DESIGN AND LOW POWER TESTS OF AN INPUT COUPLER

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Abstract

We describe the design of a prototype coaxial coupler intended as a possible candidate for the super-conducting cavities of the TESLA collider. The coupler employs a wave-guide to coaxial transition which is globally matched using reduced-height wave-guide and a thin ceramic disc window in the coaxial line at ambient temperature. A second, 'cold', window is formed from an identical thin disk. This window is of the travelling-wave type i.e. with matching elements up and downstream of the disc. We will discuss the design of the coupler and present results of low power RF measurements.

1 INTRODUCTION

A planar disc is the simplest conceivable geometry for the ceramic window in a coaxial coupler. The surface of such a window has the advantage of being parallel to the electric field of the TEM mode propagating in the coaxial line. This makes it inherently less likely to suffer from multipactor. "Half-wavelength" discs have been studied for coaxial lines as they have the merit of being matched [1]. However, the thickness of such ceramics (~ 38 mm for $\varepsilon_r = 9$ at 1300 MHz) means that they exhibit high dielectric losses. In addition it is not a simple matter to ensure a good metal-ceramic braze all along the length of such a window. The use of increasingly pure ceramics could be envisaged in order to reduce the losses but with the penalty of making the brazing operation all the more difficult. In this article we describe a coaxial coupler employing ceramic windows which are "thin" (relative to the RF wavelength) and, therefore, easier to braze.

2 DESIGN CONSIDERATIONS

The prototype discussed in this paper was designed with the requirements of the TESLA cavities in mind (resonant frequency = 1300 MHz). In order to be consistent with existing TESLA/TTF coupler designs our co-axial line has a 61.6 mm outer diameter (o.d.) and an inner diameter (i.d.) of 26.8 mm (50 Ω impedance),[2]. However, in contrast to previous designs in which the o.d. of the cold coupler part is reduced 40 mm, the 'cold' part of our coupler has the same inner/outer diameters as the warm part.

2.1 The Transition and Warm Window

Input power couplers for the TESLA cavities have two ceramic windows in order to provide some security in case of damage to one of them [2]. We have attempted to find a solution in which both windows are placed in the coaxial line. This obviates the need for a wave-guide (WG) transition which is vacuum tight thus making its manufacture simpler and hence, less expensive. To further reduce the complexity of the transition we have gone for a design without the familiar "doorknob" which normally matches the WG to the coax. Instead, we employ a 'global' matching from two elements; (i) a reduced height WG section just upstream of the coax, and (ii) an 8 mm thick ceramic window just downstream of the WG to coax transition. This form of matching inevitably results in some standing wave between the two elements but the calculated peak fields are not excessive (1.3 MV/m for 1 MW of travelling wave power). The required reduction in the wave-guide height was first estimated using HFSS simulations and then verified by low power measurements using a rectangular 'piston' which could be inserted a variable distance into the WG. The 75 mm long reduced-height section is bolted onto a WR650 WG transition which has been extruded from brass. For ease of manufacture of the prototype our ceramics, which are made from commercially available TS271 alumina (99.5% pure), have been brazed onto titanium sleeves (see figure 1) which are then welded onto titanium tubes terminated in titanium CF63 flanges .

Figure 1: Ceramic disk brazed onto titanium conductors

2.2 The Cold Window

An identical ceramic is used for the cold window. As the introduction of a thin ceramic introduces a significant return loss in a coaxial line, reactive elements have to be introduced to match the ceramic to the coax. This so-called 'travelling wave' window concept was first proposed by Kasakov [3]. The matching in our case is achieved by increasing the i.d. of the coax to 39.2 mm over a length of 19 mm centred at a distance of 42.2 mm

from the mid-plane of the ceramic [4]. Although this increase in the i.d. increases the electric field on the central conductor, once again HFSS simulations show that the fields are not excessively high, 1.2~1.4 MV/m for 1 MW of TW power as opposed to 0.9 MV/m for the standard coax dimensions (see figures 2a and 2b).
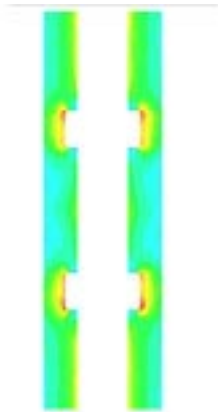

Figure 2a. Simulation of the electric fields around the TW window.

Figure 2b shows a plot of the radial electric field in the region of the ceramic (indicated by the red vertical bars) of the TW window. The enhancement of the field around the matching elements is clearly evident. The fact that the field variations are not very smooth probably indicates that the mesh employed for the simulation is not sufficiently fine for accurate calculation.
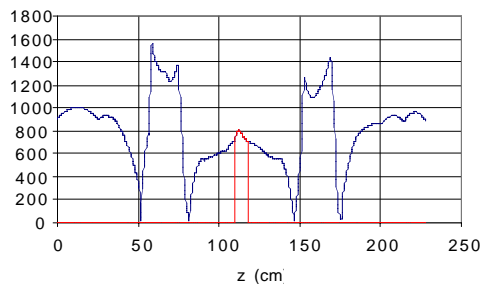

Figure 2b. Plot of the electric field along the inner conductor around the TW window.

The frequency response of the TW window and the coaxial antenna was measured separately from the transition. The measurements are performed with the antenna end of the coupler inserted into a 61.6 mm cylindrical sleeve attached to standard WR650 WG terminated in a matched load (Fig. 3).
Matching of the antenna to the transition at 1300 MHz requires the antenna to penetrate into the guide by a well defined amount [5]. The WG used was an existing piece built for another test and the length of the cylindrical sleeve fixes the length of the antenna on our prototype and hence the distance from the ceramic to the tip of the antenna. This distance would be considerably smaller on a real coupler. These measurements require the use of a
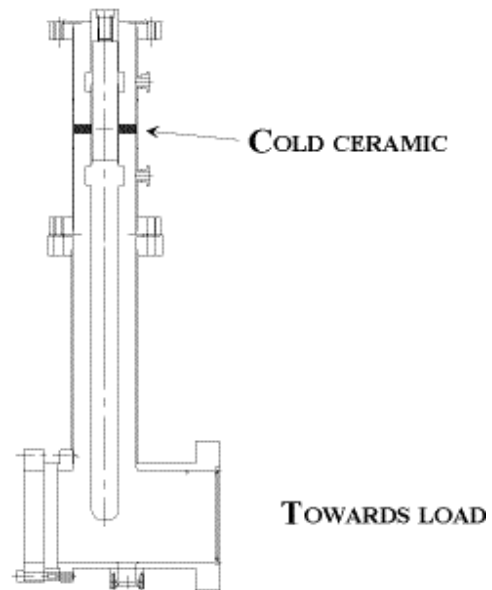

Fig 3. Schematic of the travelling wave window.

'custom built' conical coax adapter from a standard 'N' connector to the CF63 flange of the window. The measured response of the TW window and the antenna exhibits a very large 20 dB bandwidth (> 150 MHz, see figure 4).
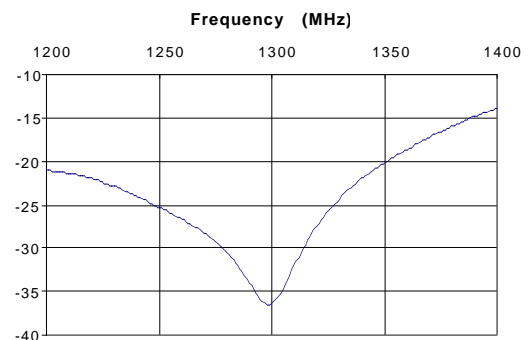

Fig 4. Frequency response of the TW window.

3 LOW POWER MEASUREMENTS

The low power measurements were performed on the complete prototype as shown in figure 5. The insertion loss and S11 response are shown as a function of frequency in figures 6 and 7 respectively. A puzzling feature of the measurements is the 20 dB bandwidth of the coupler, ~ 13 MHz, compared to a calculated value of ~ 27 MHz. For the time being we have no explanation for this discrepancy. Increasing the distance from the short-circuit plane of the transition to the reduced-height wave-guide by 1 mm, using a 'spacer', allowed us to centre the minimum of the S_{11} curve at 1300 MHz rather than the value of 1293 MHz shown in figure 7.

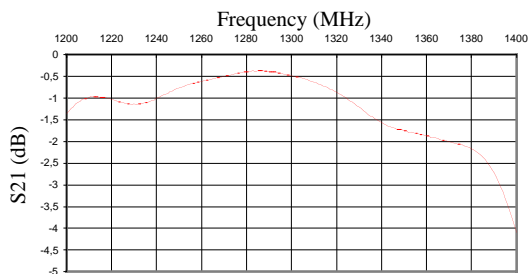Figure 5. Schematic of the prototype coupler.

Figure 6. Insertion loss as a function of frequency.

4 DISCUSSION

The measured insertion loss of 0.48 dB would be unacceptably high for a TESLA coupler. However, a definitive version of this coupler would be built from copper-coated steel parts which would greatly reduce the losses. In addition, to facilitate the mechanical mounting of the prototype we have used a 520 mm section of coax containing two pairs of inner/outer bellows which would not be used on the final version. However, even taking these points into consideration, one would not expect such a high insertion loss for the prototype. The HFSS simulations allow one to estimate the dielectric losses P_{diss}, expected in the ceramic;

$$ P_{diss} \sim \frac{1}{2} \omega \, \varepsilon \, \tan\delta \int E_r^2 \, d\tau \ , $$

where the symbols have their usual meaning. For typical values of the ceramic dielectric constant and loss tangent one would expect a contribution of ~ 0.01 dB per window with another ~ 0.01 dB from resistive losses in the coax. One assumes that the additional losses are due to the numerous flange connections which are needed for the sub-parts of the coupler (transition – window – coax with bellows – TW window – transition). A high-power version of this coupler would be built essentially from only two sub-parts, thus reducing the number of connections.
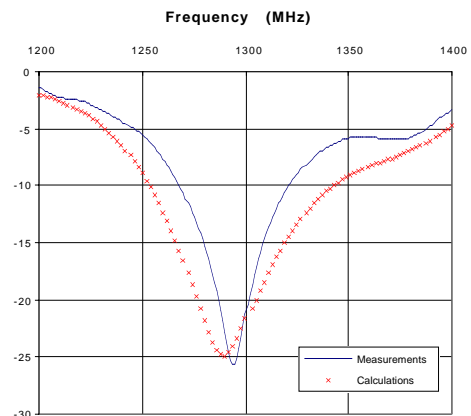

Figure 7. Return loss as a function of frequency.

5 FUTURE PLANS

At the time of writing an L-band modulator-klystron assembly, capable of providing RF pulses of up to 5 MW for 2 ms, is being installed at LAL. This equipment has been loaned by the DESY laboratory in the context of a collaboration between LAL and DESY. We intend to construct a version of the coupler described here for high power tests with this equipment.

6 REFERENCES

[1] S. Chel, M. Desmons, C. Travier, T. Garvey, P. Lepercq, R. Panvier, "Coaxial Disc Windows for a High Power Superconducting Cavity Input Coupler", Proceedings of the 1999 Particle Accelerator Conference (New York), pp 916-918.

[2] B. Dwersteg et. al., "TESLA RF Power Coupler Development at DESY," Proceedings of the 10th Workshop on RF Superconductivity (Tsukuba), 2001.

[3] Y. Kasakov, "Increased Power RF-Windows", BINP-Protvino Preprint 92-2, 1992.

[4] We acknowledge discussions with our colleagues from CEA-Saclay on the design of the TW window.

[5] M. Chanudet, "Etude d'une Transition HF Type « Antenne » Entre Guide Rectangulaire et Ligne Coaxiale", LAL pre-print, LAL-RT/97-03, July 1997.