9-1-2002

# Modeling, Fabrication, and Optimization of Niobium Cavities: Phase II Quarterly Report

Robert A. Schill Jr.
*University of Nevada, Las Vegas*, robert.schill@unlv.edu

Mohamed Trabia
*University of Nevada, Las Vegas*, mbt@me.unlv.edu

# Modeling, Fabrication, and Optimization of Niobium Cavities – Phase II

## QUARTERLY REPORT
## [9-1-02]

UNLV-AAA University Participation Program

Robert A. Schill, Jr. and Mohamed B. Trabia
Principle Investigators

## Purpose and Problem Statement

Multipacting is one of the major loss mechanisms in rf superconductivity cavities for accelerators. This loss mechanism limits the maximum amount of energy/power supported by the cavities. Optimal designs have been identified in others' studies. In practice, these designs are not easily manufactured. Chemical etching processes used to polish the cavity walls result in a nonuniform surface etch. A nonuniform surface etch will leave some unclean areas with contaminants and micron size particles. These significantly affect mutipacting. Further, a nonuniform etch will leave areas with damaged grain structure, which is not good for superconducting properties. Typically, the depth of chemical polishing etch ranges between 10 to 150 microns.

It is the purpose of this study to experimentally model the fluid flow resulting in the chemical etching of a niobium cavities with the aid of a baffle. Numerical tend to show that the current etching process with baffle does not uniformly etch the cavity surface. Multiple cavity cell geometries are to be investigated. Optimization techniques will be applied in search of the chemical etching processes, which will lead to cavity walls with near ideal properties. Figure 1

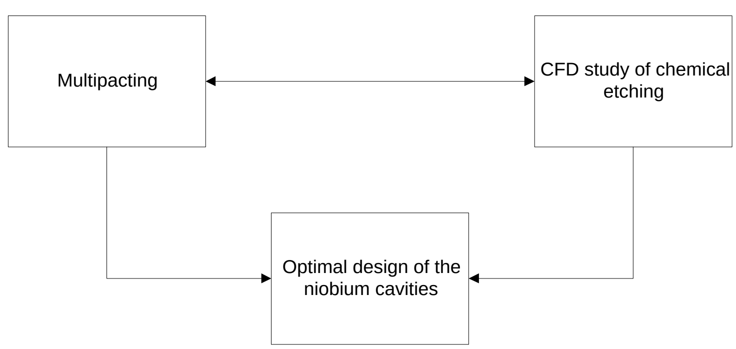



**Fig. 1** Block Diagram of Optimization Procedure

depicts a block diagram of the optimization procedure, which is intended to be fully automated among a variety of existing codes. Codes are to be modified to provide a statistical study of impacting in the multicavity geometry. Optimization techniques to be developed based on the desired resonant frequency of the geometry and/or on the multipacting condition. An existing vacuum system is, in part, to be modified for multipacting experiments to be conducted in year three of this effort.

## Personnel

Principal Investigators:

- Dr. Robert A. Schill, Jr. (Electrical Engineering)
- Dr. Mohamed B. Trabia (Mechanical Engineering)

Research Investigator:

- Dr. William Culbreth (Mechanical Engineering)

Students:

1. Ms. Myong Holl, Undergraduate Student, (Mechanical Engineering)
2. Mr. Satishkumar Subrmanian, M.S. Graduate Student, (Mechanical Engineering).
3. Mr. Anoop George, M.S. Graduate Student, (Electrical Engineering).

National Laboratory Contact:

- Dr. Tsuyoshi Tajima, Team Leader, Accelerator Physics & Engineering, LANSCE-1, Los Alamos National Laboratory

## Technical Contacts

Over the past quarter, various interactions have been made with: Drs. Tsuyoshi Tajima

## Technical Research Efforts and Accomplishments

### *Multipacting Study*

A multipacting study is essential in the design of super conducting, high power, niobium cavities for high energy proton acceleration in linacs. Multipacting limits the quality factor of the cavity due to losses associated with secondary emission resulting from impacting resonance that is spatially localized.

Commercial codes from Field Precision Inc. (Xlate, Mesh, and Wavesim), a research code (Trak_rf) developed by Stan Humphries, and various MATLAB programs developed at UNLV are used to investigate particle tracking and multipacting. The Trak_rf code is a finite element code that tracks charged particles in RF fields based on supplied initial conditions. Particles are launched when the E-field reaches a threshold value as determined by the programmer to simulate field emission. This study focuses on the significant localized increases in impacting on the cavity surface and the secondary electron emission coefficients generated by each particle launched at each point of impact. Trak_rf only tracks the primary particle launched and not the secondary particles. Even so, the trajectory of the electron after impact is an averaging of all possible secondary trajectories. If the primary particle exhibits some type of spatial impacting resonance and the secondary electron coefficient is greater than one at each impact, one usually interprets the impacting as multipacting. Although this is valid and satisfies the multipacting criteria, it is believed to be a special case of multipacting. If the primary particle does not exhibit a spatial resonance, then based on the multipacting criteria, we only have impacting. Although this may be true, it is possible that one of the secondary electrons emitted will result in multipacting. Because the codes do not track individual emitted particles, a scheme to be able to identify potential multipacting locations based on both the spatial resonance of the primary electron and the potential spatial resonance of the secondary electron was developed.

Phase I of this study resulted in an optimization code based on the resonant frequency of the five cell geometry. Only one test case was examined. Since then, emphasis has been directed to a verification study of the Trak_rf code and the binning of the five cell geometry. We have been able to almost reproduce key results provided in Humphries's paper.[1] Figure 1 illustrates the bins of the surface area of one cell in the five cell geometry. An Excel spreadsheet is linked by means of a MATLAB code to extract impact data from the Trak_rf code. Figure 2 shows the statistical results of a trial run of the code where 1,188 particles are launched both in the end cell and in a mid cell of the five cell geometry. The maximum longitudinal component of the electric field on the z-axis is 4 MV/m. The particles were launched along 11 positions on the straight section inside both cells 4 (mid cell) and 5 (end cell). At each position, three different momentum launch conditions were prescribed each with 36 different phases in increment differences of $10^o$. The five cell geometry was operated in $\pi$-mode at a resonant frequency of ~700 MHz. The conditions chosen are similar to that in Humphries's paper. The kinetic energy range of the kinetic energy range of the particles exceeded his values by a factor of about 3 or so. Figure 2 shows that the multiplication factor became large (>10) at certain phases.

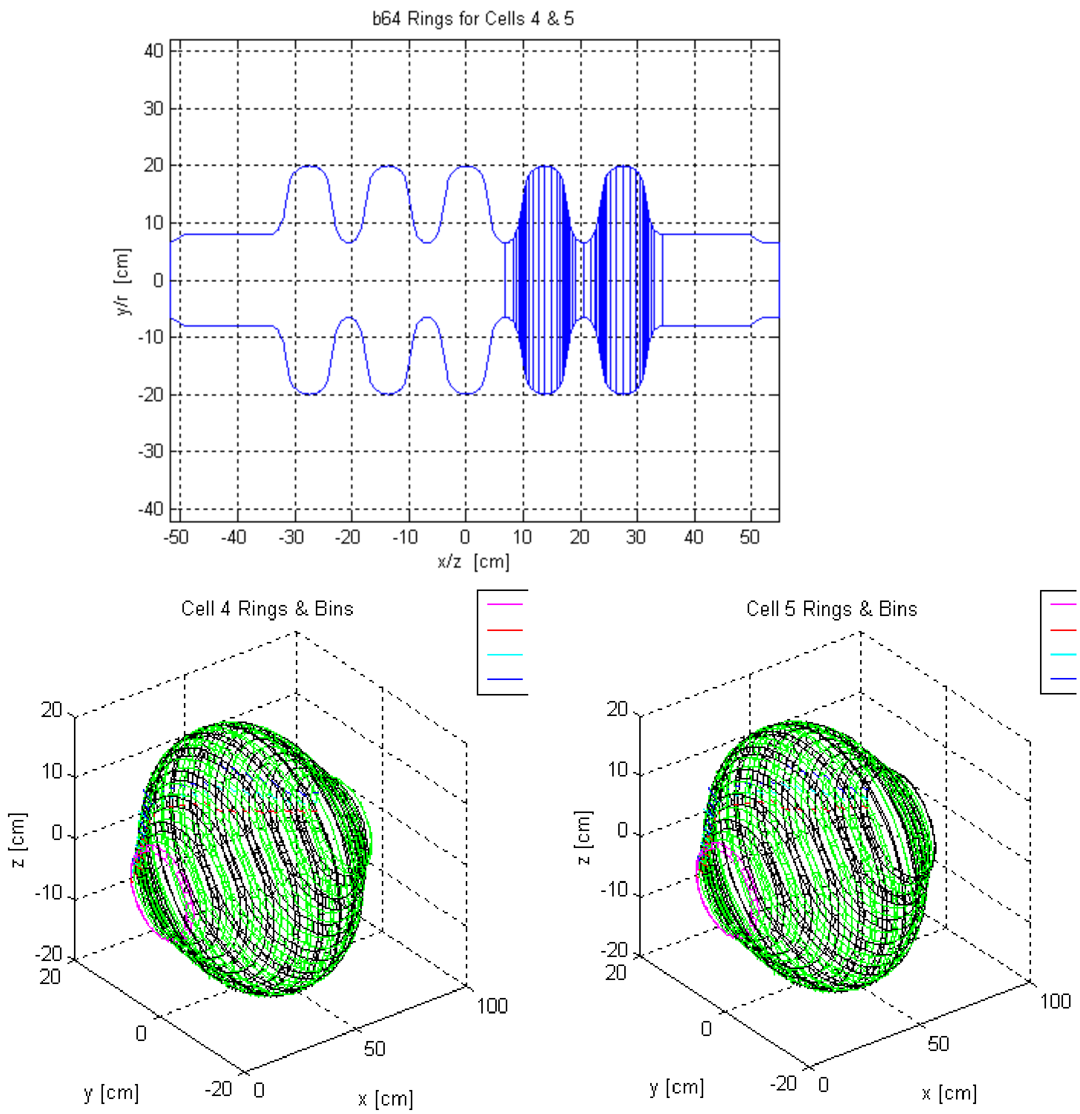
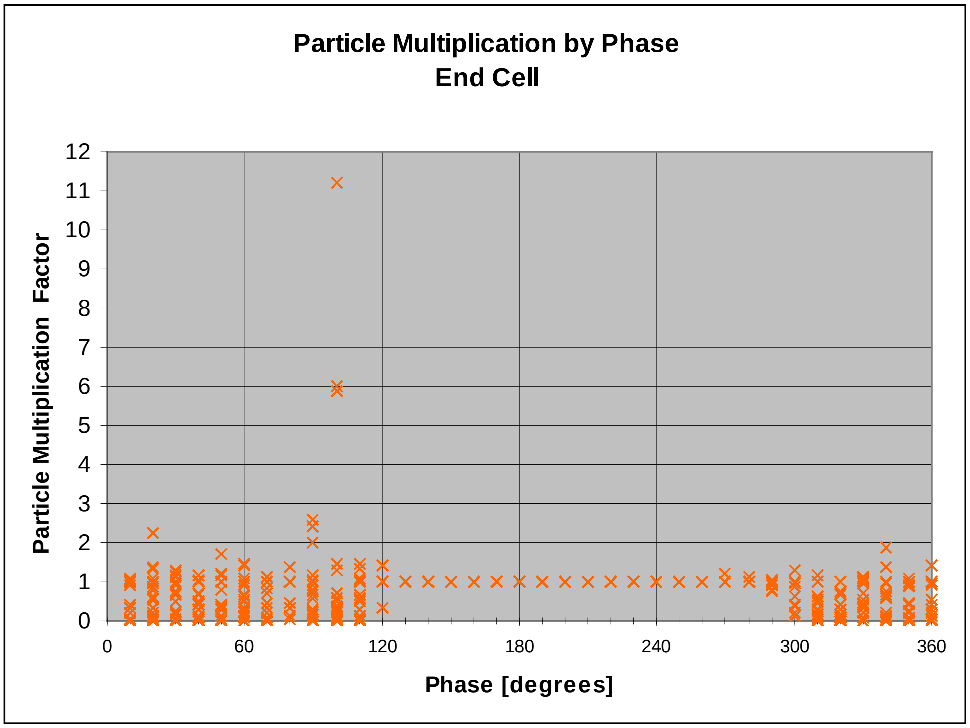



**Fig. 1** A visual picture of the bins of a single niobium cell in a five cell geometry. Cell 4 is a mid cell where as cell 5 is an end cell in the five cell geometry.



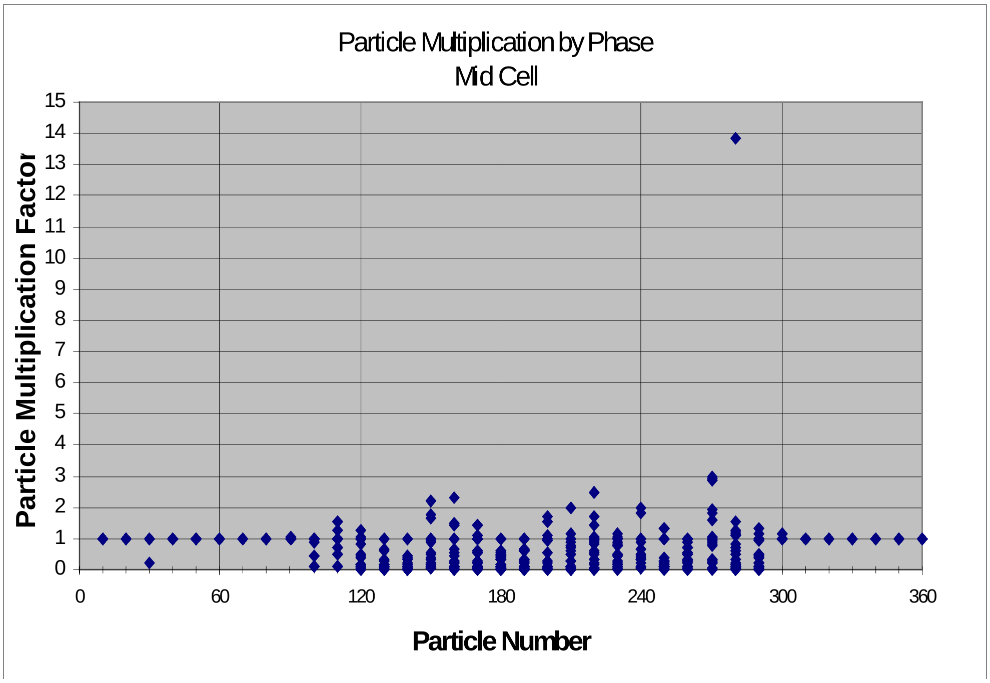




**Fig. 2** The statistics of a trial multipacting study.

The secondary electron emission predicted due to impacting is only as good as the data supplied to the code. In year three of this proposed effort, we will experimentally study impacting from a flat niobium sample under cryogenic conditions. An effort is underway to refurbish an existing vacuum system at UNLV for this purpose. A CTI-8F cryogenic pump has been donated to the university from Helix Inc. to replace a faulty turbomolecular pump. The pump is to be installed sometime in September. Old flanges have been removed from the existing vacuum chamber. Some of the conflat flanges have knife edge surfaces that have been rolled over. Specially designed copper gaskets have been found for these damaged knife edges for high vacuum purposes. An old Veeco MS-170 leak detector is currently being refurbished. This detector is to be used to identify leaks in the vacuum system. Several electron guns and ion surface cleaning guns have been identified for use with the vacuum system. A cryogenic manipulator with x,y,z linear motion and theta rotation is currently sought. These expensive pieces are crucial in the experimental study of secondary electron emission under cryogenic condition. Gas and special liquid helium and nitrogen dewars are also being sought. A means to optically align the electron gun to the target surface is currently under investigation. At this time due to the cost of individual pieces, parts have not been ordered. The budget only allows for the purchase of some of these parts. We are trying to put together a complete system on paper before ordering a fraction of what is needed to perform the experiment within budgetary limits.

### *Flow Visualization Study*

The previous year's numerical work produced velocity distributions within the etchant used to produce the final finish in the niobium cavities. The flow is laminar and pockets of re-circulating flow were reduced by changing the baffle design.

Flow visualization is needed to help verify the FEA simulations and to give better insight to the problem. Dr. Tajima has loaned us a transparent plastic cavity that will be used in UNLV to simulate different etching conditions. Verification of the predicted velocity distributions can be done on a prototype niobium cavity using acid etchant at great expense. Fortunately, laminar and turbulent flow distributions can be verified experimentally through dynamic similitude by choosing a "model" fluid that has the same Reynolds number for the desired flowrate.

Water, for example, has a viscosity and density that is similar to that of the acid etching fluids at the desired flow velocities. The Reynolds number is a dimensionless group that relates the inertial forces in a fluid to viscous forces. By matching the Reynolds number of the flow in a model to the prototype cavity, the resulting flow patterns will be the same. The velocity of the "model" fluid must be adjusted for differences in fluid density and viscosity:

$$V_m = V_p \left( \frac{\rho_p}{\rho_m} \right) \left( \frac{D_p}{D_m} \right) \left( \frac{\mu_m}{\mu_p} \right)$$

In this expression, the subscripts for the model (m) and prototype (p) system are related through dimension, D, density, $\rho$, and dynamic viscosity, $\mu$.

The following steps are taken to design the flow visualization experiment.

1. A plexiglass box was designed and manufactured, Figure 3. The box will enclose the cavity. It will be filled with water to avoid reflection on the cavity walls.
2. A plexiglass baffle is designed. It will be manufactured within the next two weeks.
3. A pump and piping for the experiment are selected, Figure 4. They will be ordered by next week.
4. Two quotes of a two-dimensional traverse system for moving the camera along the baffle are obtained. We will obtain a third quote before submitting a purchase request.
5. The specifications of the digital cameras are agreed upon. It will be ordered soon.

**Figure 3. A Photo of the Cavity Container**

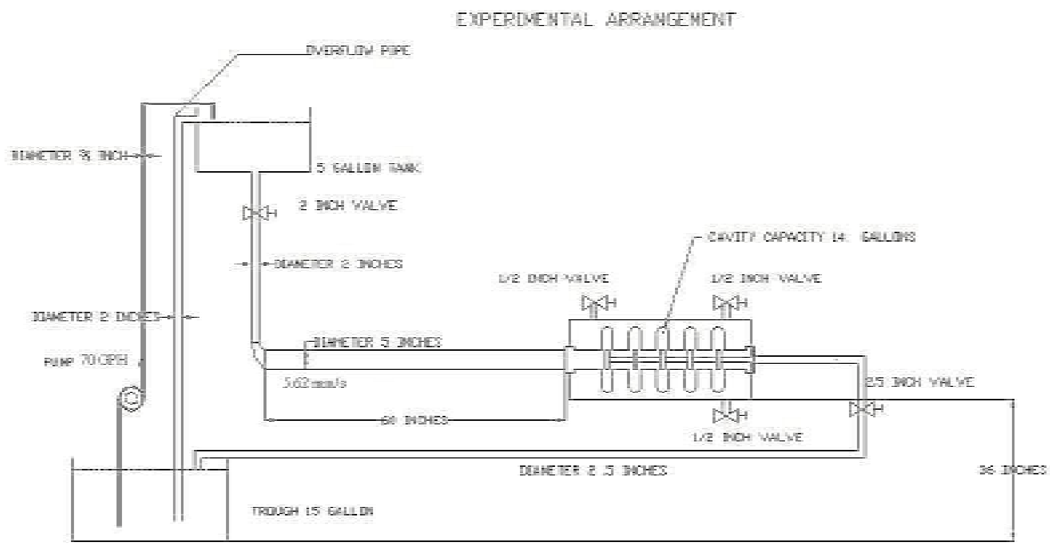



**Figure 4. Layout of the Flow Visualization Experiment**

**References:**

1. S. Humphries Jr. and D. Rees, *Electron Multipactor Code for High-Power RF Devices*, 0-7803-4376-X/98, IEEE, 1998, pp. 2428-2430.