MULTIPACTING SIMULATION ADN TEST RESULTS OF BNL 704MHZ SRF GUN*

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Abstract

The BNL 704MHz SRF gun has a grooved choke joint to support the photo-cathode. Due to the distortion of grooves at the choke joint during the BCP for the choke joint, several multipacting barriers showed up when it was tested with Nb cathode stalk at JLab. We built a setup to use the spare large grain SRF cavity to test and condition the multipacting at BNL with various power sources up to 50kW. The test is carried out in three stages: testing the cavity performance without cathode, testing the cavity with the Nb cathode stalk that was used at Jlab, and testing the cavity with a copper cathode stalk that is based on the design for the SRF gun. This paper summarizes the results of multipacting simulation, and presents the large grain cavity test setup and the test results.

INTRODUCTION

The R&D program [1] at Collider-Accelerator Department (C-AD) in Brookhaven National Laboratory and Stony Brook University aims to demonstrate a high charge, high current SRF electron guns, and the knowledge and experience gained by this effort will benefit future high current machines like high repetition rate light sources and eRHIC [2]. A half-cell 704MHz cavity is used to provide various electron beams (high current or high charge, and with energy from 2-2.5MeV) for the 704MHz 5cell cavity. A quarter-wave choke-joint was designed to support the photocathode stalk and the surfaces on the choke-joint were grooved triangularly to prevent multipacting. Two 704MHz SRF cavities were fabricated, one of fine-grain Nb cavity and the other of large-grain Nb cavity. The fine grain gun cavity was tested in Jlab and the gradient reached 35MV/m (the required gradient for 2MeV electron beam is 23.5MV/m). However, strong multipacting at 3-4MV/m and 5-6 MV/m was observed when the test was carried out with Nb cathode stalk. After this test, the investigation of the choke-joint showed that the triangular grooves were distorted by buffer chemistry polishing (BCP). Then, a number of multipacting simulations by FishPact [3] were done based on the distorted grooves on the choke-joint. The test results of fine grain cavity and most of the multipacting simulation results were addressed in reference [4]. Recently, the effort to use the spare large-grain cavity for multipacting test in the Small Vertical Test Facility (SVTF) at BNL. The testing program will progress in three distinct stages from a cavity performance test without cathode, to a cavity test with the Nb cathode that was used in the fine grain cavity test, and finally, testing of the newly-fabricated copper cathode stalk, which is the same structure with ERL SRF gun cathode stalk. This paper will briefly introduce the multipacting simulation result, and detail the goals of the program, the facility, and the experimental apparatus involved in the testing program.

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MULITPACTING ON CHOKE JOINT

Figure 1 shows the SRF gun for the BNL ERL and the grooved choke-joint. It is a 704MHz half-cell SRF gun to provide 500mA, 2 MeV electron beams for the 5-cell cavity. So, two symmetrical fundamental power couplers were needed to deliver 1MW CW RF power to the gun. The photo-cathode was supported by a quarter wave choke joint, which is then transported from the cathode preparation chamber.

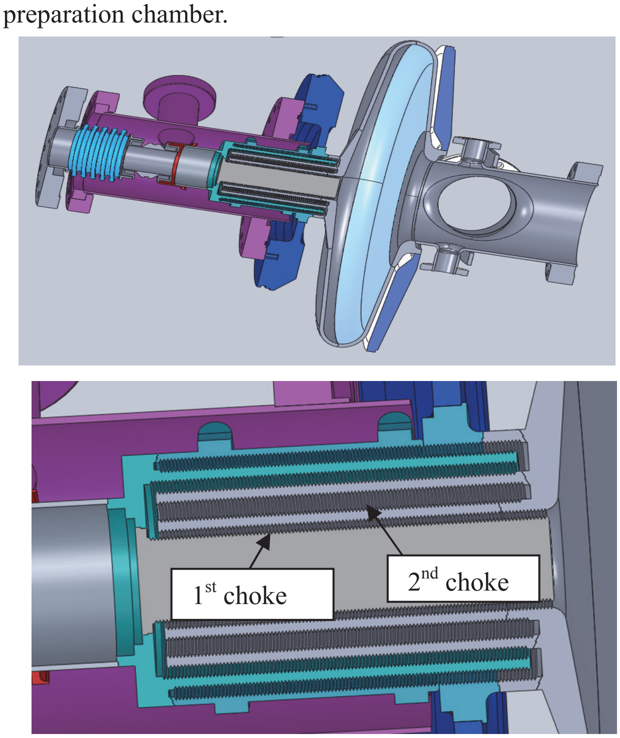

Figure 1: BNL SRF gun (top) and the grooved choke-joint for cathode support (bottom).

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Multipacting simulation was carried out with the ideal triangular grooves on the choke-joint. It turned out that there is no multipacting in ideal triangular grooved choke joint. Furthermore, no multipacting was found in the multipacting simulation of misalignment of the ideal grooves. Finally, we modelled the distorted grooves with 0.2 mm rounding radius, as it is shown in Figure 2, and found the multipacting occurred at several levels in the 1st choke and 2nd choke (see Figure 1). In the 1st choke, there are three main multipacting barriers: 3 MV/m, 6 MV/m and 11 MV/m, as shown in Figure 2. For the 2nd choke, there are two main multipacting barriers at 6 MV/m and 11 MV/m, as shown in Figure 3. For the higher gradient, the location of multipacting was closer 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 at the 2nd choke. This is because the electric-magnetic field 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.

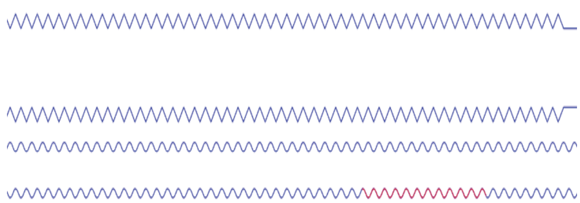

Figure 2: Multipacting model for round grooves.

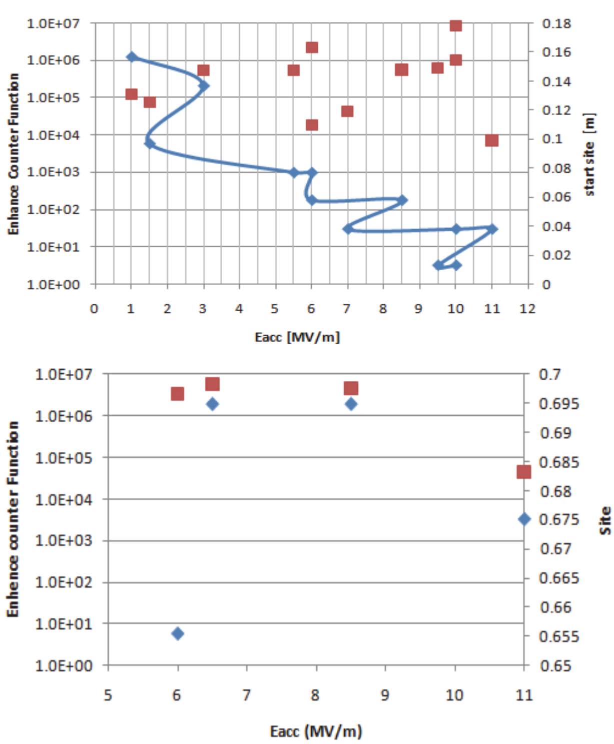

Figure 3: Multipacting result of 1st choke (top) and 2nd choke (bottom), red square: enhance counter function; blue diamond: position following the curve of grooves, the cathode surface is at 0m.

TEST SETUP AND PROGRAMS

Test Setup

The test is carried out in a 28 inches diameter and 70 inches length dewar, as shown in Figure 4. The large grain cavity is hung on the top plate with four stainless steel rods. One fundamental power coupler port is used for vacuum pumping. In addition, a vacuum pump on the cathode side was added to help condition possible multipacting. When the cathode is installed, a camera will be attached on the beam pipe so that we can observe the locations of the multipacting. A heater is installed on the bottom of the dewar and 5 temperature sensors are located at various locations: at the bottom of the dewar, on both ends of the cavity, on the cavity equator and on one of the mounting rods. A tunable fundamental power coupler was designed to achieve unity coupling at various Qs. The total static heat loss in the dewar is about 2 W. Magnetic shielding is added to the outside of the dewar. It turned out that both horizontal and vertical magnetic fields at the cavity area are at micro-gauss levels.

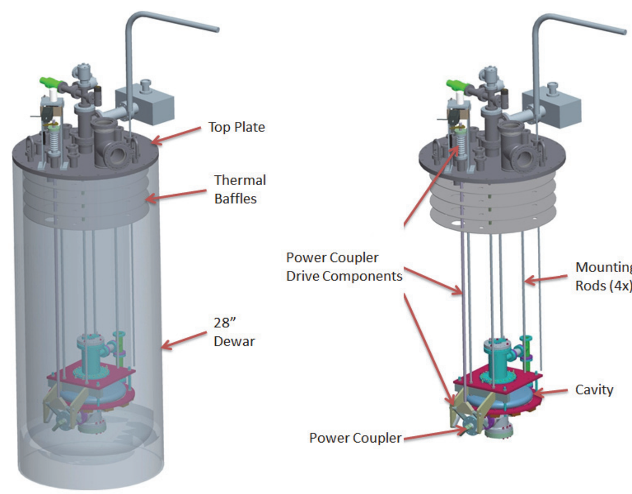

Figure 4: Layout of the test Dewar.

Test Program

The test of the large grain cavity will be carried out in three stages. First, we would like to test the performance of the large grain cavity with a 20 W RF amplifier. This step is important to configure and verify the experimental apparatus. It will be interesting to compare the performances of the large grain cavity and fine grain cavity. This performance test will also be the baseline of the cavity test with cathode stalk insertion in the future. Second, it is important to repeat the test of fine grain cavity by using the same Nb cathode stalk. In this step, we will use a 200 W RF amplifier. For the large-grain cavity, the grooves on the choke joint are protected during BCP so that only the grooves on Nb cathode stalk are distorted. The Q values at these two steps are expected to be ~10^{10} at 2K. Finally, a copper cathode stalk will replace the Nb cathode stalk. This is to simulate the real SRF gun configuration except for better cooling on the

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cathode stalk. With the copper cathode insertion, the Q values will be about 10^8 according to Superfish [5] simulation. All of the above cavity tests will be carried out at 2K. However, in every step, the expected Q values will be at levels from about 10^8 to 10^{10} depending on the configuration, so the required RF power is different. Figure 5 shows the required RF power under critical coupling (by adjusting the input coupler) with Q = 10^8 and 10^{10}. Although for the 200 W RF power, the gradient of the large-grain cavity will be 17 MV/m, it is still higher than the highest multipacting zone at 11 MV/m (about 93 W required for input power), so we will try to use the 200 W to condition the multipacting. If this power is insufficient, we will use the 50 KW IOT transmitter to condition the multipacting.

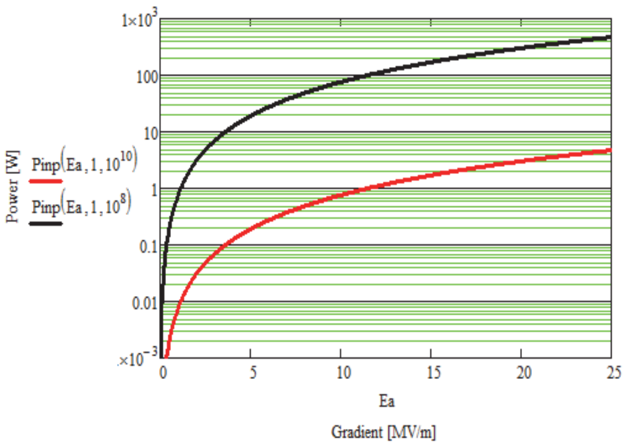

Figure 5: RF power required for various Q values at critical coupling.

FIRST TEST AND IMPROVEMENT

The first cool-down test of the large grain cavity happened from May 2nd to 3rd. The cavity was processed at Jlab and backfilled with N_2 gas. The test used a fixed-coupling input coupler, as used for the fine grain cavity test at Jlab. Figure 7 shows the cavity hanging from the top plate. The main goal of this test was to exercise the cavity installation, cool-down procedure, data acquisition system, cable calibration and measurements of cavity performance. Because of safety requirements, the He supply dewar was located outside the block house and the 4K LHe was transferred into test dewar by a ~10m transport line. It took about 20 hours to empty the 500 L LHe dewar due to the low transfer rate of the LHe. Ultimately, the cavity was even not immersed in the 4K LHe. However, the cables and RF system were calibrated, and the cavity was also powered at 4k and the the loop was closed for short time. Due to the unstable temperature, the cavity performance could not be measured accurately at 2K. Over all, it met the first cool-down goal to verify the configuration and procedure. Several items will be improved for future tests, such as the LHe transfer procedure, calibration of the RF system, etc.

Figure 6: The large grain cavity (top) and the top plate assembly for the test (bottom).

SUMMARY

We are studying multipacting of groove-distorted choke joint in the BNL R&D ERL SRF gun to explain the test results with the fine-grain cavity. To study, verify and condition the multipacting in the choke joint, a three-stage testing program using the spare large-grain cavity has been devised. The first cold experiment took place and some practical issues were revealed, which will serve as basis for improving future tests. The SRF gun is a critical component for the BNL R&D ERL and the large-grain cavity test will greatly benefit the ERL program. The next test of the large grain cavity will occur in a couple weeks.

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