MULTIPACTING ANALYSIS OF A QUARTER WAVE CHOKE JOINT USED FOR INSERTION OF A DEMOUNTABLE CATHODE INTO A SRF PHOTOINJECTOR*

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Abstract

The multipacting phenomena in accelerating structures and coaxial lines are well documented and methods of mitigating or suppressing it are understood. The multipacting that occurs in a quarter wave choke joint designed to mount a cathode insertion stalk into a superconducting RF photoinjector has been analyzed via calculations and experimental measurements and the effect of introducing multipacting suppression grooves into the structure is analyzed. Several alternative choke joint designs are analyzed and suggestions made regarding future choke joint development. Furthermore, the problems encountered in cleaning the choke joint surfaces, factors important in changes to the secondary electron yield, are discussed and evaluated. This design is being implemented on the BNL 1.3 GHz photoinjector,[1] previously used for measurement of the quantum efficiency of bare Nb, to allow for the introduction of other cathode materials for study, and to verify the design functions properly prior to constructing our 703 MHz photoinjector with a similar choke joint design.

INTRODUCTION

The 1.3 GHz photoinjectors have been used to study photoemission from the back surface of the injector, measuring the QE of niobium and comparing it to measurements made in a DC test stand. The results were good, and the effort has led to further R&D on QE measurements of other superconducting materials in a Nb gun. After the initial testing we decided to modify one of our 1.3 GHz guns to allow for the insertion of a demountable cathode stalk, a key technology needed for the 703 MHz SRF photoinjector being designed and built for the BNL High Average Current Energy Recovery Linac project, and subsequent installation in the RHIC II electron cooling injector design. We began our analysis investigating the FZ Rossendorf design which has been successfully implemented for use with Cs_2Te photocathodes.[2] Due to the need for active cooling of our cathode stalk, and for simplicity sake, a new design, the quarter wave choke joint, was chosen as it allows for implementation of active cooling more readily and presents itself as an easier design to engineer and build. Initial cold model experimental measurements were carried out by Tunnel Dust Inc. on three potential choke joint geometries, these were smooth parallel plates, rectangular grooved parallel plates and triangular grooved parallel plates. The cold model measurements showed that the triangular grooved plates provided the best multipacting suppression, processed the quickest and once stable did not degrade with time. After the cold model testing the SRF gun was modified to incorporate these triangular grooves, a challenge when working with niobium, and initial RF measurements were carried out. The results were not as expected, thus prompting this investigation.

INITIAL DESIGN

The initial design of the choke joint was constructed based on the above mentioned cold model and simulations and the gun is shown in figure 1. The RF results of the cavity before being modified are shown in figure 2, and from this graph one can see the excellent performance obtained.

Figure 1. The 1.3 GHz photoinjector with the cathode stalk.

After the choke joint was added the gun was again tested however the results were most discouraging. Figure 3 and 4 show the test results first with the cathode stalk removed, and then with it inserted. After evaluating the cavity performance, and the fact that there was a hard barrier at 2 MV/m, it was realized that the multipacting

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suppression grooves which were meant to be cut in all choke joint surfaces, had in fact been left out of the outer coaxial section.

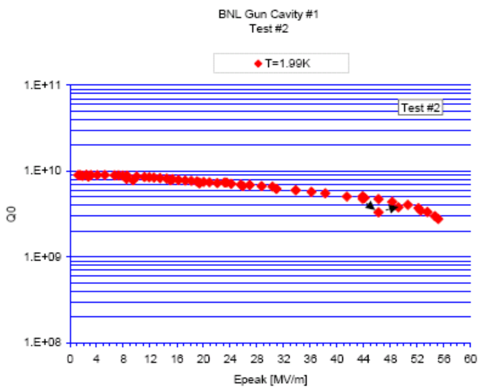

Figure 2. Initial cavity performance prior to the cavity modification, data collected by Peter Kneisel.

After this discovery it seemed fairly straight forward to install the grooves in the outer section, but before doing so this study was undertaken to better understand what had happened and what other methods might be available to mitigate it.

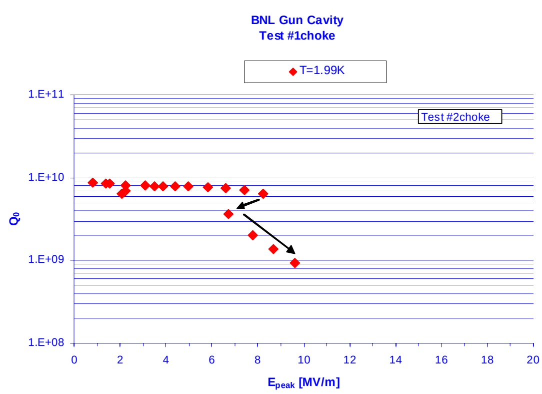

Figure 3. The performance of the cavity without the cathode stalk inserted.

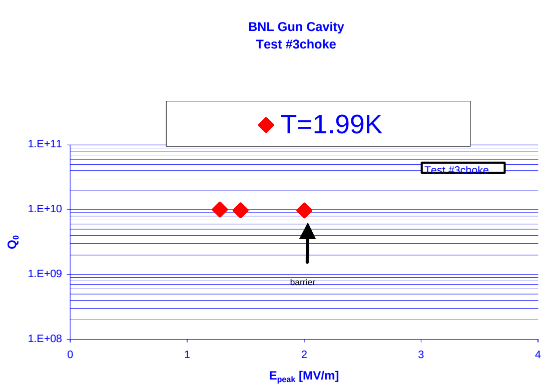

Figure 4. The performance of the original cavity with the cathode inserted.

The multipacting code FISHPACT (courtesy of Genfa Wu, Fermilab) was implemented to study the choke joint design. [3,4] More details on the code can be found in references 3 and 4, but in short the program is a multi-purpose electron tracking code that was developed based on the Poisson/Superfish Field solvers.[5] The program allows the user to track the electron trajectories between impacts under varying accelerating gradient (E_{acc}), RF phases, and emission locations. The user can also change the secondary electron yield and initial electron energy.

The initial geometry of the choke joint, as shown in figure 5 was used as the input file and the program was run while varying a number of parameters to try and reproduce the experimental results while also studying the effect different parameters had on the outcome. In the end the multipacting analysis, shown in figure 6, was obtained which shows significant multipacting barrier over a very wide range of accelerating fields. One thing that was noted while using the program is how sensitive it is to the input geometry mesh, as one would expect. Any perturbation in the mesh can produce an area which appears to contain significant multipacting, but in truth may only be due to the mesh variation. This was a particular challenge for the choke joint as the grooves are very small, thus requiring a very fine mesh.

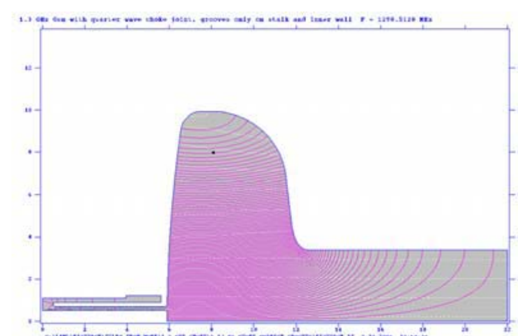

Figure 5. The original superfish file with the as built choke joint.

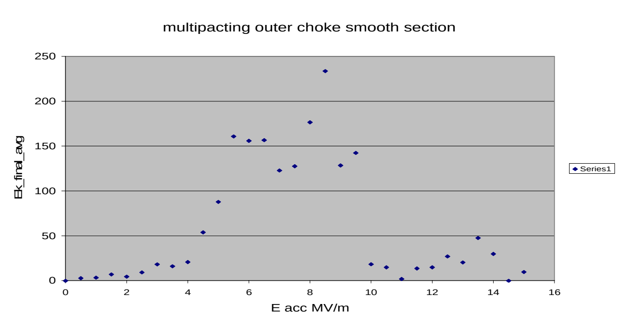

Figure 6. The multipacting analysis from the initial choke design.

CHOKE JOINT MODIFICATION

Following the initial choke analysis several possible solutions were identified and analyzed. The most obvious was the grooves on all surfaces. This would require removal of the outer section of the choke joint, machining of the grooves and re-welding the assembly. Several less labor intensive solutions were also investigated. These included using a tapered outer coaxial section, thus removing the resonant condition required for multipacting, or simply enlarging the dimensions of the outer choke region. The analysis of several different geometries are shown in figures 7-9 below.

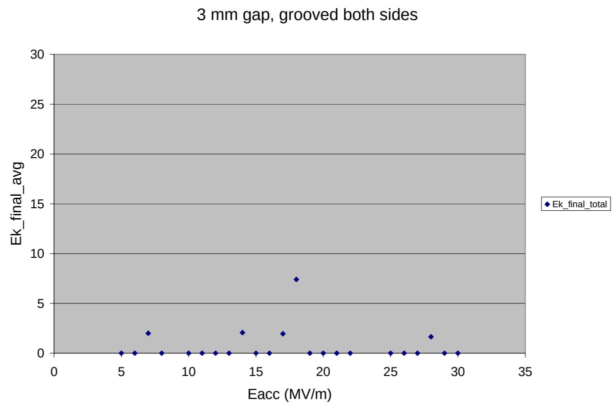

Figure 7. The results of the multipacting simulation on the choke joint design with grooves on all faces.

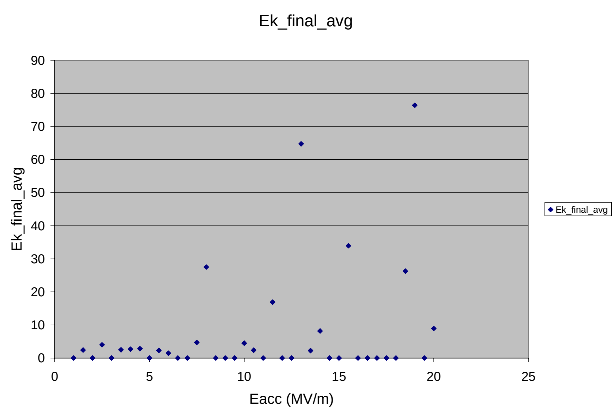

Figure 8. Multipacting analysis of the tapered outer choke section. The taper goes from 13 mm to 20 mm radius.

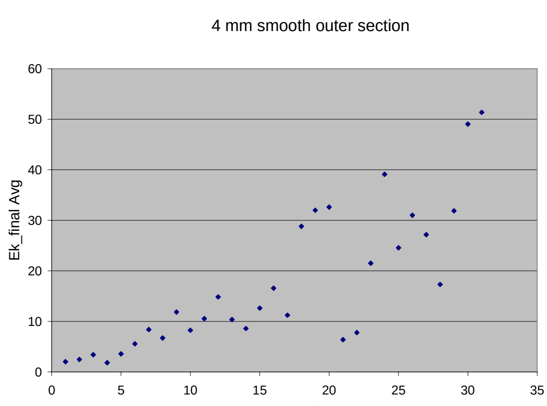

Figure 9. The multipacting analysis of a 4 mm wide outer choke joint that is smooth on both faces.

CAVITY MODIFICATION

Following several months of analysis, boiled down to the graphs above, it was decided to go with the safe path and have the grooves installed on both sides of the outer choke joint. The dimension between the two adjacent walls was increased from 2 to 3 mm in the interest of making cleaning of the choke joint easier, thus improving our chances for success. The modification of the joint was a technical challenge due to the small dimensions and the 60 single point grooves that had to be cut in each face of the choke joint. The section was successfully machined and then e-beam welded back together. It then received a very thorough BCP cleaning and will be tested shortly, results of which will be published separately. The real challenge for a design like this is the ability to clean and assemble the structure such that one does not compromise the cavity performance and success of the project. Once this baseline design is proven, it will then be possible to begin analysis of different photocathode materials using this photoinjector, including such cathode materials as CsK_2Sb and GaAs, both of which have promising future applications to high average current ERLs.

REFERENCES

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