Update on the Broadband Waveguide to 50 Ω Coaxial Transition for Parasitic Mode Damping in the DAΦNE RF Cavities

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Abstract

A novel device has been conceived to allow the dissipation of the parasitic mode beam power of the DAΦNE RF cavities on a broadband coaxial 50 Ω load. This avoids the use of RF lossy materials in the waveguides in ultra vacuum. This paper summarizes the project criteria and the experimental tests performed on prototypes made of Aluminum. Furthermore, up-to-date results at high power in under vacuum copper models are reported.

1. INTRODUCTION

The Φ-Factory DAΦNE [1] is under construction at the INFN, Laboratori Nazionali di Frascati. It is a multibunch double ring collider providing e^+/e^- 1020 MeV center of mass collisions at a maximum repetition rate of 368.25 MHz with 47 mA per bunch.

An inherent drawback of multibunch operation of a storage ring is the coupled bunch instability that can arise from the interaction of the particles with the high order modes (HOM) induced in the RF cavities by the preceding bunches. Damping the HOMs of the accelerating cavities is considered the most powerful remedy to this problem; different techniques have been developed depending upon the type of cavity (i.e. normal or superconducting) and the accelerator requirements.

In normal conducting cavities, rectangular waveguides (WG) can be directly applied onto the resonator to extract the HOM energy and dissipate it on matched loads. As an R&D for the DAΦNE project we have tested [2,3] a single cell cavity prototype equipped with three rectangular WGs with cut-off at 492 MHz. The position of the WGs has been chosen in order to have the best coupling with the highest impedance HOMs, like TM011. The HOM energy propagates along the WGs in the TE10 fundamental mode (FM) and must be dissipated on matched loads placed at the opposite side of the WG itself.

2. THE HOM ABSORBERS

The HOM energy coupled out of the cavity must be absorbed by matched loads to reduce the decay time of the parasitic modes (i.e. their quality factor Q). Several kinds of HOM loads have been studied and are being used elsewhere. An overview of the R&D in this field is reported in [4].

In DAΦNE we have chosen a different way of damping the HOMs. The propagating mode of the HOM beam power is converted from the WG TE10 to a coaxial TEM by means of a broadband transition which allows to dissipate the energy on an external commercial 50 Ω load through a ceramic vacuum window of standard design. It is possible, in this way, to sample the HOM power with a directional coupler.

The study and the experimental work which led to the development of the broadband transition is widely reported in another paper [5]. In this report we summarize the concepts which the transition is based on and report updated information and experimental results.

2.1 The Waveguide to Coaxial Line Transition

A broadband waveguide to coaxial transition for HOM damping (BTHD) in particle accelerators has been studied and proposed for the use in the DAΦNE RF cavities.

The BTHD essentially consists, as sketched in Fig. 1, in a tapered 50 cm long WG connected to a mode transducer from the WG TE10 to the TEM of a 7/8" 50 Ω coaxial line. The taper transforms the 305 x 40 mm^2 rectangular WG cross section at the cavity side into a 140 x 40 mm^2 double ridge WG section with 63 x 17 mm^2 ridges. This tranformation is necessary to increase the ratio of the cut-off frequencies TE30/TE10 and, hence, to increase the BTHD bandwidth.

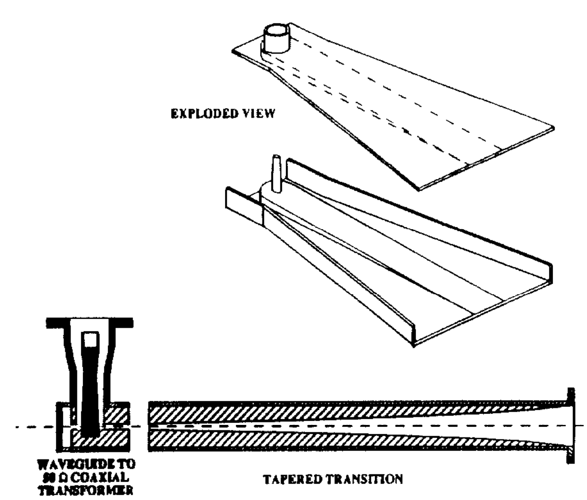

Figure 1. Sketch of the BTHD Broadband Transition.

The BTHD design has been first studied analytically following the indications of the existing technical literature [6,7]. Then the project has been refined with a step-by-step procedure with the 3D Hewlett Packard computer code HFSS [8]. The longitudinal profile of the ridges is of exponential type and has been calculated in order to keep the TE10 cut-off frequency of the tapered WG within ± 2 MHz around the nominal value. This yields a smooth variation of the characteristic impedance along the tapered WG and therefore a better frequency response in the full bandwidth is obtained. The mode transducer has been also designed by means of HFSS with a "cut and try" procedure. The length of the shorted WG section behind the inner coaxial (also called "back cavity") must be experimentally adjusted to optimize the frequency response of the BTHD. The ridge gap at the coaxial output position is 6 mm. The output ceramic feedthrough is a 7/8" coaxial which can safely handle the parasitic beam power that has been estimated below 1 kW per WG. Three Aluminum BTHD prototypes have been built and low power tested. Figure 2 shows an open view of a BTHD model and Fig. 3 gives the measured S11 parameter vs frequency.

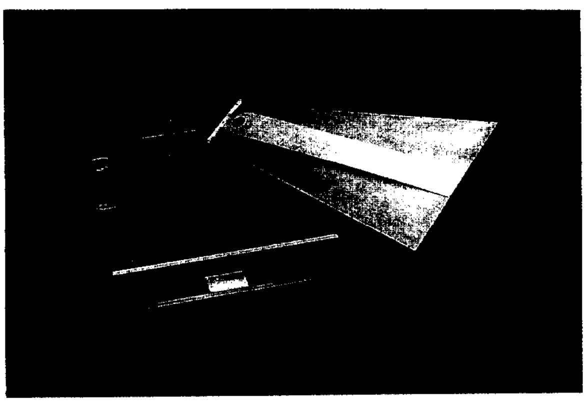

Figure 2. The BTHD Prototype: the open view.

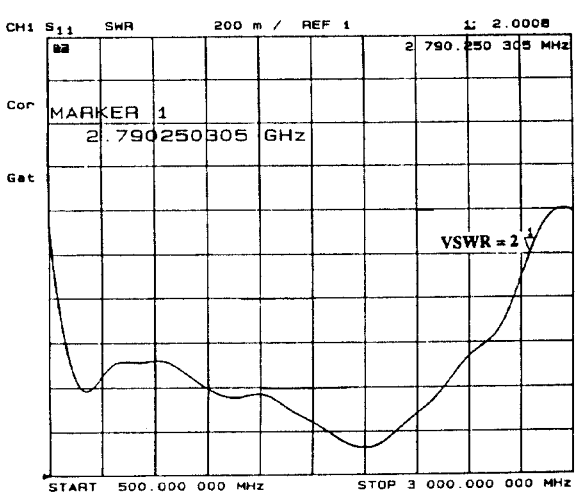

Figure 3. The BTHD response: VSWR vs Frequency.

The VSWR of the Aluminum BTHDs is below 2 in the range 500 + 2800 MHz; therefore, they have been incorporated in the cavity prototype and the HOM damping has been measured [5]. The result has been considered satisfactory enough to proceed with the construction of a model to be tested in vacuum at high power.

2.2 The BTHD Copper Model

In order to check the capability of the transitions to operate reliably at high RF power in ultra high vacuum (UHV), three oxygen free high conductivity (OFHC) copper BTHDs have been fabricated. All the joints have been brazed under vacuum at 900 °C at INFN Legnaro National Lab. A water cooled straight 30 cm rectangular WG has been added to the BTHD to avoid excessive penetration of the cavity FM into the transition. The FM dissipation in the WGs has been estimated ≈ 1 kW per WG. The BTHD external structure has been also mechanically reinforced to reduce the stress due to the atmospheric pressure when operating in UHV. One copper transition is depicted in Fig. 4. The flanges vacuum tightness is obtained with Helicoflex gaskets. The RF contacts are ensured by Silver plated Be-Cu springs on both rectangular and circular 7/8" flanges and with Silver plated La-Cu sliding contacts on the back cavity port.

Figure 4. The OFHC Copper BTHD.

2.3 The ceramic vacuum feedthrough

A 50 Ω coaxial ceramic window has been designed to carry the HOM power out of the BTHD and feed an external load. The 7/8" standard has been considered sufficiently safe to withstand 1 kW CW RF power.

The feedthrough has been also studied with the HFSS code. The goal was to design a device with the widest possible frequency bandwidth. The project is outlined in Fig. 5.

A 5 mm thick Al_2O_3 disk, to be brazed to the inner/outer conductors, ensures the vacuum tightness. In addition, a 5 mm thick Macor disk is placed onto the air side of the Al_2O_3 disk. This allows to have more gradual variations of the dielectric constant. In this way, the feedthrough frequency response is excellent, being the simulated VSWR lower than 1.2 in the full range 500 + 3000 MHz. The ceramic window is being manufactured by the French company Ceramex.

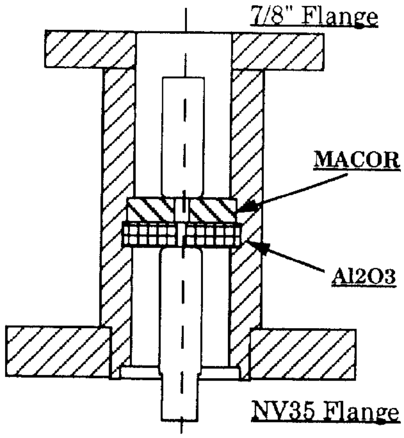

Figure 5. Sketch of the coaxial ceramic window.

2.4 The BTHD Power Tests

Two Copper BTHDs have been RF power tested in UHV. They were connected through the rectangular flanges by means of an intermediate stainless steel WG section which is needed to house the pumping ports and the vacuum gauge. The test bench is shown in Fig 6. Two 7/8" coaxial vacuum connectors of 1.5 GHz bandwidth, already available in the Laboratory have been used for the connection to a TV tetrode amplifier and to a 50 Ω load. The BTHDs have been tested at 740 MHz, close to the TM011 frequency, at a power level of 1 kW/CW which is the maximum estimated HOM power extracted from the cavity in 30 bunches operation. The test has been performed at $2 \cdot 10^{-9}$ Torr which is the DAΦNE nominal UHV. Although no Titanium coating was provided inside BTHD, no multipactoring discharges occurred at any power level up to 1 kW.

4. ACKNOWLEDGMENTS

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5. REFERENCES

[1] The DAΦNE Project Team, "DAΦNE: The Frascati Φ-Factory", in Particle Accelerator Conference, Washington DC, USA, May 1993, p. 1993.

[2] S. Bartalucci et al., "The RF Cavity for DAΦNE", in Particle Accelerator Conference, Washington DC, May 1993, p. 778.

[3] S. Bartalucci et al., "Analysis of Methods for Controlling Multibunch Instabilities in DAΦNE", LNF 93/067(P), 1993.

[4] I. Campisi, "The Workshop on Microwave-Absorbing Materials for Accelerators", in Particle Accelerator Conference, Washington DC, May 1993, p. 1115.

[5] R. Boni et al., "A Broadband Waveguide to Coaxial Transition for HOM Damping in Particle Accelerator RF Cavities", LNF 93/075(P), 1993, (to be published on Particle Accelerators)

[6] K. Walton et al., "Broadband Ridged Horn Design", Microwave Journal, Vol. 7, March 1964, pp. 96-101.

[7] J. Kerr et al., "Short Axial Length Broadband Horns", IEEE Transaction on Antennas and Propagation, September 1973, pp. 710-714.

[8] Hewlett Packard Company, "HFSS: the High Frequency Structure Simulator", trademark.

Figure 6. The BTHD power test bench.