Task 2

Modeling, Fabrication, and Optimization of Niobium Cavities

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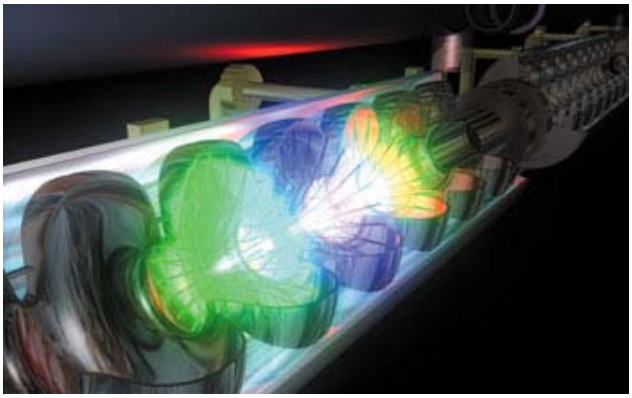
BACKGROUND

One of the key technologies for the deployment of accelerator-driven transmutation systems is the accelerator itself. To increase the efficiency of the high-power accelerators needed to support the transmutation mission, the national and international accelerator teams have proposed using elliptical superconducting niobium cavities. This project is tasked with examining the impacts of the design and fabrication technologies for these elliptical niobium cavities on their performance. Niobium was selected primarily due to its behavior at low temperatures.

One of the major sources of energy loss from a superconducting accelerator cavity is a process known as multiple impacting (or "multipacting") of electrons. This phenomenon limits the maximum amount of energy and power that the niobium cavity can store. As a result, the maximum power available for accelerating the desired charge, as well as the overall performance of the accelerator is reduced. Furthermore, the energy absorbed as a result of multipacting eventually turns into heat. This negatively impacts the performance of both the super conducting cavity and the accelerator.



Schematic of the elliptical cavity portion of an accelerator system.

Multipacting is effected by the surface properties of the niobium wall. This is usually described in terms of the secondary electron emission coefficient. The presence of chemical products or foreign particles on the surface of the cavity undesirably impacts this coefficient. To help reduce this potential source of multipacting, the cavity walls are polished after manufacturing using chemical etching and high pressure rinsing. However, these chemical etching processes can result in non-uniform cavity surfaces with some unclean areas with contaminants and micron size particles. These imperfections significantly affect multipacting. Further, a non-uniform etch leaves areas with damaged grain structure.

These defects further reduce the superconducting properties of the niobium. Researchers at Los Alamos National Laboratory (LANL) employ a baffle to improve uniformity in the etching process. The baffle's ability to improve the uniform etching was not known *a priori*.

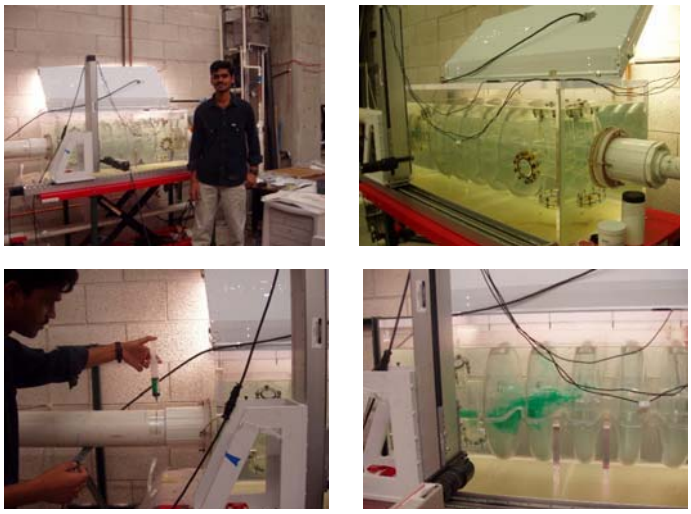
Mitigating multipacting processes is the major concern dictating the elliptical shape of the superconducting cavity. This complicates the etching process and, in particular, the uniform etch. Modeling codes, optimization techniques, and experimentation will provide UNLV researchers with a well-rounded study to examine existing and novel niobium cavity designs for the superconducting radio frequency high-current accelerator.

RESEARCH ACCOMPLISHMENTS

Development of Optimization Model: A framework for interacting two dimensional field codes and an optimization program was created. The code has been used to optimize the end cell of a five-cell niobium cavity based on resonant frequency and mode. Multipacting studies are well underway for this new geometry. Some of our results have been disseminated at the 2003 American Nuclear Society Conference on Accelerator Applications in a Nuclear Renaissance in San Diego, California.

SEE (Secondary Electron Emission) Studies: The vacuum chamber and various elements have been purchased for secondary electron emission studies on niobium in a superconducting mode. Computer simulations are underway to aid us in the study of the secondary electron trajectories in the presence of the cryostat, electron gun, and electron positioning diagnostic. These simulations will aid us in choosing the diagnostic tool to measure SEE.

Revised Etching Process: The current etching method, which uses a baffle to direct the etching fluid toward the surface of the cavity, partially succeeded in achieving this task. However, flow was restricted to the right half of the cavity with very limited circulation in the left half. An alternative design is proposed and modeled. The proposed baffle design is also modified so that it can be extended inside the cells of the cavity. The exit flow is now parallel to flow inlet. Results show that flow circulation is eliminated. The flow is now closer to the surface of the cavity. We used optimization techniques to improve this design.



Satishkumar Subramanian demonstrates a flow visualization experiment.

Developed Flow Visualization System: To confirm the predictions from the fluid flow models used to analyze the etching process, the UNLV team developed and deployed a flow visualization system. LANL lent UNLV a transparent model of an elliptical cavity section to assist with flow visualization while simulating different etching conditions. A transparent plexiglass box was manufactured to enclose the cavity. The external pump and piping system were also modeled. A complete experimental setup, including a computer-controlled x-y traverse and digital camera, was assembled. Flow visualization experiments using a plastic prototype of the niobium cavity provided by LANL are currently going on. Dye is injected to verify that the numerical codes accurately predict the flow behavior seen in the experimental model system. Dye injection provides quantitative verification that laminar flow exists within the niobium cavities during etching. Additionally, it verifies the absence of re-circulation pockets within the cavities.

FUTURE WORK

This task examines the flow characteristics in chemical etching of a niobium cavity with the aid of a baffle. It also examines the multipacting properties of a five-cell niobium cavity employing modeling codes with optimization techniques included.

HIGHLIGHTS

- "Modeling and Optimization of the Chemical Etching Process in Niobium Cavities" presented at the International Congress on Advanced Nuclear Power Plants (ICAPP), Hollywood, Florida, June 2002.
- "Modeling Optimization and Flow Visualization of Chemical Etching Process in Niobium Cavities" presented at the ANS Student Conference, Berkeley, CA, April 2-5, 2003.
- "Optimization of a Five-cell Niobium Cavity" presented at the ANS Annual Meeting, San Diego, CA, June 1-5, 2003.

Myong Holl explains her work at the ANS Annual Meeting, San Diego, CA, June 2003.

Future work will conclude experimental studies of flow characteristics and compare these to simulation. Alternative baffle studies may be improved upon based on fluid flow models. Designing an expanding baffle presents a challenge due to space limitations and the chemically aggressive environment.

Optimization techniques have been imbedded in a MATLAB controlling code based on the desired resonant frequency and mode of operation. The optimized geometries are to be examined using multipacting codes and compared to the existing LANL five-cell cavity. The controlling code will also be modified to allow mid-cell parameters to be optimized.

Secondary electron emission experiments are to be conducted on niobium at superconducting temperatures in the last year of this research. The data obtained from this study will be made available for multipacting codes.

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