DEMONSTRATION OF COAXIAL COUPLING SCHEME AT 26 MV/M FOR 1.3 GHZ TESLA-TYPE SRF CAVITIES *

Yi Xie†, A. Kanareykin (Euclid TechLabs, Solon, Ohio)
T. Khabiboulline, A. Lunin, V. Poloubotko, A. Rowe,
N. Solyak, V. Yakovlev (Fermilab, Batavia, Illinois), J. Rathke (AES, Medford, New York)

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 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 Fig. 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 Fig. 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.

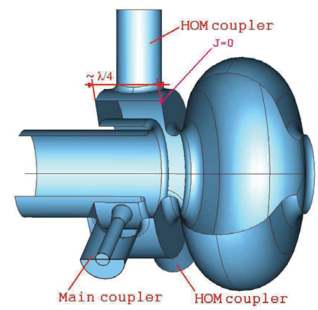

Figure 1: Schematic of Euclid proposed quarter-wave coaxial coupler.

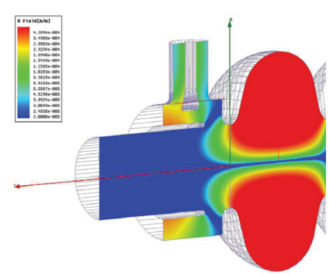

Figure 2: The magnetic field pattern in the coupler for the operating mode.

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 3 shows the position of the magnetic field zero in the final design of the coaxial coupler. It satisfies the detachable design requirements.

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 vs its pene-

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† yixie@fnal.gov, now at Fermilab.

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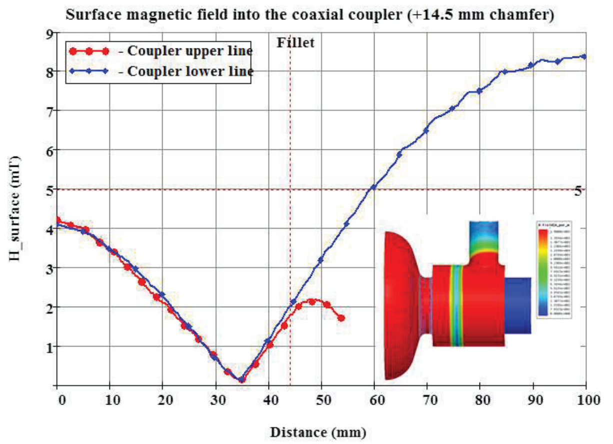

Figure 3: The magnetic field distribution on the surface of coaxial coupler with insert (with E_{acc} = 31.5 MeV/m).

tration depth, covering a wide range of values beginning at the lowest value of 10^6.

Multipacting simulations based on CST particle studio 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 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 **??** 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 Fig. 4.

WARM RF MEASUREMENTS AND SURFACE TREATMENTS

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 5 shows the measured Q_{ext} with designed values around 10^6. It proves that our coaxial coupler design can effectively works under beam condition.

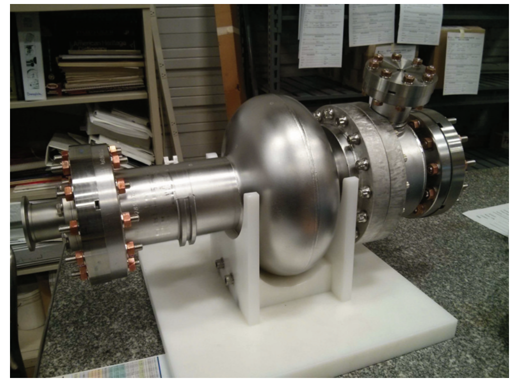

Figure 4: The quarter-wave coaxial couple with a single cell cavity.

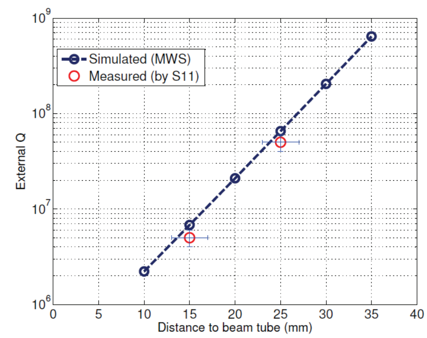

Figure 5: Measured v.s. simulated Q_{ext} of the quarter-wave coaxial coupler.

We examined the Nb1Zr flange. Figure 6 shows 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.

Figure 6: Microscopic picture of the knife edge of the hardened Nb1Zr flanges.

The following procedure was given to the coupler cavity after the warm leak check:

- Optical inspection of the cavity and the coupler unit;
- Thickness measurements;
- BCP/HPR validation (due to exotic geometry);
- 120 um BCP ;
- Pre-bake cleaning/HPR;
- 600C bake 3 hour;
- Light BCP (20 um);
- Installation with niobium seal (SC joint);

RF TEST RESULTS AND DISCUSSION

The cavity was tested at 1.7 K with a variable coupler in Fermilab SRFD, the low field Q_0 reached $9 * 10^9$ as can be seen in Fig. 7, indicating there is only slight loss due to supercoducting joints. The cavity reached 26 MV/m without hard quench limit, far exceeding previous efforts. After the

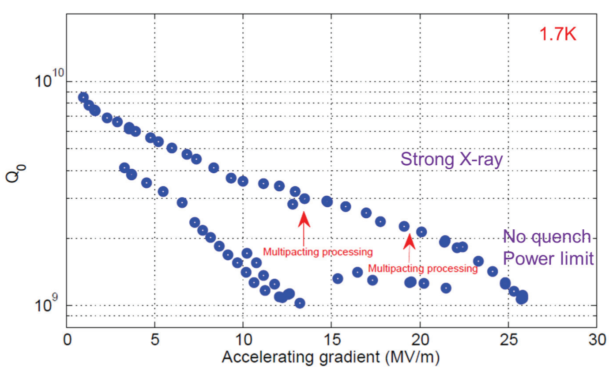

Figure 7: The Q_0 vs E_{acc} of the coupler cavity.

first test, we baked cavity at 120C for 48 hours to get rid of possible water vapor, in order to eliminate multipacting. The second test at 1.7 K the cavity still perform the same and with strong multipacting until 26 MV/m.

Track3P [5] was used to recheck multipacting spots based on the precise surface field extracted from Omega3P. The simulation clearly shows a strong correlation with Q_0 vs E_{acc} results as measured. The detailed study will reported elsewhere. Figure 8 shows electron impact energy as the function of accelerating gradient for the coupler cavity near the coaxial seal regions. As can be observed from Fig. 8, multipacting will start from 15 MV/m, right around that was measured at the cavity rf test, although this multipacting barrier never was predicted by previous CST Particle studio.

If future tests possible, we are going to do a detailed thermometry study around the suspected multipacting region. The temperature data will reveal whether or not there is a multipacting barrier as simulated by TRACK3P but not predicted by CST particle studio.

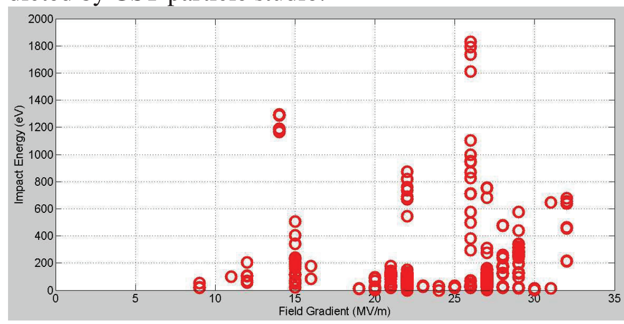

Figure 8: The impact energy vs E_{acc} of the coupler cavity.

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. Our experiment is a major breakthrough in realizing coaxial coupling scheme. In this first cold test, we reached 26 MV/m (no hard quench limit) with a quarter-wave detachable coaxial coupler. It also demonstrates the highest field gradient ever reached with a superconducting joint. Realization of coaxial coupling scheme and superconducting joints will significantly advance the design of the next generation superconducting rf cavities.

ACKNOWLEDGEMENT

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