Prototype 500 MHz Planar RF Input Window for a B-Factory Accelerating Cavity*

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INTRODUCTION

The Laboratory of Nuclear Studies is proposing an upgrade to the existing CESR electron positron storage ring to make possible the study of CP violation of B meson decays. This "B-Factory", because of the required luminosity and the resultant high beam current, will require very high RF power levels to replace the synchrotron radiation and the HOM (higher order mode) energy losses of the beams.

The proposed design at this time[1][2] would require 16 superconducting cavity structures, each with an RF input power of approximately 400 Kilowatts at 500 MHz.

DESIGN REQUIREMENTS

This power level for a cavity window is rather high by present day standards. Klystrons commonly in use at this time have achieved above this power level using coaxial RF vacuum windows in this frequency range. These windows, in spite of their reliability in Klystrons, have not been shown to be easily adapted to application on accelerating cavities. The reasons for this are as follows; 1) the vacuum in Klystrons is usually better than in accelerating cavities. 2) extreme care is taken with Klystrons to assure that there is very low reflected power back to the Klystron and therefore no standing waves at the window, and 3) in a cavity there may be present HOM power that alters the magnetic and electric fields present at the window, possibly exciting some high frequency resonances associated with the window structure.

In an accelerating cavity and in particular in a superconducting accelerating cavity, with heavy beam loading, the input coupling is usually adjusted to be critical (β=1), that is, with no reflected power at full beam conditions. In the situation of zero beam current the input is overcoupled and therefore, in the case of superconducting structures, essentially all of the input power is reflected. This assumes that the coupling cannot be dynamically adjusted. This condition of high reflected power cannot be avoided because there exists the time before the beam in injected as well as the time after the beam has been lost. In other words, the incident power level can be controlled but the fraction of this power to be reflected will be determined by β which is determined by Q_L of the cavity for fixed coupling. The value of Q_L is determined by the Q_O of the cavity (very high in the case of a superconducting cavity) and the beam loading. In the case of the B-Factory cavity the curve of possible P_r (power reflected) versus P_i (incident power) is shown in figure 1. In this curve, any input power level above 125 Kwatts would maintain the cavity voltage and would be capable of maintaining increasing amounts of accelerated beam currents. The curve assumes that the coupling has been set to β=1 corresponding to input power of 500 Kwatts.

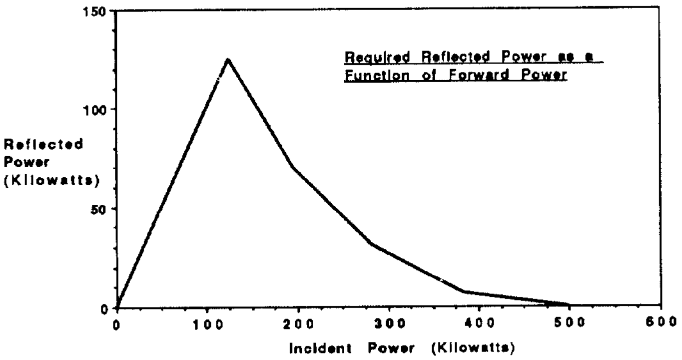

FIGURE 1

The other requirement is that the VSWR of the window be low in order to avoid loss of incident power and to prevent window damage due to heating or arcing because of excessive current or voltage at the required incident power level of 500 Kwatts.

One feature of the requirements is as follows. The reflection of the power from the cavity due to a coupling mismatch ($\beta \neq 1$) comes from a fixed reflection point, probably the coupling iris. This means that the VSWR phase pattern is spatially fixed in the input waveguide. Knowing where the voltage maximums and the current maximums are located along the waveguide, the window can be placed at the most advantageous position or phase for its survival.

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[1] Cornell Univ. Internal Report, CLNS 91-1050

[2] Cornell Univ. Internal Report, CLNS 90-1039

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WINDOW DESIGN

Several coaxial windows are in use on superconducting cavities at this frequency up to power levels of 200 Kwatts. To accommodate the higher power levels, it was decided to investigate the feasibility of a planar waveguide vacuum window.

Several qualified commercial manufacturers were requested to propose a design which they felt would meet our requirements and which they could economically produce. Two proposals were satisfactory and the proposal of Gamma Microwave[3] was chosen for development. The window that they designed incorporates the following features;

- WR1800 Planar Waveguide window.
- Beryllium Oxide ceramic.
- All metal parts are copper or Stainless, no Kovar.
- The Ceramic is brazed directly to Copper.
- The window has anti multipacting coating.
- The unit is water cooled.
- The unit is compatible with vacuum baking.
- The unit will have low VSWR over sufficient bandwidth.
- The vacuum side is reduced height WR1800.
- The window uses 3 small ceramic disks.

A drawing of the window is shown in figure 2. In the process of the detailed electrical design, GAMMA used 1 Mwatt traveling wave as the design objective.

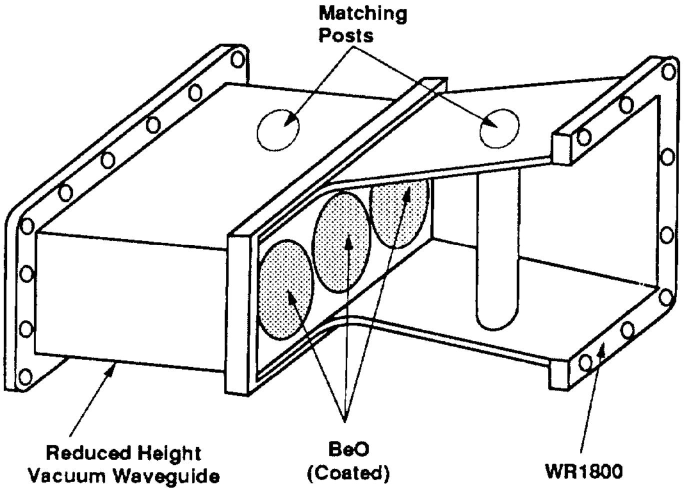

FIGURE 2

The responsibility for high power testing of the window was left to Cornell. While it would have been desirable to have purchased a tested window with guaranteed performance, the cost would have been much higher for two reasons; 1) the manufacturer would have had to purchase and operate a high power transmitter facility and 2) extra contingency would have been placed in the price to cover the risk involved in guaranteed performance.

In order to be able to test the window design at full power under vacuum, two windows were required. If two windows were not available, then the high power load would be required to operate in a vacuum (as does the final cavity with beam current).

LOW POWER MEASUREMENTS

Low power measurements were made using a Network Analyzer, a WR1800 full height to half height taper and WR1800 to type N adapters. Measurements were made of VSWR, transmission, and phase shift of each window as a function of frequency. The results are shown in the following graphs; figure 3A - VSWR, figure 3B - power transmission, figure 3C - Phase shift through the window and a taper, and figure 3D - the calculated electrical length of the window, all versus frequency.

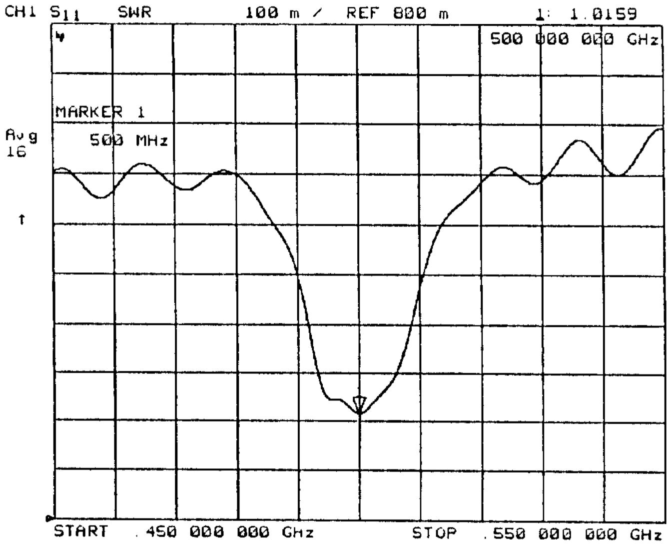

FIGURE 3A

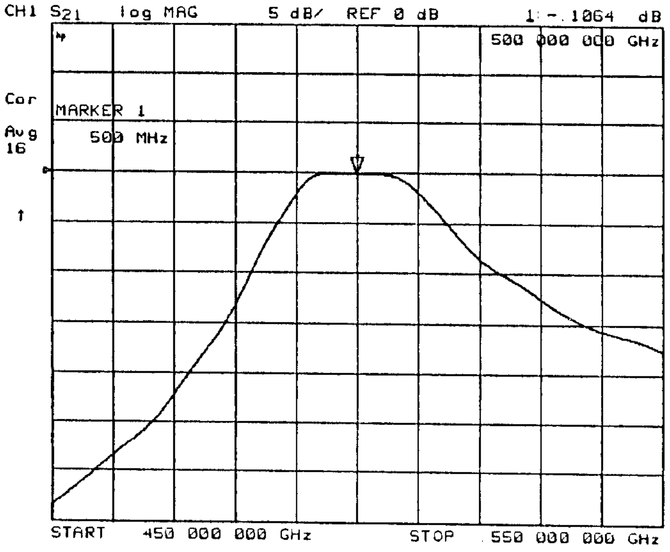

FIGURE 3B

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[3] GAMMA Microwave, Santa Clara,CA 95054

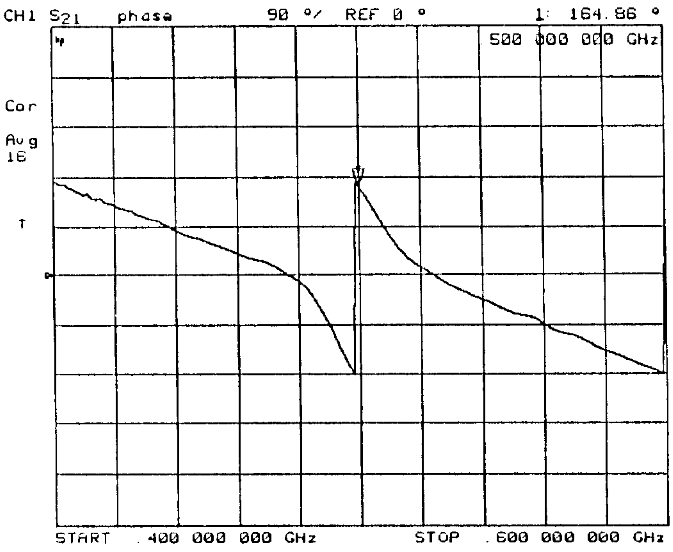

FIGURE 3C

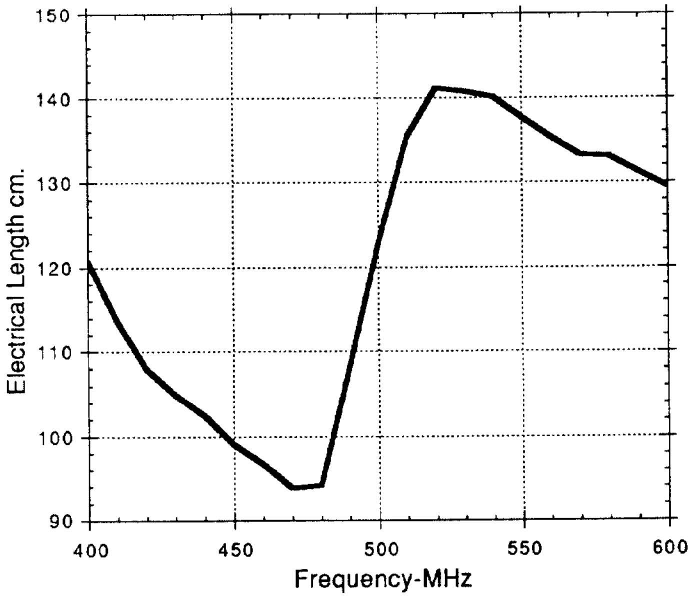

FIGURE 3D

As can be seen the VSWR was less 1:1.05 over ± 5 MHz, there was no measurable transmission loss, and the phase shift was a smooth function of frequency.

HIGH POWER MEASUREMENTS

In order to determine the capability of the windows to operate at the 500 Kwatt power level a series of three tests were planned. The first test is a medium power test with a single window used as part of a resonant waveguide. This test was done primarily because of its simplicity, because it could be done before the second window was delivered, and because the test could be done with a 200 watt amplifier instead of the 500 Kwatt transmitter. The test set up is shown in figure 4.

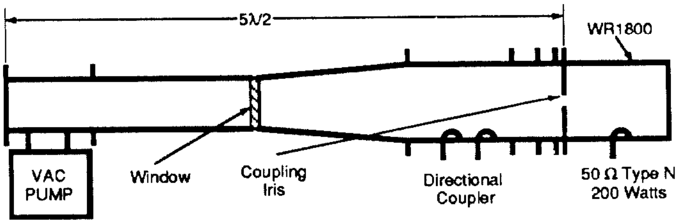

FIGURE 4

With the available 220 watts of input power, the resonant circulating power at the window was 26.8 Kwatts, 13.4 Kwatts in each direction.

The other two high power tests will include both windows and a high power transmitter consisting of a 500 Kwatt Klystron, a high power circulator and a 500 Kwatt high power RF load.. These 500 Kwatt tests have not yet been completed.

The first of these tests, as shown in figure 5, will subject the window to full transmitted power . In this test we will determine the capability of the window to operate at 500 Kwatts transmitted power corresponding to the full beam condition.

The second test, as shown in figure 6, will test the ability of the window to operate at high VSWR. We will be able to vary the phase of the standing wave pattern relative to the ceramic in order to determine the best place to locate the window relative to the cavity. This test will determine the capability of the window to operate at low or zero beam current conditions.

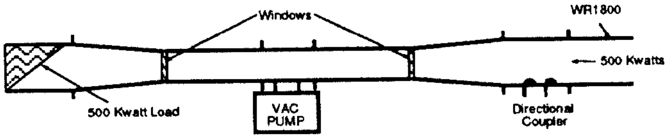

FIGURE 5

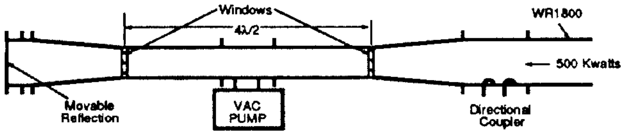

FIGURE 6

RESULTS

The test as described in figure 4 was completed. The circulating power in the resonant waveguide was measured to be 13.4 Kwatts in each direction, or 26.8 Kwatt total. The maximum temperature rise of the window cooling water was less than 3 degrees C. The vacuum base pressure before the test was 6 x 10^{-9} torr. During the test the maximum measured pressure was 7 x 10^{-9} torr.

Some temperature rise was observed in the hollow matching posts or tubes on each side of the ceramic. During this test the posts were near a current maximum. For the 500 Kwatt tests, these tubes will be cooled with circulating water.