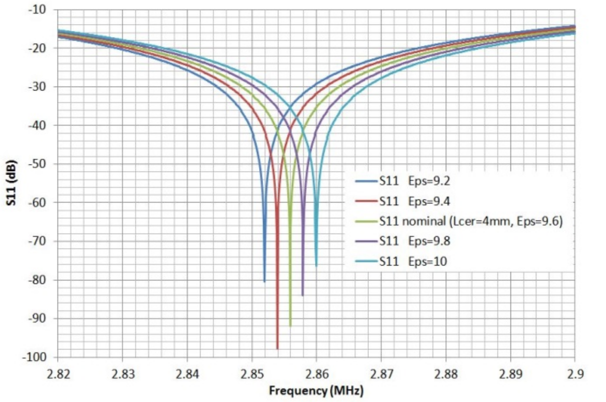

Figure 3. *Reflection vs. frequency for varying ceramic permittivity.*

The maximum electric and magnetic fields on the metal appear on the ellipticaly-shaped joint between the circular and rectangular waveguides Figure 4 shows that at 65 MW through the window, the maximum electric field on the metal is 11 MV/m and the maximum electric field in the ceramic is 1.75 MV/m.

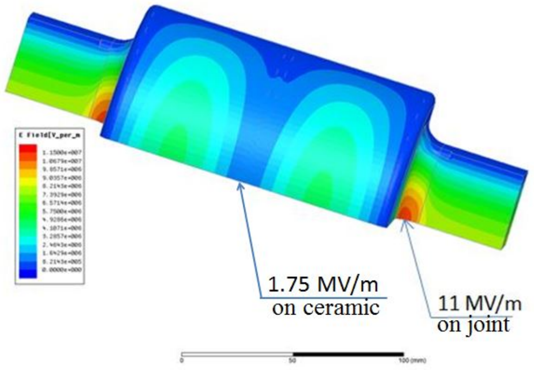

Figure 4. Surface Electric field at 65 MW.

Figure 5 shows that the maximum magnetic field on the metal is 20 kA/m and on the ceramic it is 17 KA/m.

As a comparison, the SLAC 5045 klystron uses a dual window, and each window has a maximum electric field of 11.6 MV/m on the circular to rectangular waveguide joint and 3.3 MV/m on the ceramic and 11.6 MV/m on the circular to rectangular waveguide joint and 3.3 MV/m on the ceramic with half of 65 MW transmitted through it. The new design is a vast improvement considering that we would need only one window instead of two for the same function.

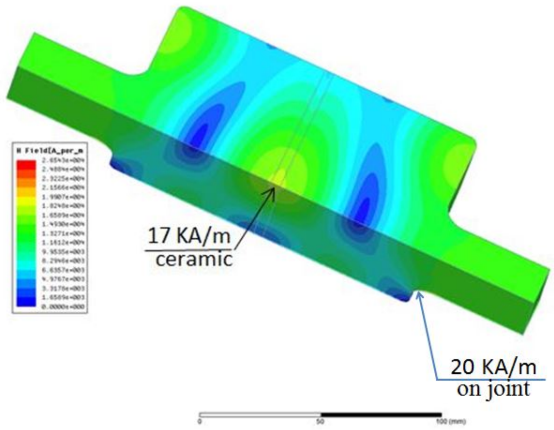

Figure 5. Surface magnetic field at 65 MW.

After the design was finalized, we investigated the rapped and ghost modes for this window. The study included the variation in the ceramic permittivity and thickness based on manufacturing variation. We found that the nearest ghost mode is more than 200 MHz away from the nominal 2856 MHz. The closest trapped mode is more than 60 MHz away.

Summary

We have designed an S-band window which should comfortably operate at 65 MW, has much lower surface fields than the current S-band windows on the SLAC 5045 klystrons, and a single window of the design offered here can replace the dual window of the 5045. At the time of this publication, this window is in the manufacturing process for experimental verification at SLAC.

Acknowledgement

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References

[1] S. Y. Kazakov, Presentation at LC93 Workshop, SLAC, Stanford University, Oct. 1993C.
[2] S.Michizono, Y.Saito, H.Mizuno, S.Yu.Kazakov,"High Power Test of Pill-Box and TW-in Ceramic Type S-Band Windows", Proceedings of the 17th International Linac Conference (LINAC94), Tsukuba, Japan, August 21-26, 1994
[3] W. R. Fowkes et al, "Reduced Field TE01 X-band Traveling Wave Window", PAC95, Dallas, May 1995, p. 1587, (1995)
[4] W. R. Fowkes et al, "Large Diameter Reduced Field TE01 Traveling Wave Window for X-band", PAC99, New York, March/April 1999, p. 785, (1999)
[5] Cascade, http://www.LexamResearch.com/products/cascade
[6] HFSS, http://www.ansoft.com/products/hf/hfss