High Power Window Tests on a 500 MHz Planar Waveguide Window for the CESR Upgrade*

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ABSTRACT

We describe the low power and high power performance of planar waveguide windows designed and fabricated by Thomson Tubes and tested at LNS. These windows are intended for use in the phase III upgrade of CESR.

INTRODUCTION

In the recent CESR beam test of the SRF cavity we used a planar waveguide window designed and built by Premier Microwave, shown in Fig. 1. As reported in [1], this window was tested off-line at 500 MHz with 250 kW traveling wave power and 125 kW reflected power. The conditioning time to reach 250 kW was about 200 hours, with vacuum bursts as the most frequent trip event. When the SRF cavity was installed in CESR[2], the maximum beam power supplied to a 120 mA beam through the window and SRF cavity was 155 kW, again limited by vacuum bursts during window conditioning in the presence of beam and with the cavity on resonance. For the phase III upgrade of CESR, we need to supply 325 kW to the beam. We plan to continue high power off-line tests on the Premier window.

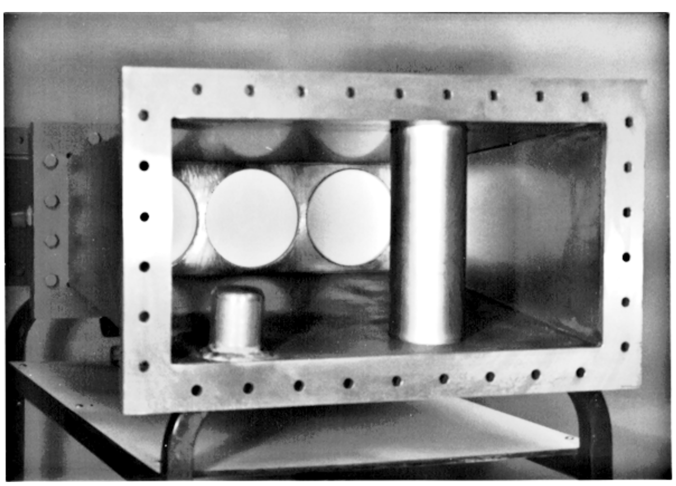

Fig. 1: Premier Microwave window with three BeO disks. Full height WR 1800 waveguide, air side is shown.

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THOMSON WINDOW

We also started to evaluate a 500 MHz planar window design from Thomson. The design is as shown in Fig. 2 and Fig. 3. The disk is alumina ceramic and coated on the vacuum side with TiN.

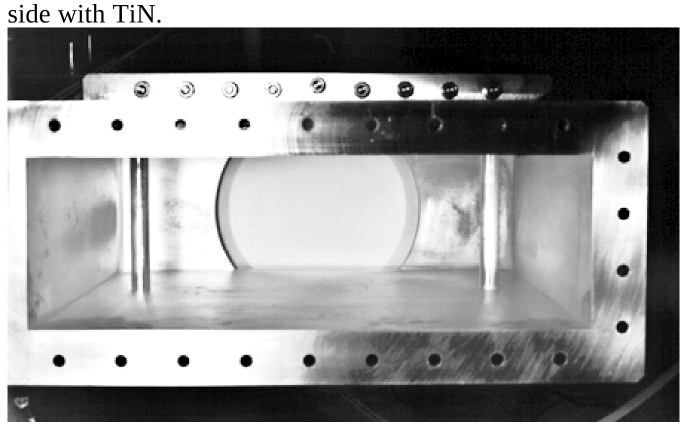

Fig. 2 Thomson Window with one alumina disk. Half-height WR 1800 waveguide, vacuum side is shown.

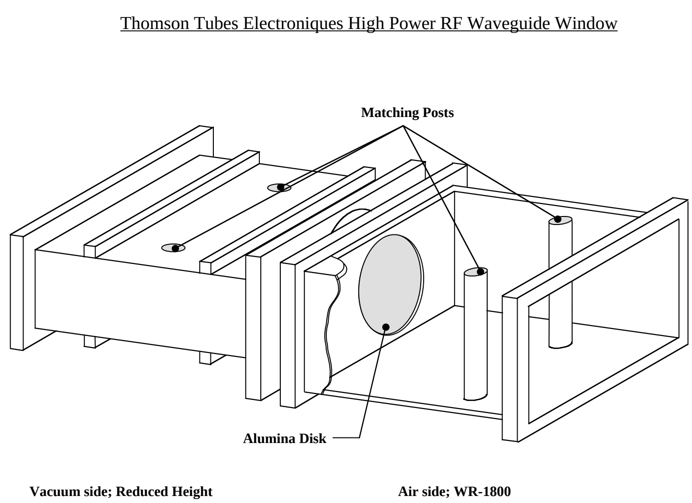

Fig. 3: Schematic layout of Thomson window showing ceramic disk and matching posts.

The VSWR of each window was measured at low power using the TRL method with an HP network analyzer. The geometry of the window was also studied using the MAFIA program. Fig. 4 compares the measured and calculated VSWR, about 1.04 at 500 MHz.

MAFIA calculations also give the electric fields in the window assembly region, and these are shown in Fig. 5. We note that similar MAFIA studies on the Premier window revealed that the maximum electric field between the posts and the window region was nearly a factor of 5.0 over that of WR 1800 as compared to a factor of 2.0 for the Thompson window, as shown in Fig. 6.

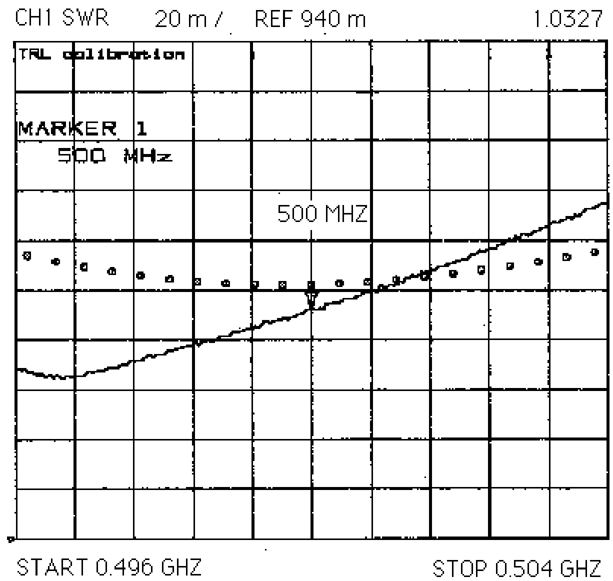

Fig. 4: Measured (line) and calculated (circles) VSWR for the Thomson window.

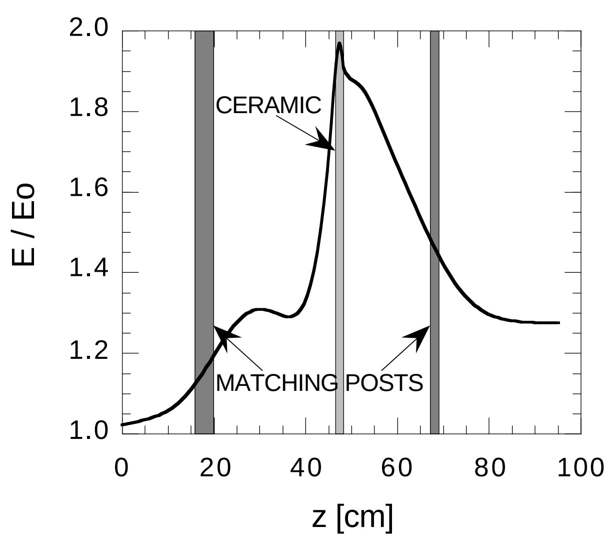

Fig. 5: Enhancement of electric field on axis over that of WR 1800 waveguide due to ceramic and matching posts in the Thomson window.

HIGH POWER TESTS ON THE THOMSON WINDOW

After cleaning, two of the Thomson windows were assembled in a clean room using Helicoflex seals to a copper vacuum pump-out waveguide box which had stainless steel end flanges. The pump-out box had ports with ZnSe windows to view the temperature of the ceramic disks with an infra red camera. (See Fig. 7) Three light detectors were used to monitor arcing, one on the air side of each window and one in the common vacuum region. An electron pick-up probe was also installed in the vacuum box. The entire assembly was baked at 225 C for 2 days, and the final vacuum was $3x10^{-9}$ torr at room temperature.

In the traveling wave mode at 500 MHz, we were able to reach 100 kW CW without any significant processing events. Above 100 kW, vacuum bursts started to trip the rf when the vacuum exceeded 10^{-7} torr. These bursts degraded the vacuum quite substantially and it took several minutes to recover.

At this stage we switched to an automated pulsed processing routine. Each time the rf level was raised by 1 kW, the duty cycle of the rf pulses was reduced to a few %, then progressively increased back to 100%. Once the CW conditions were stable at the new power level, the command power was increased by 1 kW and the pulsed procedure repeated. When there was an rf trip in the pulsed mode, we noticed that the electron pick-up current would rise for that pulse. There was no electron current for rf pulses which had no trip. This observation points to multipacting as the cause of the vacuum bursts. Pulsed power processing was also very slow, with substantial off time due to vacuum recovery.

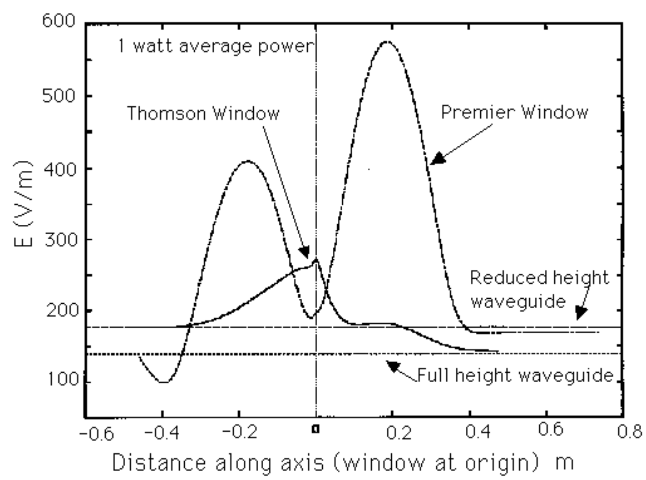

Fig. 6: Comparison of the electric fields for two types of window assemblies.

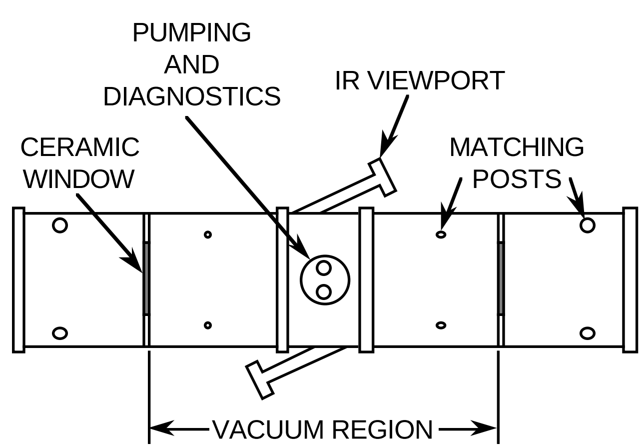

Fig. 7: HIgh power test set up schematic.

Fig. 8: Typical high power processing set up showing two windows and two 300 kW water loads.

TICKLE PROCESSING

To limit the severity of the vacuum surges, a new method of pulsed processing was applied. We call it "tickle processing". As we continued to use the pulsed processing program, we superposed 20 - 50 kW, 100 μsec wide pulses on top of the primary rf pulses as shown in Fig. 8. In this way we limited the magnitude of the vacuum bursts and improved the efficiency of the processing achieving much swifter progress. Fig.9 shows that the rate of processing to 300 kW CW was 20 hours. The highest power achieved was 430 kW at 33% duty cycle.

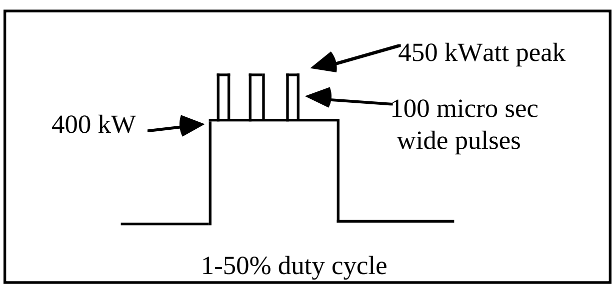

Fig. 9: Tickle processing with primary power 400 kW.

Periodically through the processing stage, we measured the temperature of the ceramic disks with the IR camera. At 250 kW CW, one disk reached $\Delta T = 37$ C and the other 56 C. The temperature profiles across the disks were cylindrically symmetric. Calorimetric measurments show that the window was absorbing 80 watt at 250 kW travelling wave. MAFIA calculations confirm this absorption level assuming a loss tangent of 10^{-4}. At 300 kW CW, the hotter disk reached 66 C, near the maximum temperature recommended by the supplier. Running CW above 300 kW was also troublesome for our aged klystron. Therefore we continued at 50% duty cycle to 350 kW and at 33% duty cycle to 430 kW. We believe that at these duty cycles, we have already carried out the needed conditioning.

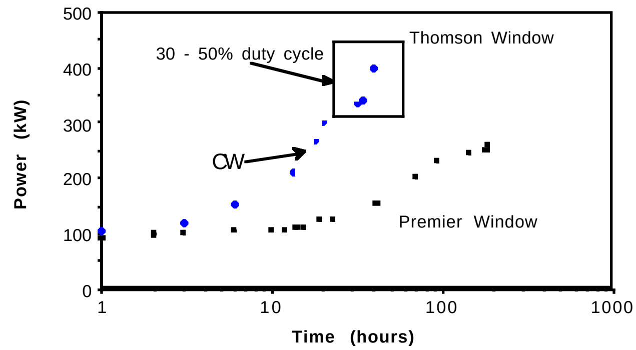

Fig. 10: Conditioning time for two Thomson and two Premier windows.

REFLECTED POWER TESTS

At a duty cycle of 50%, the input power was set constant at 125 kW and the terminating load was replaced by a short. The location of the short was changed in 5 cm steps for a total of 5 measurement positions. The maximum temperature recorded for window #1 was $\Delta T = 40$ C and for window #2 was $\Delta T = 63$ C.

FUTURE PLANS

We plan to replace our old klystron with a 600 kW unit in the near future and to continue high power tests. Meanwhile, stress calculations are in progress to determine the maximum tolerable ΔT. We also plan to provide for air flow cooling on the air side of the ceramic to proceed to 400 kW CW. For final use in CESR, we anticipate placing the window at an electric field minimum position for no beam present. This will allow us to tolerate the maximum possible power in full reflection, which is desirable for high power processing of field emission in the SRF cavity.

REFERENCES

[1] D. Metzger et al, 1993 Particle Accelerator Conference, p. 1399.

[2] H. Padamsee et al, this conference.