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HIGH POWER CO-AXIAL COUPLERS FOR SRF CAVITIES*

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Abstract

High Power RF couplers are required in a wide range of accelerator projects using superconducting RF cavities. There are a number of coupler designs for different SRF cavities, with various coupler window shapes. A majority of the SRF cavities adopt dual window design, partly due to the concern of reliability. We have proposed a novel robust coax dual window SRF coupler design using two pre-stressed disc windows [1, 2]. The matching at certain frequency is achieved by choosing the window spacing so that the RF reflected from both windows will cancel each other, without the need of additional matching elements.

We have fabricated such a dual window assembly with the dimensions of the EIA 3-1/8 50 Ω coax line. Larger sizes can be used if higher power handling capacity is desired. The assembly were originally designed to match at 400 MHz. Low power tests showed good agreement with the design. Without active cooling, the assembly was tested with travelling wave and standing wave up to 12 kW CW at 1.5 GHz with matching irises.

In this paper, we will present our latest progress in the fabrication and testing of the windows.

INTRODUCTION

In an ideal transmission line, two identical 0-thickness reflective elements with $(2n+1)/4\lambda_g$ (n is an integer) spacing can have their reflection cancelled completely. This allows us to design a dual coax window achieving perfect match at certain frequency by simply adjusting the spacing between the windows. Due to the multi-reflection inside the windows, the exact window spacing required also depends on the thickness and the dielectric constant of the window. Usually the optimum electrical length of the window center-to-center spacing is smaller than $\lambda_g/4$.

The design of this window has been discussed in our previous publications [1, 2]. The prototype window is designed with the dimensions of the EIA 3-1/8 50 Ω coax line (76.9 mm OD and 33.4 mm ID) and a ceramic thickness of 7.6 mm (0.3”). Given the dimensions and the ceramic dielectric constant, the optimum spacing for different frequency can be obtained by solving the cascaded S-matrix equation, or by using finite element solvers. This prototype has originally chosen a frequency of 400 MHz, which is for the BES Compton Light Source accelerator. With ε_r=9.5, the optimum spacing is about 157 mm.

One main factor limiting the power handling capability of RF windows is the stress due to non-uniform heating from RF losses. The disc window design also allows us to use the compression ring technology, which can provide better thermal conduction at the braze joint and can pre-stress the window, both leading to higher power handling capacity. Another novel technique we adopted is the “explosion bonding”. A thin layer of copper is bonded to the stainless steel outer tube by explosion. The tube serves as outer conductor, vacuum assembly and compression ring in one piece, and will possibly host the cooling channel. Simulation shows that this window should be able to withstand at least 100°C of temperature difference across the ceramic window.

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FABRICATION PROCESS

We adopted the two-stage brazing for this dual window. Unlike the regular brazing process for single coax windows, the two ceramic windows were brazed to the inner conductor first (Fig. 1), and then brazed the sub-assembly to the outer conductor (Fig. 2). This procedure ensures precise control of window to window spacing, without introducing obtrusions at the inner surface of the outer conductor.

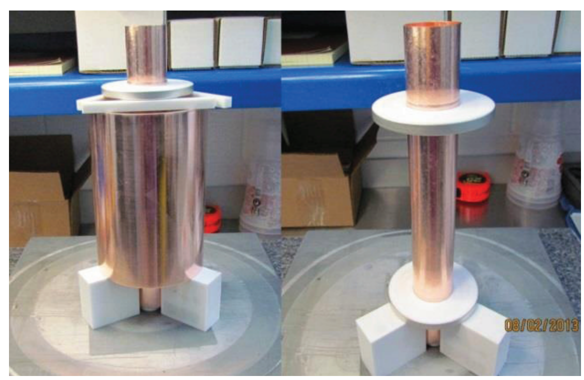

Figure 1: Inner conductor braze. Left: setup before brazing; Right: sub-assembly after brazing.

Figure 2: Outer conductor braze setup with the molly keeper ring.

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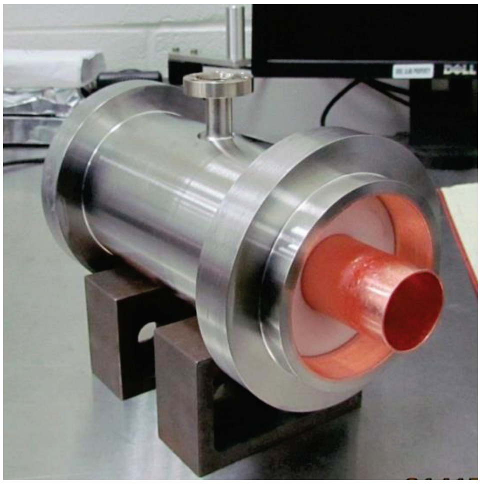

Figure 3: Finished dual window assembly.

After the inner conductor had been brazed, we found leak in one of the braze joints. Several repair runs couldn't fix it. Nonetheless, we proceeded with the outer conductor brazing and it came out leak tight, probably due to the compression during the brazing.

TESTING AND RESULTS

Low Power Testing

We have shown that the window has perfect matching at ~390 MHz with a -30 dB bandwidth of about 30 MHz in [2]. Figure 4 shows the window's 2nd notch measured with a network analyzer at 1.236 GHz, corresponding to a window spacing of ~3/4 wavelength. The high power test of the window was conducted at the JLab window test stand using a 1497 MHz klystron. The window needs to be matched to this frequency with irises. We built a pair of aluminium irises with one viewport on each piece, as shown in Fig. 5. The S-parameters measured with matching irises are shown in Fig. 6. The notch frequency is at 1.503 GHz.

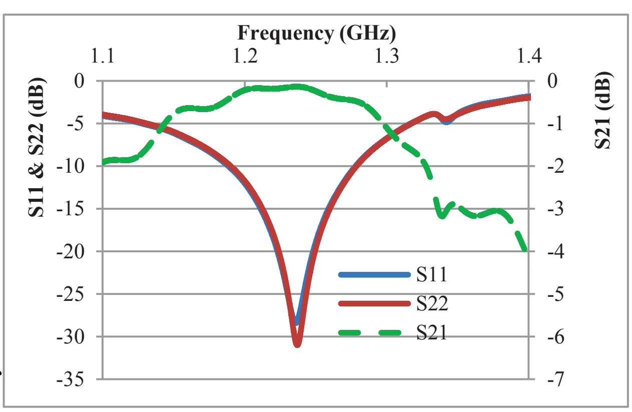

Figure 4: S-parameters for the low power RF test with inner conductor sub-assembly and mocking outer conductor.

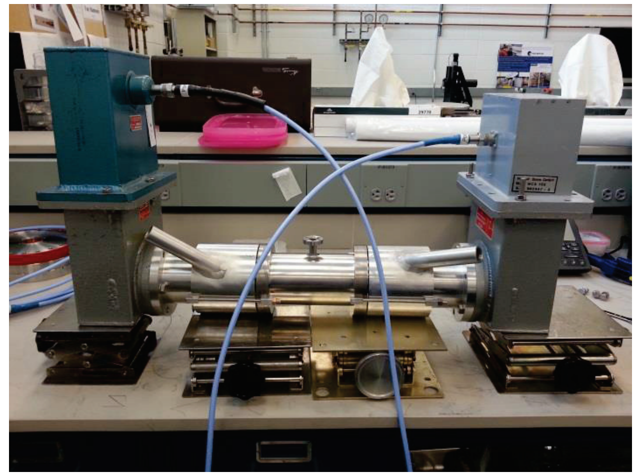

Figure 5: Dual window assembly low power RF test setup with matching irises.

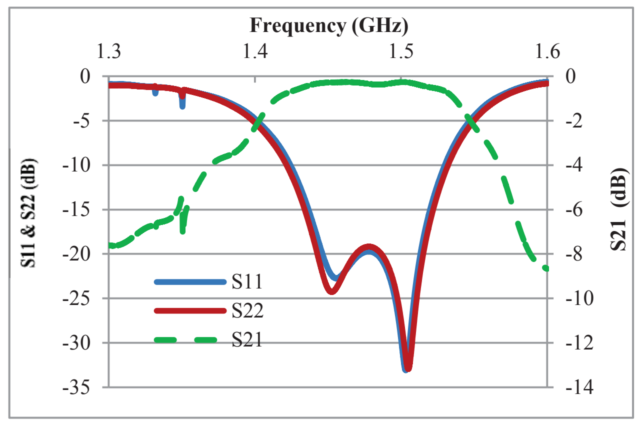

Figure 6: S-parameters for the low power RF test with matching irises.

Besides the network analyzer measurement at room temperature, we also made a liquid helium (2 K) cold cycle shock test with a previously brazed single coax window. The window came out leak tight.

High Power Testing

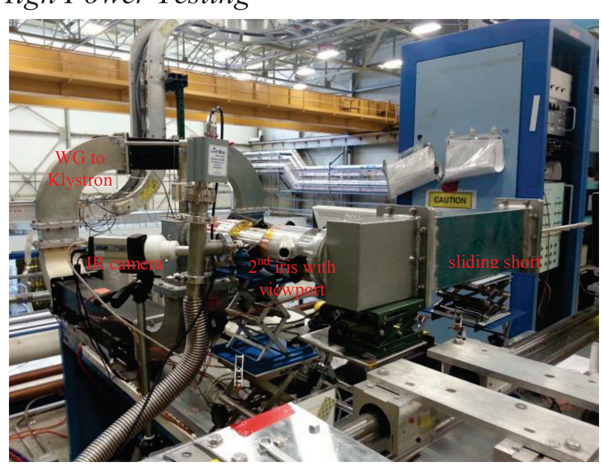

Figure 7: High power standing wave test setup; the traveling wave test used a water load to replace the sliding short in this figure.

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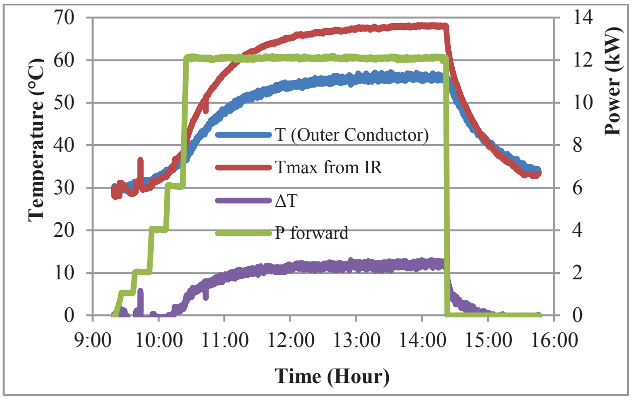

Figure 8: Traveling wave high power test results.

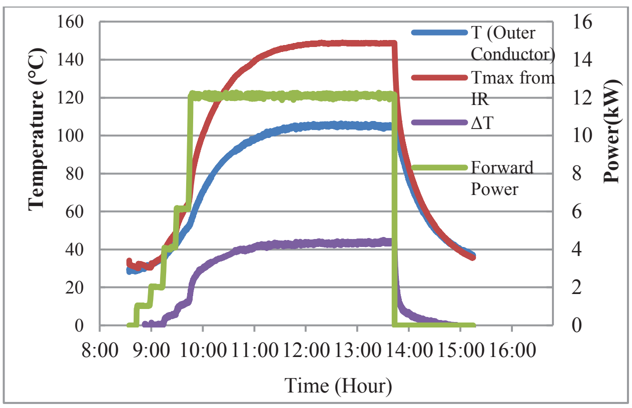

Figure 9: Standing wave high power test results.

We have tested this dual window assembly at the JLab window test stand with a CW klystron. The setup of the standing wave test is shown in Fig. 7. The setup for traveling wave test is similar, except that a water load is used instead of the sliding short. An IR camera is used at one viewport to record the temperature across the window.

We first tested the window with CW travelling wave, ramping up the forward power to 12 kW. The reflected power is at the level of ~100 W. The IR camera was looking at the klystron window first, and then we checked the load side window to confirm that the temperature rise is not higher than the klystron side window. We tested the window both in air and under vacuum. All the travelling wave tests showed similar temperature behaviour, with 12 °C temperature difference shown in Fig. 8 after 4 hours of 12 kW run.

During the standing wave test, the camera was looking at the klystron side window. We first tuned the sliding short to maximize the temperature rise at about 3 kW, and then made a run at 12 kW for 4 hours. The temperature difference shown in Fig. 9 is about 44 °C, which agrees with the travelling wave test results and is well below the limit predicted by simulation.

The viewport tube has a small diameter to minimize RF leak, so it occupies only a small portion of the camera view angle. A photo camera view in Fig. 10 helps to locate the hot spot.

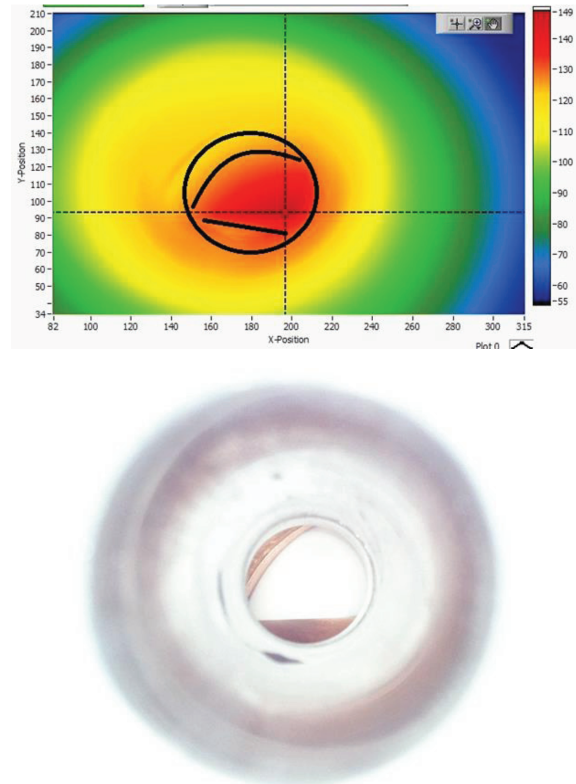

Figure 10: IR camera image (upper) compared to a photo camera image (lower). The black circle in the IR image corresponds to the edge of the viewport, the arc represents the outer braze joint, and the straight line is the inner conductor.

CONCLUSION

We have demonstrated a novel dual window coax high power coupler design using pre-stressed disc windows. Low power measurement agrees well with simulation. The window has passed 1.5 GHz 12 kW CW high power testing under both traveling wave and standing wave, with the potential to handle more power. A single coax window using similar process survived 2 K cold shock test leak tight.

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