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>
<thead>
<tr>
<th>Parameter</th>
<th>Required</th>
<th>Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (MHz)</td>
<td>2856</td>
<td>2856</td>
</tr>
<tr>
<td>3 dB BW (MHz)</td>
<td>≥ 20</td>
<td>≥ 100</td>
</tr>
<tr>
<td>Reflection (S11)</td>
<td>&lt; -20 dB</td>
<td>&lt; -70 dB</td>
</tr>
<tr>
<td>Peak Power (MW)</td>
<td>65 MW</td>
<td>65 MW</td>
</tr>
<tr>
<td>Peak E on Ceramic (MV/m)</td>
<td>Minimize</td>
<td>1.75</td>
</tr>
<tr>
<td>Peak H on Ceramic (KA/m)</td>
<td>Minimize</td>
<td>11</td>
</tr>
<tr>
<td>Peak E (MV/m)</td>
<td>Minimize</td>
<td></td>
</tr>
<tr>
<td>Peak H (KA/m)</td>
<td>Minimize</td>
<td>20</td>
</tr>
</tbody>
</table>

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 \( \varepsilon = 9.6 \) 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.

Table 1. S-Band Window Design Parameters

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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 \( \varepsilon = 0.2 \) increments on either side of the nominal. The reflection is less than -35 dB at 2856 MHz in the worst case of \( \varepsilon = 9.6 \pm 0.4 \), 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 elliptically-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.

**Figure 5. Surface magnetic field at 65 MW.**

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.

**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**

We thank David Martin for the mechanical design of this window, Michael Nicolls for simulating the current SLAC 5045 dual window for comparison purposes.

**References**