COAXIAL COUPLING SCHEME FOR FUNDAMENTAL AND HIGHER ORDER MODES IN SUPERCONDUCTING CAVITIES[*]

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Abstract

Higher Order Modes generated by a particle beam passing through a superconducting accelerating cavity have to be damped to avoid beam instabilities. A coaxial coupler located in the beam pipes of the cavities provides for better propagation of HOMs and strong damping in appropriate HOM dampers. The whole damping device can be designed as a detachable system. If appropriately dimensioned, the RF currents can be minimized at the flange position. Additionally, the coaxial system also provides efficient coupling of fundamental mode RF power into the superconducting cavity. Compared to presently available solutions for HOM damping, this scheme provides for several advantages: stronger HOM damping, attachable solution, and exchangeability of the HOM damping device on a cavity, less complexity of the superconducting cavity, possible cost advantages.

This contribution discusses modeling, which lead to an optimized layout of a cavity-coupler system and describes[*] results from the room temperature and first cryogenic temperature measurements .

INTRODUCTION

The coaxial HOM couplers were originally developed for the 500 MHz HERA cavities in 1985 and later in the early 90's they were scaled to 1300 MHz and adapted for the TESLA cavities [1]. The scheme fulfills also the specification for the ILC project, which is the TESLA successor, and can be used for the superconducting cavities in the main accelerator. The coupling device we propose here (Fig. 1) takes advantage of the TESLA HOM damping scheme and combines it with the coaxial fundamental power coupler (FPC) used for the superconducting TESLA (ILC) cavities. In this scheme, all couplers are screened by the inner tube, which is supported by the Nb "donut" (disk) welded to it
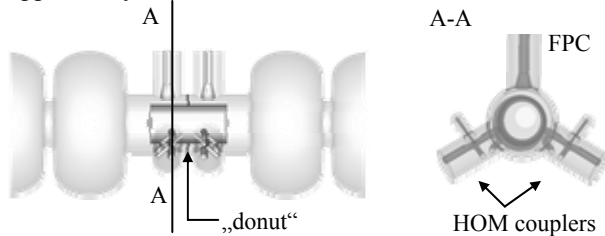

Figure 1: FPC and HOM couplers in two mirrored coaxial coupling devices placed between two cavities (left) and cross-section of the coupling device (right).

and to the beam tube. The "donut" is an electric short in the coaxial line, which is formed by the inner and outer tubes, and thus separates electrically two mirrored coupling devices and neighboring cavities. The pair of mirrored coupling devices can be placed between two cavities.

Motivation

This coaxial coupling scheme has the following advantages as compares to the standard TESLA scheme:

1. Field asymmetries and kicks from all couplers are minimized
2. The distance between two cavities can be shorter (higher real estate gradient); for the ILC, the difference is 9 cm.
3. The body of the cavity stays cylindrically symmetric, which enables its fabrication by hydro-forming as seamless device.
4. The interior of the coupling assembly and the cavities can be better cleaned before the final assembly.

MODELING AND BENCH RF MEASUREMENTS

Modeling

HOM damping and coupling to the fundamental mode have been modeled by the ACD team at SLAC. The RF model and HOM damping result for the 9-cell TESLA cavity is shown in Fig.2. For the accelerating mode, the computed Q_{ext} for the FP coupler vs. its penetration depth, covered a wide range of values beginning at a lowest value of 10^5.
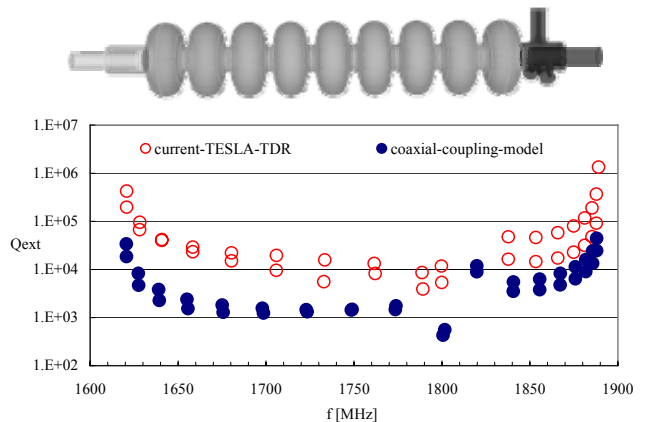

Figure 2: RF-model and damping (Q_{ext}) for the first two dipole passbands for the TESLA structure. The diagram compares the standard TESLA-TDR damping scheme with the scheme discussed in this paper.

Bench Measurements

The second step in the verification of the concept was the HOM damping and FM coupling measurements for

the copper model of the coupling device attached to the copper model of the TESLA cavity. The models, shown in Fig. 3, have been built and tested at JLab.
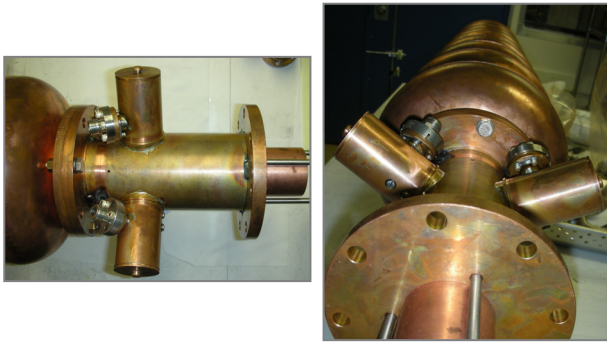

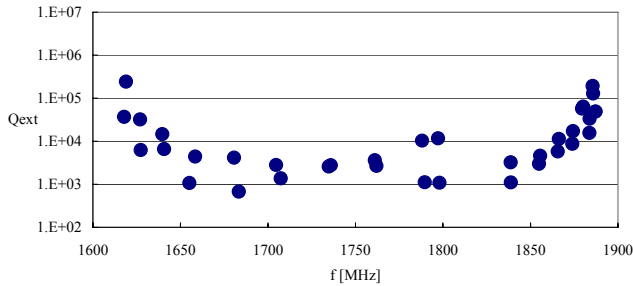Figure 3: Pictures of the copper models built at JLab.

Figure 4: Measured Q_{ext} values for the two lowest dipole passbands.

The HOM damping result for the two first dipole passbands is displayed in Fig. 4. The agreement with the modeled values is remarkable. More complete measured data and computed (R/Q) for three dipole passbands (TE_{111}, TM_{110}, and TE_{121}) and the lowest monopole passband (TM_{011}) is shown in Fig. 5. For all modes the damping specification for the ILC- $Q_{ext} < 2E5$- is fulfilled.
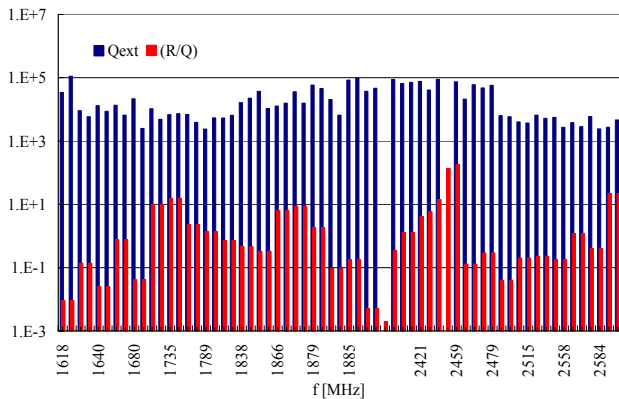

Figure 5: Computed (R/Q) and measured Q_{ext} for the copper model of coupling device.

The data for the FM coupler, Q_{ext} vs. distances to the end iris is shown in Fig. 6. These measurements have been carried out at DESY. By "x" and "y" the distances between the end iris and inner tube or end short are denoted respectively. Even for y=140.5 mm and short FPC antenna (tip hidden in the port tube) one can find "x" at which Q_{ext} is as low as 2E5. Further retraction of the

FPC antenna makes the Q_{ext} value higher, roughly - 1.5dB/mm when x < 90 mm. Smaller "x" and "y" make the Q_{ext} lower, so these two
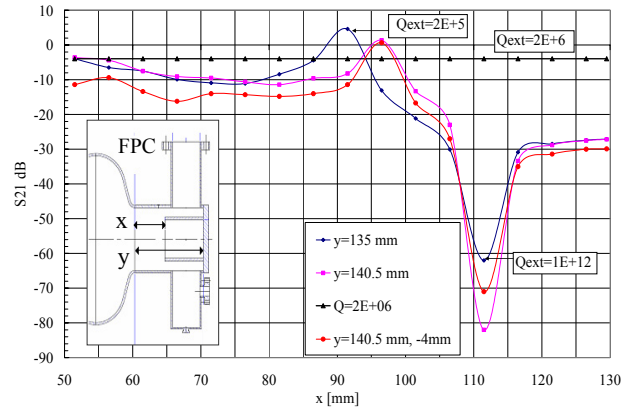

Figure 6: Measured Q_{ext} for the coaxial FPC.

variables and the penetration allow for the proper adjustment of the FPC coupling strength, maintaining reflection free operation. For example, the ILC specification $Q_{ext}=2E+6$, can be obtained for x=50 mm, 87 mm and 94 mm, when y=135 mm.

POSITIONING OF THE FLANGE CONNECTION

As mentioned above, the coupling device will be flanged to the cavity beam tube. Even though, super-conducting joints do not perform sufficiently for many other applications, due to their magnetic flux limitation to ~10 mT, one can make use of these connections for this coupling device. The reflected wave at the Nb short forms with the decaying field in the beam tube a standing wave pattern, having a B-field minimum ("notch") at 45 mm from the end iris. A superconducting connection made of a Nb gasket and NbTi or NbZr flanges, at that location will be exposed to a negligible residual magnetic flux. The B- field pattern in the beam tube for B = 150 mT on the equator (36 MV/m accelerating gradient) in the end-cell is shown in Fig. 7.
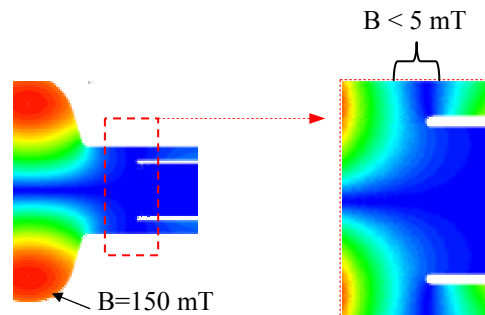

Figure 7: B-field pattern in the beam tube

FUTURE COLD TEST

The first prototype of the coupling device has been fabricated and a cryogenic test is in preparation. The

device will be attached to a large grain niobium prototype of a 1.6-cell photoinjector cavity built in the frame of another R&D project at JLab. The technical drawing and photograph of the cavity and the coaxial coupler are shown in Fig. 8. The cavity and coupling device will be
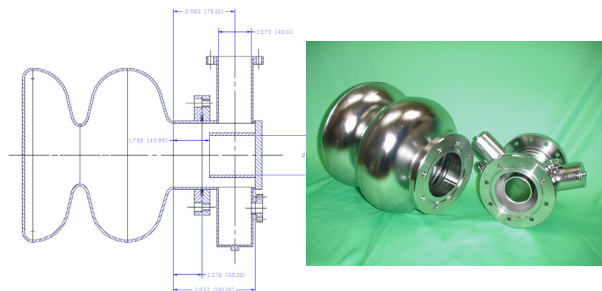

Figure 8: Technical drawing and photograph of the test cavity.

chemically cleaned ("Buffered Chemical Polishing") by standard processing techniques, high pressure water rinsed and assembled in a class 10 clean room prior to the test.

Objectives of the cold test

There are three main objectives for the cold test.

- The first objective is to investigate multipacting (MP), which has been found in the coaxial part of the beam tube by means of the MP simulation calculations. This resonant phenomenon should take place at a field level of E_{acc}=2MV/m. The electron impact energy is in the range of 540~790 eV. The predicted MP is of 4-th order two-side and thus it should be possible to process.

- The second objective is to look at possible heating of the inner tube, which can be expected for cw operation because that tube is only cooled indirectly by heat conduction of the outer beam tube and the Nb "donut". This potential limitation may require an additional devoted cooling loop at that location for cw operation.

- Finally, one needs to verify the performance of the superconducting gasket in pulse and cw operation and explore the limitation in maximum achievable field level.

SUMMARY

Model measurements at room temperature on a 9-cell TESLA/ILC-type copper cavity have shown, that a coaxial beam-line coupler for fundamental power and high order mode damping, flanged to the cell structure, can provide sufficient coupling and HOM damping to the cavity. The measurements are in agreement with model calculations and the HOM damping exceeds the obtainable Q_{ext} values of the presently used couplers for the ILC. The flangeable design requires moderate performance of a

superconducting connection between cell structure and coaxial coupler. Possibly, cost advantages can be realized by this design.

A niobium model of the coupler has been fabricated and a first cryogenic test will be carried out in the near future with a 1.6 cell photo-injector cavity. Most likely, further tests will be necessary to fully evaluate the suitability of this design.

ACKNOWLEDGEMENT

REFERENCES

[1] J. Sekutowicz, Proc. 6th Workshop on RF Superconductivity, TJNAF (JLab), Newport News, VA (1993), p.426.