POWER COUPLER DEVELOPMENT FOR SC CAVITIES

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Abstract

The TESLA input coupler has to transfer 200 kW of RF power to the beam and handle power levels up to 1 MW with short pulses for cavity and coupler processing. Some critical components, like waveguide to coaxial transition, cold window or copper plated bellows have been studied. A power test set up, equipped with various RF and optical diagnostics is installed to check the power capability of these components.

1 INTRODUCTION

The superconducting approach to a linear collider (TESLA) currently requires one input coupler for each 9 cell cavity. As 10,000 cavities are necessary for each 250 GeV linac the reliability of the input coupler is a major issue. The coupler must be capable of, (i) delivering the necessary power for beam acceleration (208 kW during 1.3 ms at 10 Hz) and (ii) providing high peak power pulses (1 MW for 100 ms) for in-situ conditioning. In addition to the RF requirements there are also mechanical and cryogenic constraints that must be respected [1]. At the time of writing two designs for such a coupler have been made, one at FNAL and the other at DESY. Although these couplers may yet meet the requirements for TESLA, there remains a strong interest in alternative coupler designs with improved or more economic features. Consequently, within the framework of the TESLA collaboration we are beginning to study the different problems related to a TESLA coupler with the aim of constructing prototypes.

2 WAVEGUIDE TO COAXIAL TRANSITIONS WITH DC BIAS

From CERN experience [2], the major problem for power capability of couplers for s.c. cavities comes from multipactor (MP). The cures to suppress MP is first the increase of the diameter and/or the impedance of the coaxial line and finally the DC bias at a few kV. Applying the same remedies, we decided to develop two types of transitions, both with a Ø60 mm coaxial line and DC bias. The first design, still under studies, is based on a transition with a cylindrical window and a DC voltage in the air side. Contrarily, in the second design which applies a doorknob transition (Fig.1), the DC voltage is in the vacuum side (the vacuum insulation is insured by a waveguide window).

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This doorknob geometry provides 140 MHz bandwidth at 1% of reflected power (Fig.2).

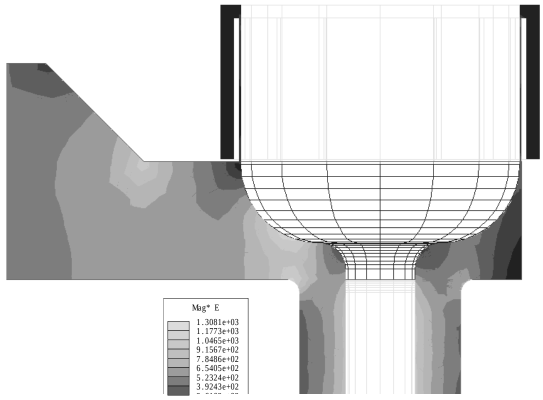

Fig.1 : Doorknob transition with a choke cavity for DC

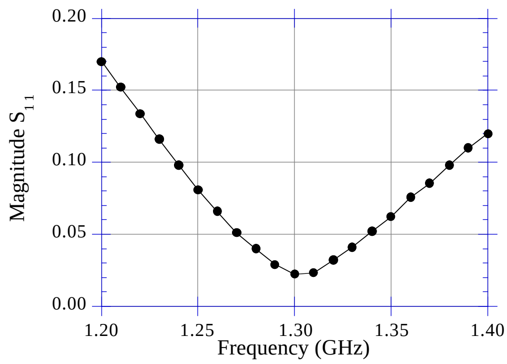

Figure: 2. Reflecting coefficient (S_{11}) vs. frequency for doorknob-type transition.

To prevent RF radiation through the radial slit necessary for the DC bias, a choke cavity is inserted. It consists of two quarter-wavelength lines with different impedances in such a way that it increases the bandwidth and reduces the wall current in the outer line. The insulating ceramic is installed in the gap between these two parts, i.e. in an open circuit location. Estimations show that the maximum voltage in the choke is 70 V (for 200 kW TW RF power), which is under the MP threshold, and that the RF radiations from the choke are negligible.

3 MULTIPACTOR STUDIES ON WINDOWS

The coaxial cold RF window of the TESLA coupler must insure the vacuum isolation, evacuate the heat coming from the inner conductor and be mechanically robust. Electron multipacting, induced in the vicinity of windows, often limits the power capability of the coupler and can even lead to breakdown through electron bombardment of the ceramic. For that reason, we decided to investigate the behaviour of different types of windows with numerical simulations of multipacting trajectories. In addition, power tests of these windows are planed in the RF test set up described below (Part 5). A numerical code calculating multipacting trajectories in any axisymmetric structure was developed. It uses the field distributions computed by the cavity code URMEL-T [3] and build standing waves or travelling waves from two field computations. A primary electron is first emitted from the alumina surface, when the local fields drive it towards the vacuum. When the electron impinges a wall (ceramic or copper part), secondary electrons can be emitted. Their number is determined by the secondary emission yield, which depends on the kinetic energy of the incident particle. The total number of re-emitted electrons is computed after N impacts either on the alumina or the copper surface. A complete scan of the ceramic surface, of the incident power and of the RF phase, provides an idea of the width and of the strength of multipactor bands.

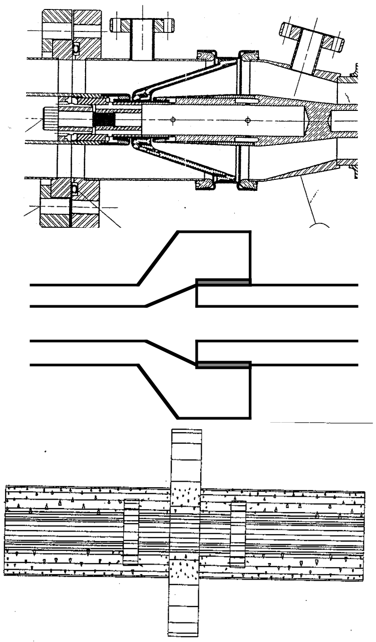

Figure 3 : Conical (upper), cylindrical (middle) and TW disc (bottom) windows

Three different types of window were tested (Fig.3) : the conical window developed by FNAL [1], a modified version of the cylindrical window developed by DESY [4], where the outer diameter has been enlarged to 60 mm instead of 40 mm and the TW disc window proposed by CEA-Saclay [5]. For the third disc window, the principle of Travelling Wave Ceramic, proposed in [6] was applied to a coaxial-type coupler. Each side of the disc is matched by capacitive elements (irises), such a way that a pure travelling wave can be established inside the ceramic. The matching does not depend on the thickness of the ceramic and the bandwidth is very large. The effective field strength is hence reduced and, besides, the TEM wave, without axial Ez component, is preserved in the window region, preventing for multipactor phenomena onto the ceramic.

Results of simulations showed that the conical window exhibits numerous multipacting trajectories, especially when it is located at "voltage maximum" of standing waves. For example, Fig. 4 shows multipacting trajectories of order 4 involving the ceramic solely, moving back and forth at the same position of the conical window. Two-points multipactor of order 1, involving copper conductor and alumina cone could be also harmful.

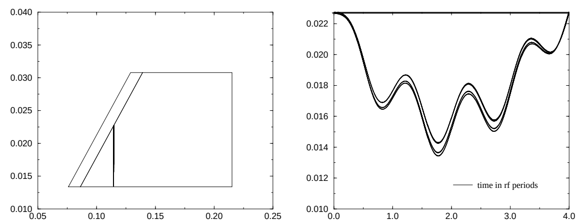

Figure 4 : Multipactor of order 4 involving ceramic in r-z plane (upper) and r-time plane (bottom)

Fig. 5 shows the total number of emitted electrons after 20 impacts at different input power levels for the upstream and downstream sides of the conical window, located at "voltage maximum". The standard curves of secondary emission yields vs. impacting energy for copper and alumina without Ti coating were used in the simulations.

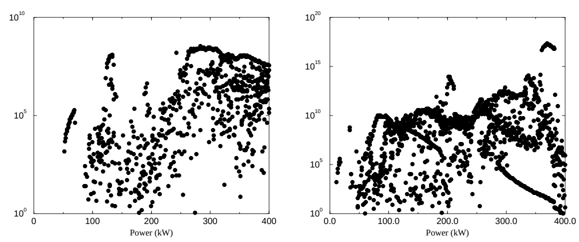

Figure 5 : Total number of emitted electrons after 20 impacts for the conical window at upstream (upper) and downstream (bottom) sides.

A few suspicious multipacting trajectories, which seem very geometry sensitive, were observed for the initial cylindrical window, connected to a coaxial line of 40 mm outer diameter. However, no multipactor trail could be disclosed, when the window was re-designed with a larger 60 mm outer diameter. As expected, no multipactor starting from the ceramic surface was found in the coaxial TW disc window, where the electric field is tangential to the alumina surface.

4 PARTICLES IN COPPER PLATED BELLOWS

Bellows are necessary for flexibility of the coupler. In order to limit the RF losses, these bellows are copper plated but this can cause contamination of the s.c. cavity. In the aim to compare procedures and treatments of copper plating on s.s. (316L) bellows, we installed in clean room (class 100) a test stand composed mainly by a long tube (one end located under the air flow of the clean room) connected to the bellow itself and a transition which carries the METONE particle counter (size of the detected particles in the range 0.16 to 5µm). An internal pumping system insures that all the particles emitted from the inside of the bellows are carried by the air flow and detected by the laser head of the counter.

For comparison between the results, the following protocol has been defined :

- 5x1min. without deformation of the bellow (noise)
- 10x1min. with 50 compressions of 10mm per min.

The tested Cu-platings (thickness about 10µm) have been done by galvanic deposition (Flühmann and Silvex) and magnetron sputtering (CEN-Grenoble). In addition, different preparations have been performed : "as received" (A), rinsing in ultra sonic bath (B), 5 bars rinsing (C), immersion in alcohol (D), passivation with chromic acid (E) and drying in clean room (F).

Part. size	Plating	Treat-ment	noise mean	noise rms	detected part. mean	detected part. rms
>0.30	Silvex	A	0.0	0.0	7.6	8.2
>0.30	CEN-G	A	0.0	0.0	0.7	1.6
>0.30	Silvex	B+C+F*	0.0	0.0	10.0	10.2
>0.16	CEN-G	A	2.3	1.0	2.6	1.8
>0.16	Flühm.	A	1.8	1.8	2.2	1.0
>0.16	Flühm.	HT**	1.6	1.5	1.9	1.5
>0.16	CEN-G	C+D+F*	4.3	1.5	65.0	47.0
>0.16	CEN-G	E+C+F	2.0	1.4	4.8	4.6

* Strong oxydation of the copper after treatment

** Heat Treatment : 350°C (1hr30')

With these first results (table above), some bellows showed a low particle contamination when tested as received whatever the methodused for the plating. We noted also a dramatic increase of the number of particles after a water rinsing (ultrasonic bath, immersion in pure water, 5 bars rinsing) and a drying in clean room, due to the presence of oxide, but the passivation with chromic or sulfamic acid seems to be a possible cure. Up to now, the heat treatments (about 400°C) have no influence on the particle contamination. We planed to make some more tests by drying with warm nitrogen gas or baking under vacuum instead of drying in the clean room in order to determine a cleaning protocol insuring that the particle contamination due to bellows is as small as possible.

5 POWER TEST STAND

For testing critical elements, we installed a 1300 Mhz power source delivering 1MW/1ms or 2MW/100µs with a repetition rate of 0.1Hz. The tested elements are connected to a 5 meter long WR650 waveguide under vacuum, ending with a short . By changing the frequency, the location of the max. or min. of E field can be shifted. Various diagnostics are implemented: electron pick-up antenna, PM (UV + optical range), vacuum gauge, light spectrum analysis and video camera. Up to now, we have tested a waveguide window (TH 20141A) with one side under vacuum. After outgassing of the window and the stainless steel guide, one can reach vacuum of 10^{-8} mbar. For different frequencies, the RF power is increased up to a maximal value defined such as the vacuum (measured close to the window) reaches 3.10^{-8} mbar. The result (Fig. 6) showed that it is possible to reach the klystron limit (1.6 MW) when the window is located at a min. of E field. For the other frequencies, the vacuum reached the limit, and we noted electron and light signals. The next step is to add two doorknobs to the long waveguide for testing coaxial windows.

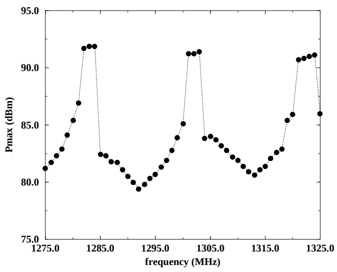

Fig. 6 : Power limitation for a vacuum<10^{-8}mbar on a waveguide window (pulse length = 200µs).

REFERENCES

[1] M. Champion, "TESLA input coupler development", Proc. of the '93 PAC Conf., Washington (p 809)

[2] J. Tuckmantel et al, "Improvements to power couplers for the LEP2 superconducting cavities", to be published in Proc. of the '95 PAC Conf., Dallas

[3] T. Weiland, Nucl. Inst. and Meth., 216, 1983

[4] B. Dwersteg et al, "Conceptional Desig n of a RF Input Coupler for TESLA", Proc. of the HEACC 92, Hamburg (p 954)

[5] X. Hanus and A. Mosnier , "Coaxial TW Window for Power Couplers and Multipactor Considerations", SCRF Workshop, Gif-sur-Yvette, Oct. 1995

[6] Yu. Kasakov, "Increased Power RF-Window", BINP Preprint 92-2, Protvino, 1992