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# MULTIPACTING-FREE QUARTER-WAVELENGTH CHOKE JOINT DESIGN FOR BNL SRF *

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*Abstract*

The BNL SRF gun cavity operated well in CW mode up to 2 MV. However, its performance suffered due to multipacting in the quarter-wavelength choke joint. A new multipacting-free cathode stalk was designed and conditioned. This paper describes RF and thermal design of the new cathode stalk and its conditioning results.

## INTRODUCTION

The 704 MHz half-cell SRF gun was designed to provide up to 350 mA, 2 MV electron beams for ERL [1] at BNL, which is a R&D project for future RHIC projects: eRHIC [2], Coherent-Electron-Cooling [3], and Low Energy RHIC Electron Cooler [4]. Without a cathode stalk insertion, the SRF gun cavity reached the design voltage of 2 MV in CW mode in horizontal tests. However, strong multipacting in the quarter-wavelength choke-joint occurred during commissioning with a copper cathode stalk. Multipacting in the choke-joint was later understood with simulations [5]. While the beam commissioning was carried out with this cathode stalk and successfully generated first beam in November 2014 [6], a multipacting-free choke joint has been designed, tested and showed that it is truly multipacting-free. This paper discusses multipacting issues observed in the old cathode stalk, and then presents the multipacting-free choke-joint design and test results.

## MULTIPACTING IN THE SRF GUN

Figure 1 shows the SRF gun cryomodule. The 704 MHz half-cell SRF cavity is the core part of the module. A quarter-wavelength choke-joint cathode is used to support photo-cathode. A pair of opposing fundamental power couplers (FPCs) is used to deliver up to 1 MW of RF power in CW mode. A high temperature superconducting solenoid (HTSS) is employed to compensate space charge. A room-temperature ferrite HOM damper with ceramic break is used to damp HOM power. Without a cathode stalk insert, the gun cavity was successfully commissioned and reached the design goal of 2 MV in CW mode. However, strong multipacting occurred during commissioning with a copper cathode stalk insert. Figure 2 shows signals during the cathode stalk conditioning, when strong multipacting was observed. The reflected power could be as low as 50% of the forward power when multipacting is active. The main reason for multipacting was distortion of grooves due to BCP and high SEY in the stainless steel area. After spending some time conditioning mutipacting (to suppress it), we were able to operate the gun at 1.9 MV with 18% duty factor. We used this cathode stalk for beam commissioning in pulse mode, while a new multipacting-free cathode stalk was designed.

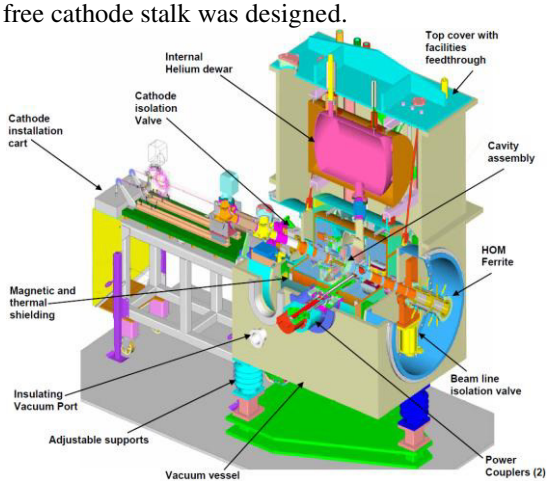


Figure 1: ERL SRF gun cryo-module.

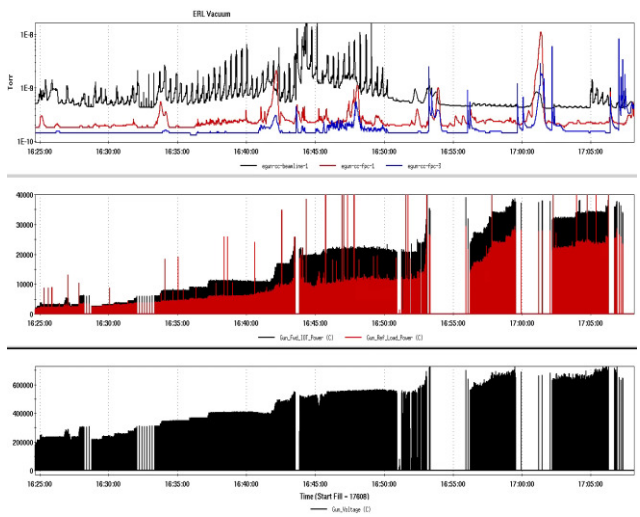


Figure 2: Signature of strong multipacting in the cathode stalk: vacuum behavior (above); reflected and forward power difference due to multipacting (middle); cavity voltage (bottom).

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## MULTIPACTING-FREE CATHODE STALK DESIGN

Figure 3 shows the cathode stalk to be inserted into the SRF cavity. There are two folded half-wavelength chokes with four gaps. The copper cathode substrate and an inner Nb cylinder compose the first gap. The second gap (end of the first choke) is formed by two Nb cylinders. The third gap is composed of the outer Nb cylinder and an inner stainless steel cylinder. Two stainless steel cylinders constitute the forth gap. The Nb cylinders are part of the Nb cavity, which stays inside the cryomodule. The copper substrate and stainless steel cylinders form the cathode stalk, which stays with a cathode transport cart.

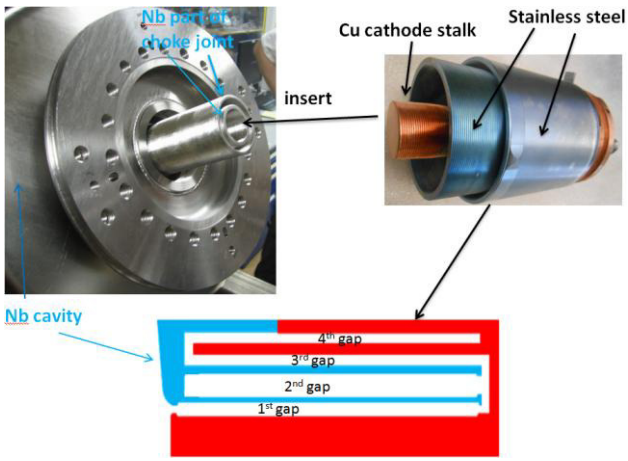


Figure 3: Quarter-wavelength cathode stalk insertion. In the choke-joint, the red part is the cathode stalk and the blue part is Nb cavity.

To run the gun in CW mode, a new multipacting-free photocathode choke joint has been designed, as shown in Figure 4. The main features of the new design are: 1) To suppress multipacting in the 1st gap, the ratio of the groove's depth over period is increased from 1 to 2; 2) To suppress multipacting in the 3rd and 4th gaps, the ratio of the groove's depth over period is increased from 1 to 1.2; 3) To suppress multipacting in the 2nd gap (Nb part), the cathode radius is reduced from 1.25 to 0.9 cm, which pushes the field higher, as shown in Figure 5. The results of multipacting simulations in the choke joint are shown in the Figure 6.

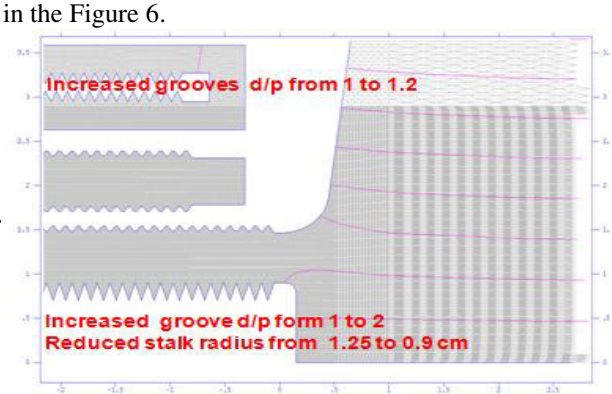


Figure 4: New design of a multipacting-free cathode stalk.

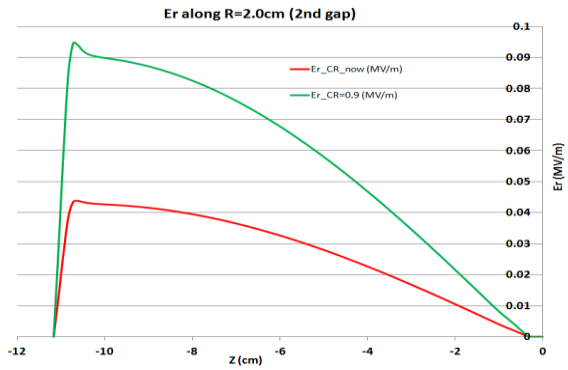


Figure 5: Electric field in the 2nd gap.

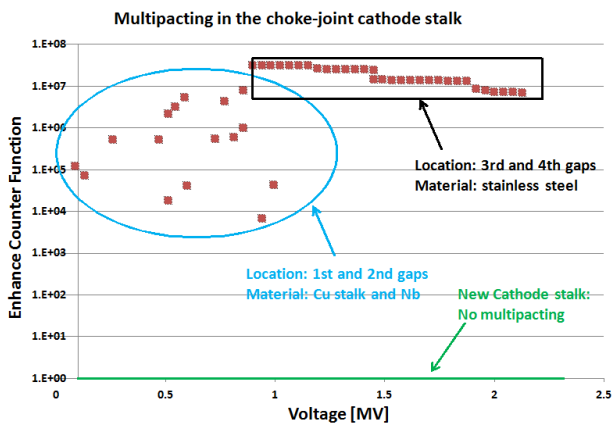


Figure 6: Multipacting simulation results in the quater-wavelength choke joint.

Figure 7 shows thermal analysis of the new photocathode stalk. One important concern is RF heating of the choke-joint as the new design has higher fields for the same gun voltage. A LN2 cooling was re-designed using fin-style channel to improve its efficiency. The cooling capacity is now 736 W, which is bigger than the heat load of 656 W. RF heat load to 2 K is only 5.22 W, as compared to 7 W in the old cooling channel design. The maximum temperature on the cathode stalk is 83.1 K. In addition to multipacting suppression, the tip of the cathode stalk is coated with tantalum to increase quantum efficiency (QE) of the photocathode.

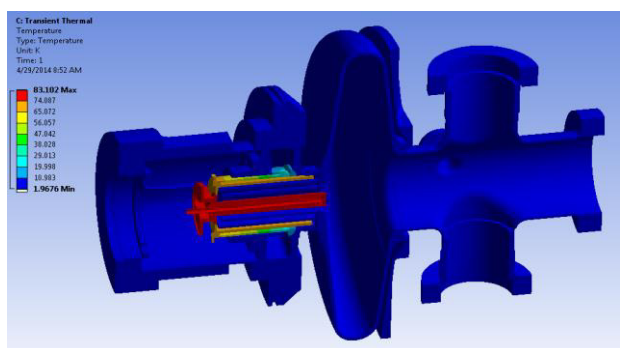

Figure 7: Thermal analysis of the new cathode stalk.

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## EXPERIMENTAL RESULTS

Figure 8 shows the new cathode stalk, which has a Ta-tip brazed on the copper stalk as a substrate of photocathode for high QE. The cathode stalk was performed ultrasonic cleaning, leak checked and baked out in a vacuum chamber at 350 °C for 48 hours. It was stored in a N2 filled bag to minimize the oxidations on the copper surfaces, waiting for assembly.

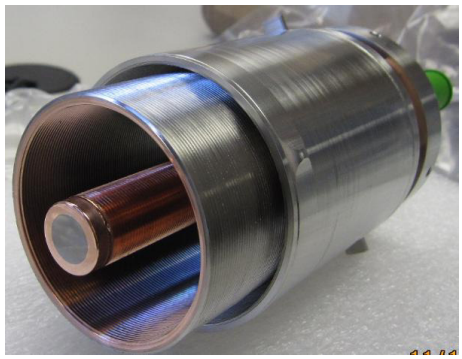

Figure 8: New cathode stalk.

The cathode stalk was inserted into the gun and tested with high power RF in mid March, 2015. Within the first 1.5 hours, the cavity voltage went up to 2 MV in pulsed mode without multipacting, which is illustrated in Figure 9. To reach the same level, it took tens of hours for the old cathode stalk. For the voltage levels above 1.4 MV in CW mode, field emission was observed but we didn't spend time on conditioning because the field was high/good enough for generating electron beam. Figure 10 shows CW operation level for the beam tests after less than 10 hours conditioning time. The previous cathode stalk never reached such CW operational mode at all.

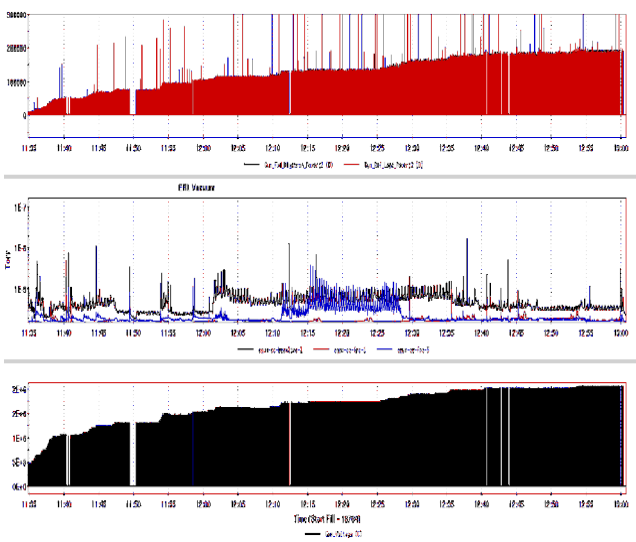

Figure 9: Multipacting-free cathode stalk tests result.

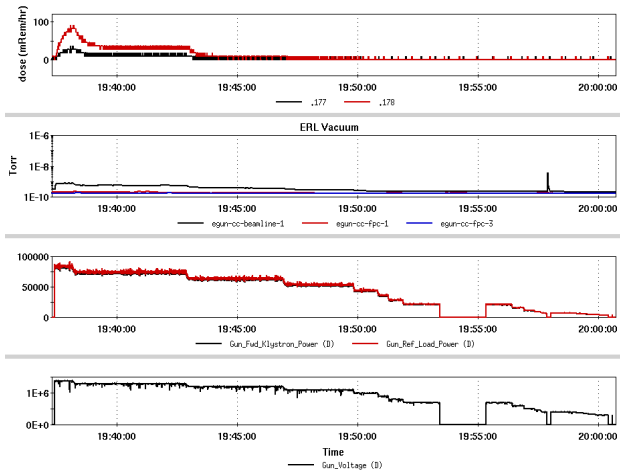


Figure 10: CW operational voltages.

## SUMMARY

During commissioning of the SRF gun for the R&D ERL, strong multipacting was observed in the cathode stalk, which prevented the gun to reach CW operation mode. A new cathode transport cart and multipacting-free photocathode stalk with Ta tip were designed. Test results show that it is a truly multipacting-free cathode stalk. Currently, we are working on preparation for beam tests with the new cathode stalk, with the expectation to generate high current beam.

## REFERENCES

[1] I. Ben-Zvi, et al., "The Status of the BNL R&D ERL," ICFA Beam Dynamics Newletter, No. 58, August 2012, p. 151.

[2] E. C. Aschenauer, et al., "eRHIC Design Study: An electron-ion collider at BNL," http://arxiv.org/abs/1409.1633

[3] V. N. Litvinenko, "Coherent electron cooling – perfect tool for high luminosity RHIC and eRHIC," http://www.cad.bnl.gov/MAC/MAC_08/PDF/15_VL_CAD_MAC_February_2008.pdf

[4] A. Fedotov, "Bunched beam electron cooling for low-energy RHIC operation", ICFA Beam Dynamics Newsletter, No. 64, December 2014, p. 22.

[5] Wencan Xu, et al., "BNL SRF gun commissioning," Proc. SRF2013, Paris, France, 2013, pp. 155-158.

[6] Wencan Xu, et al., "First beam commissioning at the BNL ERL SRF gun," *these proceedings*.