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EXPERIMENTAL AND SIMULATIONAL RESULT OF MULTIPACTORS IN 112 MHz QWR INJECTOR

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Abstract

The first RF commissioning of 112 MHz QWR superconducting electron gun was done in late 2014. The coaxial Fundamental Power Coupler (FPC) and Cathode Stalk (stalk) were installed and tested for the first time. During this experiment, we observed several multipacting barriers at different gun voltage levels. The simulation work was done within the same range. The comparison between the experimental observation and the simulational results are presented in this paper. The observations during the test are consisted with the simulation predictions. We were able to overcome most of the multipacting barriers and reach 1.8 MV gun voltage under pulsed mode after several round of conditioning processes.

INTRODUCTION

The CeC PoP system is being installed in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory [1]. The commissioning of 112 MHz QWR superconducting electron injector with the beam pipe coaxial fundamental power coupler (FPC) and choke joint cathode stalk was done in late 2014 and continued into early 2015. During the test we observed mainly three bands of multipacting barriers which correspond to the resonators located in cavity, FPC and cathode stalk, respectively. The observed multipactors consistent with the previously simulated results given by Track3P package.

EXPERIMENT SETUP

The general layout of experiment is showed in Figure 1. The cryomodule of 112 MHz QWR gun was connected with RHIC main Helium loop via a Quiet Helium Source and working at 4.3 K.

Beam pipe coaxial FPC can transmit up to 2 kW RF power and establish 2 MV gun voltage in the cavity. The inner conductor of the FPC is water cooled and the surface of the FPC is gold plated in order to reduce emissivity. The location of the FPC tip was designed to be adjustable within a ±2 cm range for the sake of coupling tuning [2].

The half wavelength cathode stalk was also install for the commissioning. The stalk was designed to create a choke joint between the cathode plane and the cavity nose cone. Special impedance mismatching is utilized so that the RF loss on the surface of the stalk is minimized. The surface of stalk is also gold plated to reduce the static thermal load to the cryosystem.

The design parameters of the injector are shown in Table 1. The cavity is designed to run at 112 MHz in CW mode. The energy gain of electron is 2 MeV and repetition rate is 78 kHz. During this experiment we didn't use the multi-alkali cathode but a dummy molybdenum puck as the placeholder to provide correct RF boundary condition.

Table 1: Design Parameters of the 112 MHz Electron Injector

Parameters	Value
Frequency	112 MHz
Charge per Bunch	1~3 nC
Repetition Rate	78 kHz
Acceleration Voltage	1~2 MV
Cavity Q_0	1.8e8
R/Q	122 Ω

Experimental Results

Several multipacting barriers were observed during the commissioning of the injector. We've already seen the 50 kV barrier in the previous experiment with this cavity [3]. The new structures in this experiment are the FPC and cathode stalk. Both of them are coaxial structures hence are vulnerable to multipacting. As the matter of fact, we observed three most persistent barriers while ramping up the cavity voltage. The first one was found near 50 kV, which we knew is located in the cavity. The second and third relatively strong barriers were encountered when gap voltage was in the range of 100 kV to 200 kV and 600 kV to 800 kV respectively. Since the field strength in the FPC gap is much stronger than that of the cathode stalk, we believe the former multipactor is located in the FPC and the latter one in the cathode stalk. This expectation is further confirmed by simulation results given by the SLAC Track3P package and will be discussed in more detail in the next section.

After several rounds of conditioning, most of the multipacting barriers were overcame and the cavity can now reach 1.8 MV gun voltage in pulsed mode and 1.3 MV in CW mode. The CW mode voltage is limited by field emission. Further condition process is undergoing.

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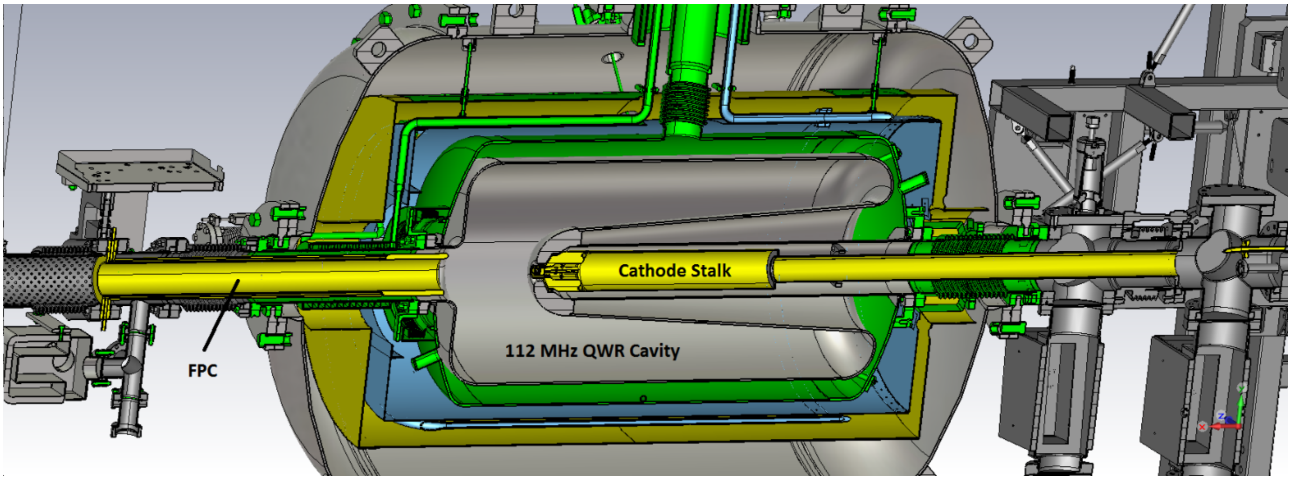

Figure 1: Experiment layout of 112 MHz QWR superconducting electron injector.

SIMULATION RESULTS

The multipacting simulation was performed with the SLAC Track3P package.

Figure 2 shows the model used for RF/Tracking simulation (tetrahedron mesh generated by cubit 14.2). There are two feedthroughs symmetrically located at the end of the FPC and the pickup antenna is located near the end of the half wavelength cathode stalk.

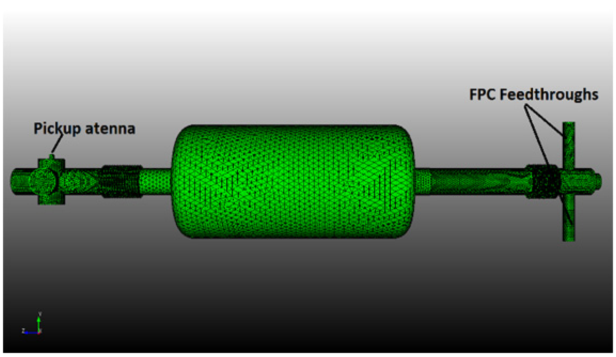

Figure 2: Tetrahedron mesh generated by Cubit with a number of elements equal to 1.5 million.

There are three main types of surface specified as secondary electron emitters. The cavity and part of the beam pipe are niobium, the FPC and cathode stalk are gold plated and the beam pipes outside the cryomodule are copper plated stainless steel. Figure 3 shows the SEY curves we used to interpolate the generated secondary electrons from each impact and calculate enhanced counter function. The SEY curves were generated by Furman's three components model [4].

The primary particles were emitted from the surface triangles in the vicinity of the central symmetric plane and tracked under RF field for 50 cycles. If the particle survived the whole process a cumulative product of secondary electron yields from each impacts is calculated and gives the so-called Enhanced Counter Function. It is the number that tells how many secondary electrons will be generated from a single electron if it met the resonance condition and survived after 50 cycles.

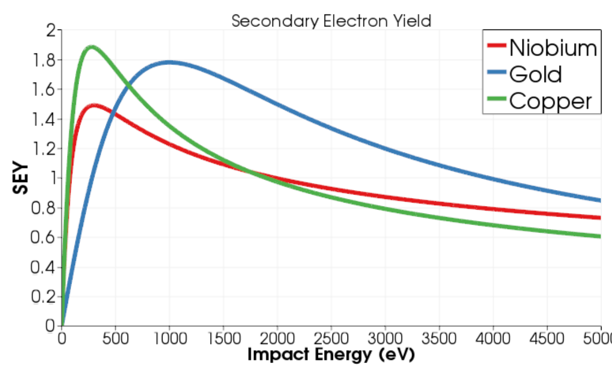

Figure 3: Secondary electron yield curves used in Track3P simulation.

Figure 4 shows the calculated enhanced counter function from all particles at different gun voltages. Each cross represents the final enhanced counter function of one particle.

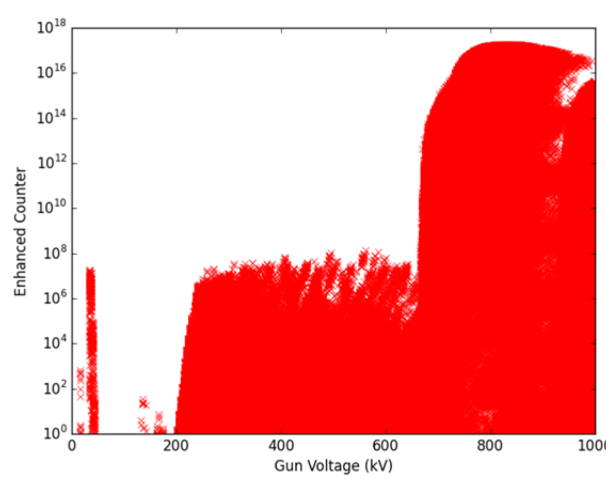

Figure 4: Enhanced counter function vs gun voltage.

One can clearly see three multipacting bands in the simulated results. The locations of the multipacting barriers are shown in Figure 5. The first one appears near 50 kV gun voltage. This is the multipactor located inside

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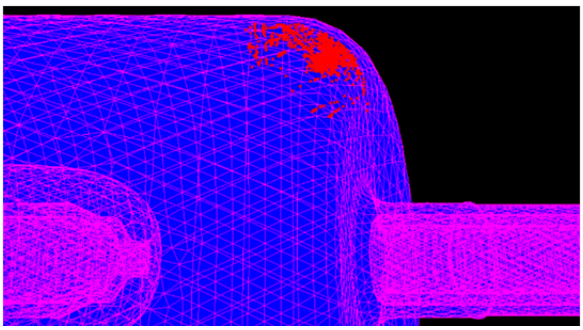
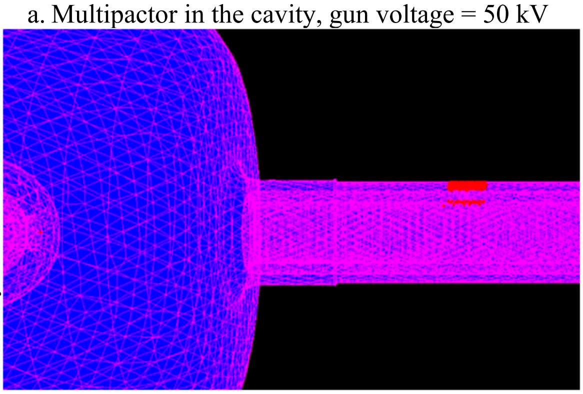
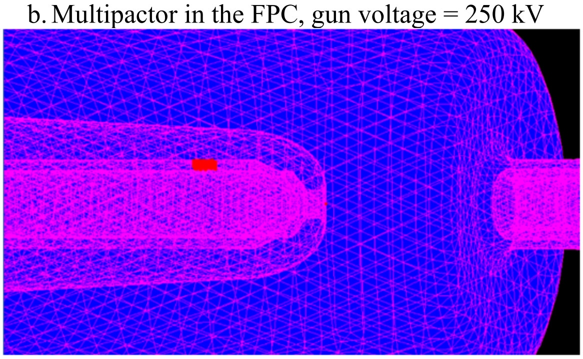
the cavity. The second multipacting band appears after the gun voltage reaches 200 kV and continues to exist up to above 600 kV. This multipactor is in the FPC and migrates along the coaxial structure from the cavity side to low field side while the gun voltage increases. The third one appears in the cathode stalk area after the gun voltage reaches around 700 kV. Similar to the one in the FPC, this one also migrates along the structure with increasing gun voltage due to the changing of location of the resonance condition along the coaxial structure.



a. Multipactor in the cavity, gun voltage = 50 kV



b. Multipactor in the FPC, gun voltage = 250 kV



c. Multipacters in the cathode stalk, gun voltage = 800 kV

Figure 5: Simulation results of the three most persistent multipactor barriers at different gun voltages. Red dots are the resonance particles.

The impact energies of resonance particles are shown in Figure 6. As we can see, due the coaxial structure the dangerous particles exist through a large range of gun voltage. This is one of the most important issue we need to address in future works.

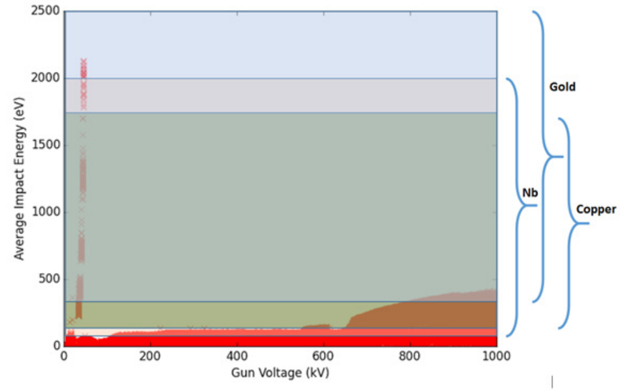


Figure 6: Impact energy of resonance electron vs. gun voltage and dangerous ranges of different materials used in the simulation.

CONCLUSION

The first RF commissioning of the 112 MHz QWR injector gave us a good opportunity to benchmark the simulation work against the measurements in experiment. We encountered three relatively strong multipacting barriers during the experiment and all of them were observed in the simulation results. The coaxial structures lead to continuous multipacting bands in large range of the gun voltage thus making conditioning more difficult. Special treatment, such as introduction of groves might need to be considered in future designs.

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