MULTIPACTING IN A GROOVED CHOKE JOINT AT SRF GUN FOR BNL ERL PROTOTYPE*

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Abstract

The 703 MHz superconducting gun for BNL ERL prototype was tested at JLab with and without choke-joint and cathode stalk. Without choke-joint and cathode stalk, the gradient reached was 25 MV/m with $Q_0 \sim$ 6E9. The gun cathode insertion port is equipped with a grooved choke joint for multipacting suppression. We carried out tests with choke-joint and cathode stalk. The test results show that there are at least two barriers at about 3.5 MV/m and 5 MV/m. We considered several possibilities and finally found that fine details of the grooved shape are important for multipacting suppression. A triangular groove with round crest may cause strong multipacting in the choke-joint at 3.5 MV/m, 5 MV/m and 10 MV/m. This paper presents the primary test results of the gun and discusses the multipacting analysis in the choke-joint. It also suggests possible solutions for the gun and multipacting suppressing for a similar structure.

INTRODUCTION

The 703 MHz photo-injector is used to produce high current, high brightness electron beam for BNL high current Energy Recovery Linac (ERL) prototype, shown in Figure 1 [1]. Its design parameters are listed in Table 1. The photo-injector consists of a half-cell 703.75 MHz superconducting cavity, followed by a solenoid for emittance compensation, four dipoles (the 4th dipole merges high and low energy beam into the linac) and another two solenoids turned on in opposite direction to matched the electron beam with the linac entrance. The superconducting cavity requires a total of 1 MW of RF power in order to meet the high current specification (0.5 A, 2 MeV), necessitating two 500 kW fundamental power couplers. A quarter wave choke joint has been utilized for the cathode insertion mechanism. In order to suppress the multipacting inside the choke joint, the surface of the choke joint is triangular grooved, which is based on the cold model measurements on three potential geometries, including smooth, rectangular grooved and triangular grooved.

This paper describes test results of the gun cavity, design of the choke joint, multipacting simulation and multipacting combined thermal analysis of the choke joint.

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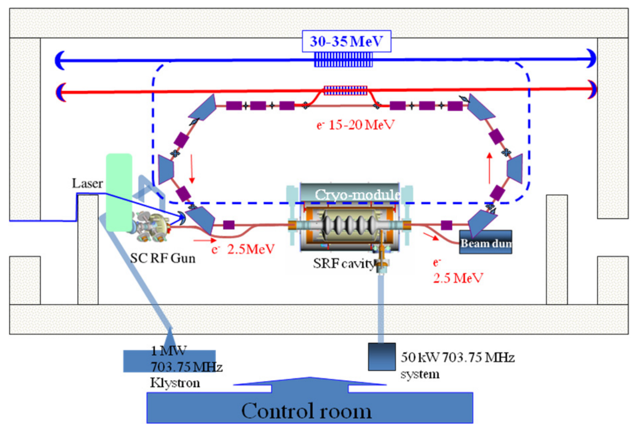

Figure 1: Layout of BNL ERL prototype.

Table 1: BNL ERL prototype parameters

Parameters	High Current	High charge
Bunch charge[nC]	0.7	5
Passes	1	1
Energy max/injection, [MeV]	20/2.5	20/3.0
Bunch rep-rate[MHz]	700	9.383
Average current[mA]	500	50
Injected/ejected beam power[MW]	1.0	0.15
RMS emittances ex/ey, [mm*mrad]	1.4/1.4	4.8/5.3
RMS □E/E	3.5×10^{-3}	1×10^{-2}
RMS Bunch length[ps]	18	31

GUN TEST RESULTS

Without Cathode

The gun cavity was chemically etched approximately 120 um as measured via ultrasonic thickness measurements of the cavity at 15 locations around the cavity and beam-pipe. Then the cavity was high pressure rinsed for about 45 minutes. Following the assembly and leak check, the cavity was baked for 60 hours at 200°C. The higher temperature and longer duration is to reduce the secondary electron yield on the surface of the Nb, which is not the "standard" 120°C bake for 24 hours to improve the Q-slope.

After the bake, the cavity was leak checked again and placed in the dewar for testing. The 4 K test showed very good performance with no field emission. After the 4 K test, the cavity was cooled to 2 K. The test results are shown in Figure 2. At 2 K, the cavity can sustain operation at 23.5 MV/m, which is related to our desired 2 MeV electron energy gradient with a dynamic load of < 7 Watts.

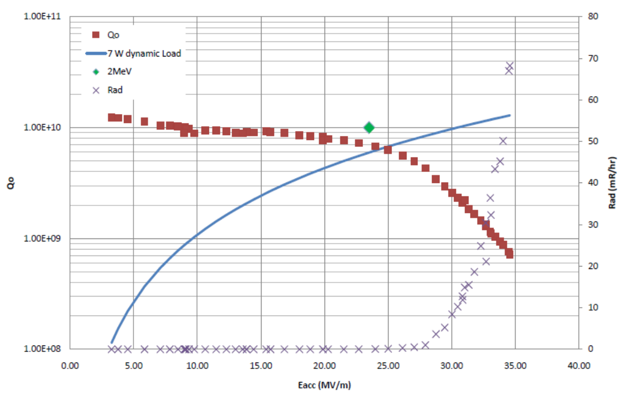

Figure 2: The cavity RF performance at 2 K.

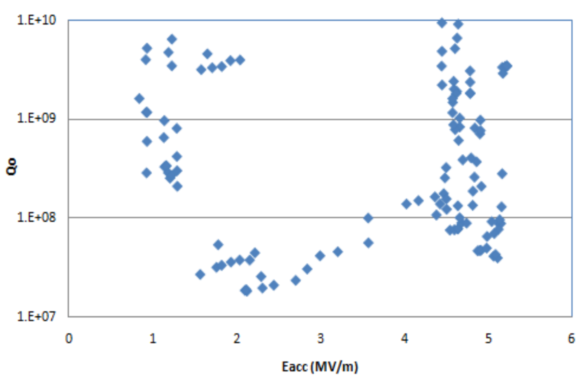

Figure 3: The RF performance with cathode stalk at 2 K after bake.

With Cathode

The high RRR niobium cathode stalk with grooves was installed and tested. The gradient could not go through 3 MV/m due to multipacting in the cathode region. We baked the cavity with cathode and tested again and a DC bias is also added. As it is shown in Figure 6, the DC bias helped to go through 3 MV/m and then there was another multipacting berrier at about 6 MV/m.

MULTIPACTING SIMULATION

Without Cathode

To understand the reason for multipacting, we did computer simulations by FishPact[3] for various cases. The case one is to check multipacting in an ideal triangular groove, which was the original design. The simulation results confirmed that there is no multipacting in the choke joint. Case two is based on the suspicion of misalignment of the grooves, and the result also showed no multipacting. Case three is for the rounded valley of the groove, but not the crest and it turned out no multipacting as well.

Finally, we modeled the groove with 0.2 mm of rounding radius and simulated using Fishpact. The groove model is shown in Figure 4. The simulation was carried out for the gradient up to 24 MV/m in the cavity. In the 1st choke, there are three main multipacting barriers, which are at 3 MV/m, 6 MV/m and 11 MV/m, which is shown in Figure 5. And for the 2nd choke, there are two main multipacting barriers, at 6 MV/ and 11 MV/m, which is shown in Figure 6. The higher the gradient, the closer location of multipacting to the cathode surface, which is reasonable as the electric field is stronger when it is further from the cathode surface. The 3 MV/m multipacting barrier disappeared because of the electric-magnetic field at the 2nd choke is not high enough to reach its first barrier when the gradient of gun is 3 MV/m. The simulation seems to explain the test results with cathode stalk well.

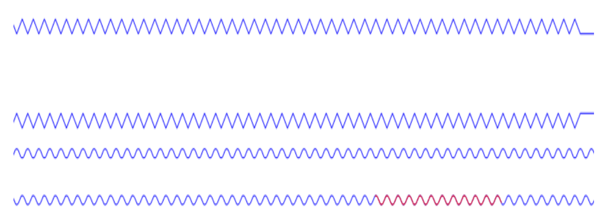

Figure 4: Multipacting model for round grooves.

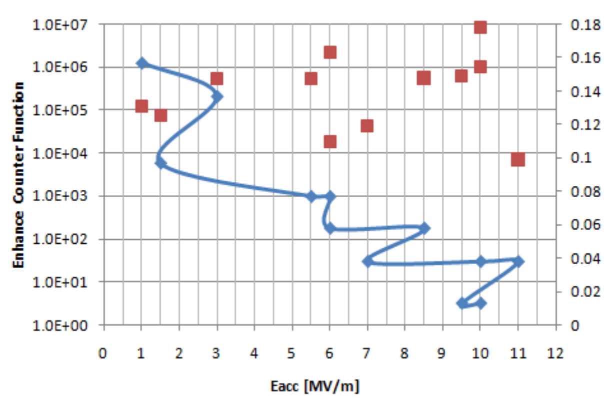

Figure 5: Multipacting result of 1st choke, square red: enhance counter function; diamond blue: position following the curve of groove, the cashode suface is at 0.

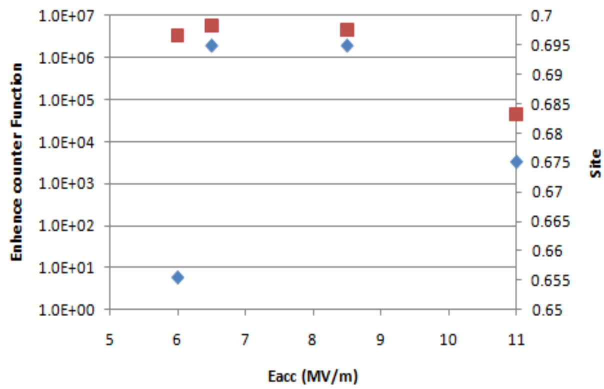

Figure 6: Multipacting result of 2nd chokesquare red: enhance counter function; diamond blue: position following the curve of groove.

HEAT LOAD SIMULATION OF MULTIPACTING

We carried out the heat analysis combined with the multipacting simulation results, which is to add heat load at the particular location from multipacting simulation. The model for the analysis is the actual gun layout[4], which is shown in Figure 7. The result of simulation in figure 8 shows that the further from cathode surface, the easier to quench, due to the difficulty of cooling. This result is encouraging, that is if we can process through the 3 MV/m region by conditioning, it might also be possible to process through all other multipacting barriers, because they are closer to 2 K and get better cooling.

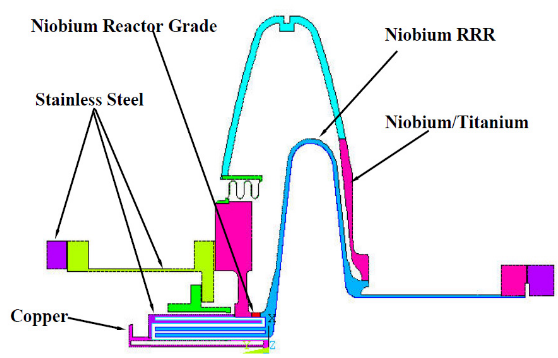

Figure 7: Thermal analysis model

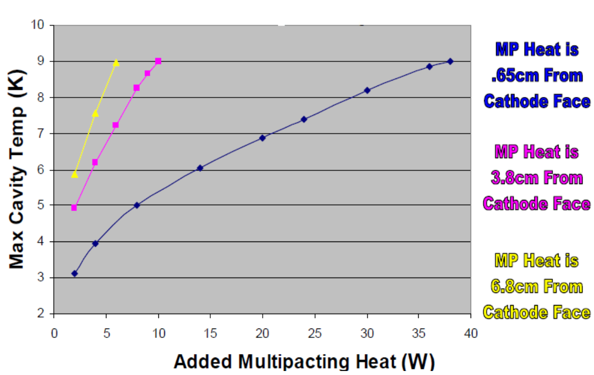

Figure 8: Heat load analysis with added multipacting heat.

SUMMARY AND FURTHER PLAN

BNL 704 MHz gun cavity demonstrated good performance without cathode stalk inserted. However, it was limited by the multipacting when the Nb cathode was installed. The multipacting simulation with rounded crests of the triangular grooves seems to explain the 2 K test results. However, the BCP test

The gun cavity is going forward to be assembled into the cryostat and shipped to BNL. This decision was made after obtained encouraging results from the thermal analysis combined with multipacting heat load. In the cryostat, the cathode is made of copper and cooled by liquid nirtogen. We expect that multipacting can be conditioned with running the 1 MW klystron at short pulse and low duty factor to reduce the heat load, which could not be done at JLab due to the power limitation of RF source.

At the same time, the conditioning of multipacting will be studied further in a vertical test at BNL on a large-grain SRF gun cavity with cathodes made of different materials and at higher power levels.

REFERENCE

[1] V.N. Litvinenko et al, High current energy recovery linac at BNL, Proceedings of the 2004 FEL Conference, 570-573

[2] Burrill et al, Multipacting analysis of a quarter wave choke joint used for insertion of a demountable cathode into a SRF photoinjector, Proceedings of PAC07, New Mexico, USA.

[3] http://www.jlab.org/~genfa/fishpact/

[4] http://www.ansys.com/