DEVELOPMENT OF A QUARTER-WAVE COAXIAL COUPLER FOR 1.3 GHz SUPERCONDUCTING CAVITIES[*]

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Abstract

Superconducting ILC-type cavities have an rf input coupler that is welded on. A detachable input coupler will reduce conditioning time (can be conditioned separately), reduce cost and improve reliability. The problem with placing an extra flange in the superconducting cavity is about creating a possible quench spot at the seal place. Euclid Techlabs LLC has developed a coaxial coupler which has an on the surface with zero magnetic field (hence zero surface current). By placing a flange in that area we are able to avoid disturbing surface currents that typically lead to a quench. The coupler is optimized to preserve the axial symmetry of the cavity and rf field. The surface treatments and upcoming rf test of the prototype coupler with a 1.3 GHz ILC-type single-cell cavity at Fermilab will be reported and discussed.

INTRODUCTION

The standard 1.3 GHz TESLA type SRF cavity has a fundamental power coupler and two asymmetric HOM couplers both upstream and downstream. The couplers break the cavity axial symmetry that in turn causes a rf field distortion and transverse wake field which may cause beam emittance dilution [1]. In order to preserve the axial symmetry of the acceleration channel, different schemes of coaxial coupler were proposed and developed [2], [3].

We suggested another design for the coupling unit, as shown in Figure 1. This coupler has the following features:

- The coupler unit preserves the axial symmetry of the acceleration channel. There are no RF kicks or wakes that lead to emittance dilution;
- It is a quarter-wave resonant coupler for the operating mode;
- The coupler is detachable, because in the operating mode the currents are small in the coupler corners, and non-welded superconducting joints may be used. Thus, the coupler unit can be a separate device that can be treated independently of the structure;
- It may be manufactured of low RRR niobium (reduced cost) compared with the main cavity;
- It is compact.

The magnetic field distribution for the operating mode is shown in Figure 2. One can see that the field in the corners is much smaller than in the main cavity. For the maximal acceleration gradient of 35 MeV/m the surface magnetic field is 147 mT. In this case in the corner it is about 0.15 mT, lower enough to definitely permit superconducting joints.

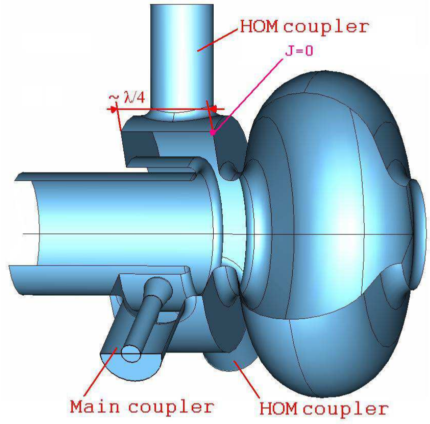

Figure 1: Schematic of Euclid proposed quarter-wave coaxial coupler.

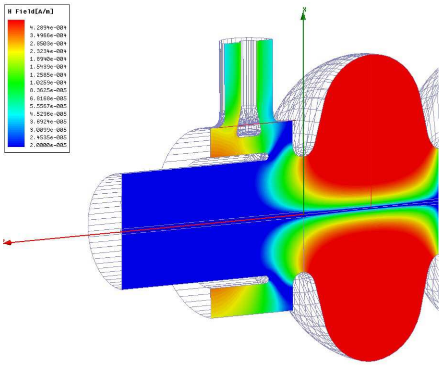

Figure 2: The magnetic field pattern in the coupler for the operating mode.

ELECTROMAGNETIC DESIGN

The first step in the coaxial coupler development was an adjustment of the shape to get the zero of the magnetic field at an accessible point for split flanges. The coaxial coupler which behaves like the coaxial resonator has an rf magnetic field and surface current minimum at the point $\lambda_{rf}/4$ from the corner (λ_{rf} is the wavelength in vacuum). This position can't be changed by appropriate choice of radii of the coaxial unit. Figure shows the position of the magnetic field zero in the final design of the coaxial coupler. It satisfies the detachable design requirements.

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[*] This Work is supported by the US DOE SBIR Program DE-SC0002479.

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ISBN 978-3-95450-132-8

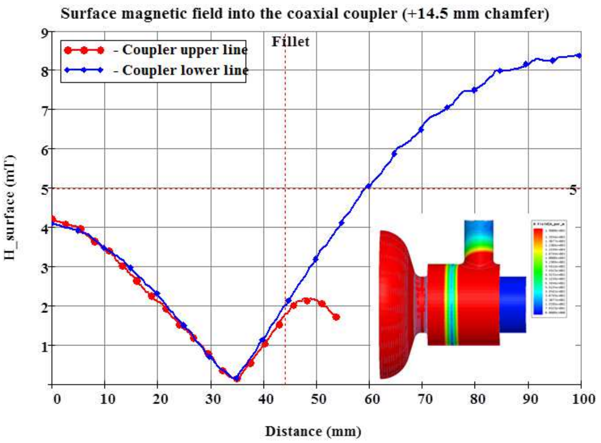

Figure 3: The magnetic field distribution on the surface of coaxial coupler with insert (with E_{acc} = 31.5 MeV/m).

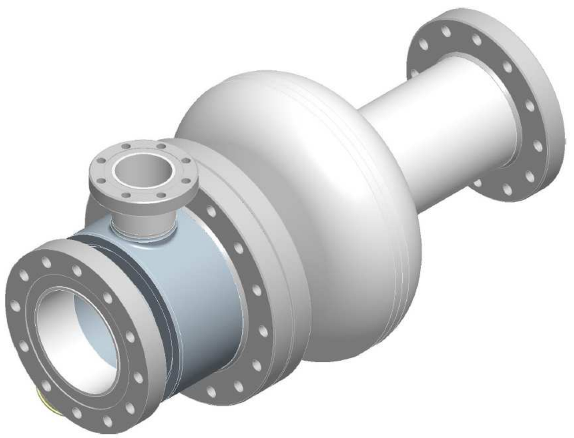

Figure 4: The CAD design of coupler and a 1.3 GHz single cell ILC-type cavity.

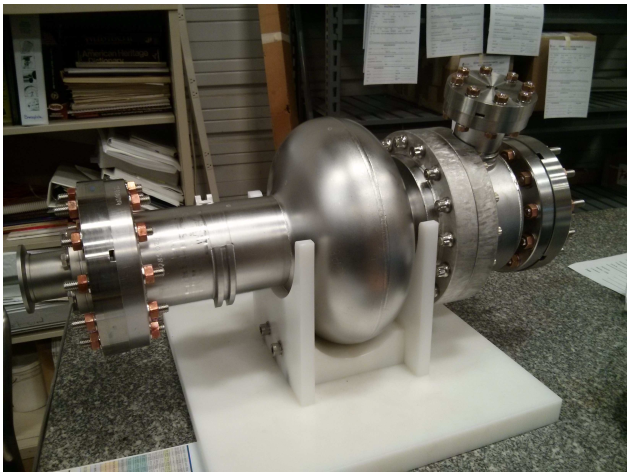

Figure 5: The quarter-wave coaxial couple with a single cell cavity

The coupling to the fundamental mode has been modeled by the HFSS eigenmode solver for the shape depicted above. For the adjustment of the feed coupler the external Q-factor of the nearest semicell was calculated. The computed Q_{ext} for the fundamental power coupler v.s. its penetration depth, covering a wide range of values beginning at the lowest value of 10^6.

Multipacting simulations were made for the coupler. The analysis shows now significant activity near the coupler region.

A comparison of the coaxial-coupler unit and the regular TESLA coupler for the Q-factor of the most dangerous modes (with high loss factor and strong synchronism with accelerated beam) was made to ensure the coupler will meets the HOM damping requirements.

MECHANICAL DESIGN AND AND MANUFACTURING

As the goal of the first high power test is to demonstrate the proof-of-principle concept we are considering omitting the HOM coupler and possibly the TTF drive coupler. The structure can be excited in a standard single cell testing configuration - through the beam pipe. For the first test we opted to utilize a design derived from [4]. In this design a Nb1Zr flange was used which is similar to conflat. Figure 4 shows the CAD model of the couple with a 1.3 GHz ILC single cell cavity.

A pair of hardened Nb1Zr Conflat Flanges (CF) was welded to the coupler and the shortened single cell cavity. Niobium gaskets will be used to seal with the CF flanges. The cavity was made by AES and can be seen in Figure 5.

WARM RF MEASUREMENTS, SURFACE TREATMENTS AND RF TESTS

Upon receiving the cavity, we have performed warm rf measurement to verify the magnetic field at the seal region. It is measured that the magnetic field is smaller than 1/300 of the maximum magnetic field at the equator. Figure 6 shows the measured Q_{ext} with designed values around 10^6. It proves that our coaxial coupler design can effectively works under beam condition.

We examined the Nb1Zr flange. Figure 7shows a picture of the flange knife edge. The grain size of this material is large. It may be possible to improve the knife edges with a polishing operation. However, we have no experience with this material, so it is not possible to predict success. Thus we proceed with a test seal with a copper gasket seal, it seals very well. Since the copper gasket has nearly or larger hardness compared with niobium gasket, we believe that the Nb1Zr flanges most likely will seal well with the niobium gaskets in the future clean room assemblies.

Currently the coupler-cavity assembly has undergone a heavy BCP and 600C heat treatment at Fermilab SRFD department. We expect the first vertical rf test will be performed very soon and the results will be reported elsewhere.

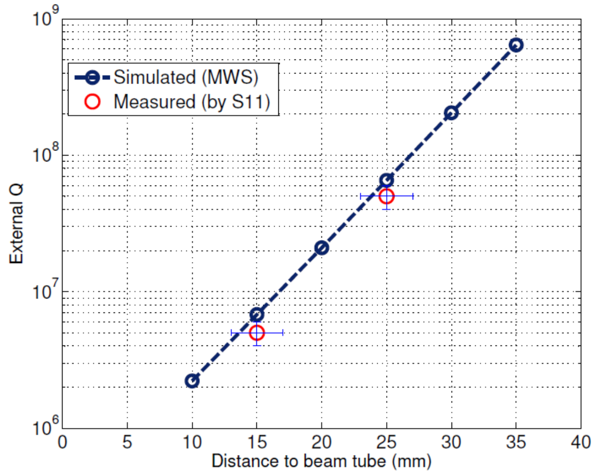

Figure 6: Measured v.s. simulated Q_{ext} of the quarter-wave coaxial coupler.

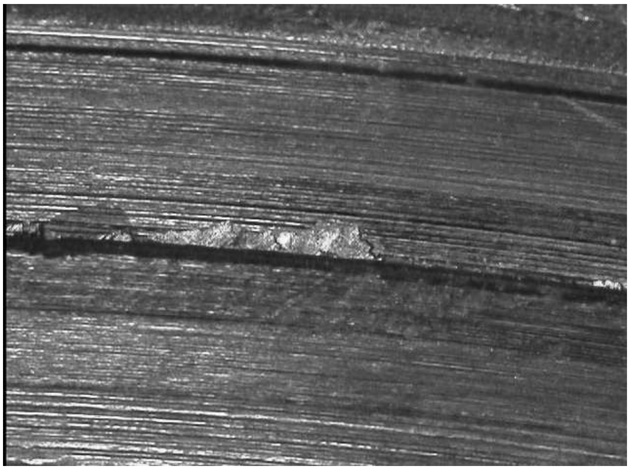

Figure 7: Microscopic picture of the knife edge of the hardened Nb1Zr flanges.

CONCLUSIONS

Euclid Techlabs have developed a detachable, quarter-wave coaxial coupler for 1.3 GHz TESLA cavities. It has many advantages including better coupler kick shielding, easy surface treatments, detachable feature. It will be rf tested to verify the design specs. This type of coupler is very useful for future projects such as LCLS-II, PIP II and ILC.

ACKNOWLEDGEMENT

We thank Allan Rowe, Curtis Crawford and their surface treatment group for their help. This work was supported by the US DOE SBIR Program DE-SC0002479.

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