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Modeling, Fabrication, and Optimization of Niobium Cavities: Phase III, Third Quarterly Report

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Modeling, Fabrication, and Optimization of Niobium Cavities –Phase III
Third Quarterly Report

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AAA Research Area:Accelerators / Transmuter

Introduction

This quarterly report provides an update to the last phase of the Modeling, Fabrication, and Optimization of Niobium Cavities in the no-cost extension period. Designing the experimental setup of secondary electron emission was well underway in early summer of 2003 when funding was made available for this portion the study. By March 2004, many of the components of the experimental study reached UNLV with some assembly accomplished. The first secondary electron emission (SEE) measurement was made from the surface of a Faraday cup in September 2004. In December of 2005, the software for the particle positioning detector was finally up and running. The integrity of the code and detector are currently being fine-tuned with the aid of the manufacturer and should be completely operational in the next quarter. Three studies in support of this last phase are being conducted in parallel. The accomplishments and directions in these three areas are presented below.

Material Secondary Electron Emission Studies:

Achievements: The Monte Carlo Back Scattering and Secondary Electron Scattering code developed by Dr. David Joy (ORNL and University of Tennessee Knoxville) has been converted to a C++ language to increase its speed and allow for more flexibility in performing future modifications. The new version of the code now accepts up to four layers with a rigorous treatment of a multiple component material composition of varied thickness (machine dependent) in determining the SEE energy and trajectory. The code's architecture has been restructured to employ both a pre-calculated look-up table and run-time generated values. Now, multiple generations of secondaries can be created AND tracked. The previous version of the code only tracked the primary electron. A batch-processing driver has also been written.

Direction: Thoughtful code inputs are required. With the use of an RGA and time, we will estimate the formation of gas layers on the sample (partial pressures). After appreciable pumping at around 1e-9 Torr, RGA measurements will be monitored as the sample is brought down to cryogenic temperatures from room temperature. Keeping in mind that cold surfaces act as pumps, the change in the background environment will be noted. Since only the sample and the cold heads of the cryostats will be cold, changes in partial pressures will be attributed to these surfaces. This will allow for one to estimate the layers of material deposited on the sample surface and in what order. The sequential layer composition and thickness may be determined and implemented into the SEE code for evaluation.

Experimental Set-up for the SEE from a Niobium Test Piece:

Achievements: The experimental setup, for secondary electron emission (SEE) studies, is currently operational for some experiments. The following tasks have been completed:

- The detector is assembled and appears to be working. If the UHV chamber has been vented to air (venting is a slow process, ~ 5 hours), then, once UHV pressures are reached, it takes about 2.5 hours to properly prime the detector to the operating voltages required for detection. A special source regulation circuit has been designed and implemented. This device enforces voltage stability across the MCP stack. A new voltage supply was purchased to drive the grid potential. This supply has been successfully incorporated with the mix of equipment to operate the detector.

- The electron beam generated by the electron gun is difficult to find. A phosphor coated glass disk (phosphor P43 coated on a glass substrate with charge dissipation properties and an aluminum coating for increase brightness) manufactured by Phosphor Solutions was purchased to aid in the detection of low current, low energy, electron beams and examine the electron beam profile. The glass disk was mounted on the Faraday cup attached to the moveable xyz manipulator.
- Thermally conductive greases do not seem to aid the cooling process of the sample without substantial pressure applied to the sample under test. This may preclude experimental studies hoped for in niobium's superconducting state. Mounts needed to apply this pressure prevent for the ability to align the piece under test with the electron beam.
- Figure 1 depicts one of the preliminary secondary electron emission studies of niobium at room temperature. Currently, the software is being fine-tuned with the detector and checked for accuracy. Working with the Germans, it is anticipated that this task will be completed during the month of January.
- Course grid potential adjustments have been studied. As expected, the grid potential influences the number of secondary electrons detected.

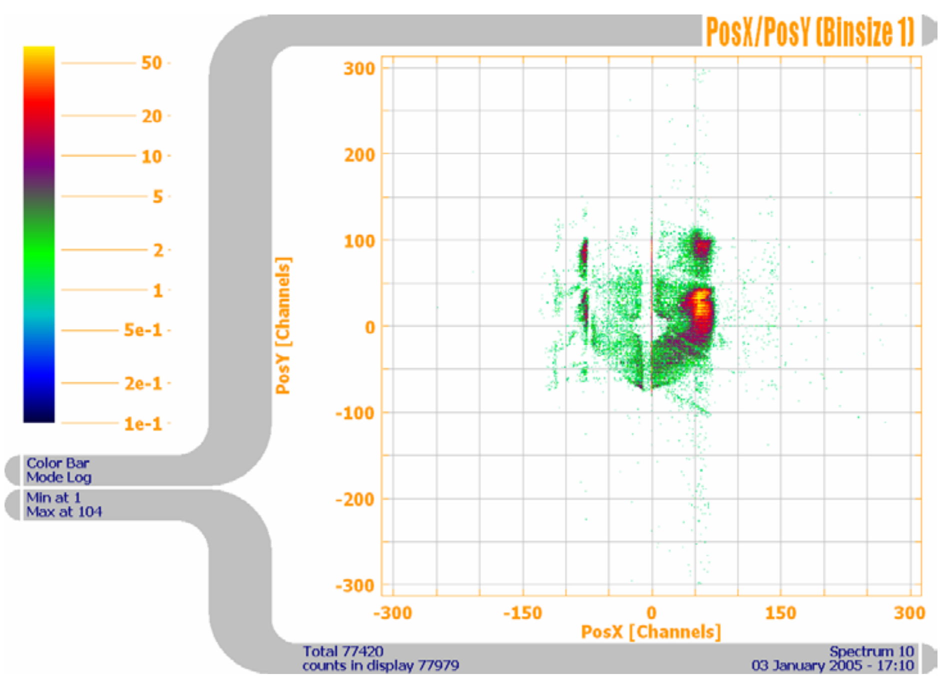
Direction: The beam-target-detector system in the UHV vacuum chamber environment is being thoroughly studied. Repeatability and measurement stability is the main concern during the next phase along with data taking and understanding the results obtained. With this in mind, the following tasks will be examined in the near future:

- Currently, two Lakeshore calibrated diodes (purchased at different times) are reading temperatures that differ as much as a couple of degrees Kelvin. Since a couple of degrees difference is significant when reaching temperatures down to 8.5 to 9 deg. K, the superconductivity transition temperature, these temperature measurement errors may lead to incorrect conclusions. Consequently, the discrepancy is being investigated and amended.
- Since the working temperature of the cryostat is near the transition temperature for conductivity of niobium, various thermal shield techniques to minimize radiation heating in the environment have been examined. The practicality for thermal shields has precluded the design of such a shield in the experimental setup. The presence of other materials in the region between the detector and the sample under test will influence the electrostatic fields drawing the charge to the detector surface. Further, line of sight ports are required for various operations in the experiment. Consequently, large thermal gradients exist between the detector and the sample being cooled and the ports and between the vacuum chamber ports and the sample. Time allowing, a moveable fixture with a hole slightly smaller than the piece under test will be built and loosely attached to the secondary cooling stage of the cryostat. The fixture will weigh down the test piece allowing for a greater thermal contact between the test piece and the cryostat. Further, the piece if connected to the secondary cooling stage of the cryostat will offer thermal shielding that is currently non-existent on top of the cryostat (In Fig. 2, it is observed that the top of the cryostat "sees" the detector and the view ports as a thermal load with a large thermal gradients). Thermal shorting and connection logistics have not been resolved. Further the presence of the fixture on the already studied electric field line profile has not been examined at this time.
- A telescope with reticle is needed to measure the beam diameter with some accuracy.

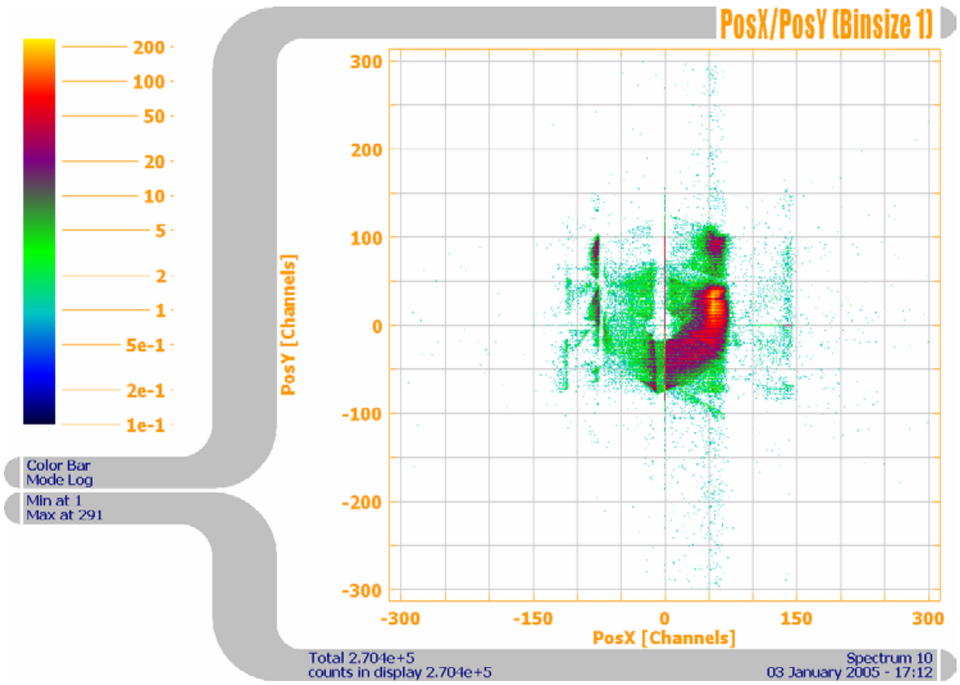
- The beam width adjustments and detector orientation need to be examined.
- *In situ* sample cleaning techniques will be examined with the present equipment.
- Adjustments to the grid potential and its influence on the secondary electrons are to be studied.
- Some detector-target-gun distance adjustments are needed allowing for a reasonable uniform field region between the grid and target. These distances are crucial in order to capture both low and high energetic secondaries by varying the grid potential.
- Experiments will be conducted on the niobium samples.

Theoretical Study for the SEE from a Niobium Test Piece:

In support of the numerical Monte Carlo and experimental studies, a particle tracking numerical/theoretical study is also underway. This study will aid in explaining experimental results. A 2-D electrostatic code and a 2-D particle tracking code are being used to map all possible secondary electron trajectories with the same termination conditions as obtained from experiment. At this time, the parameter space has been mapped for the electron beam impinging upon the surface at a 0^o, 30^o, and 45^o angle with respect to the surface normal. This data will aid in determining what family of secondary electrons with suitable initial conditions will reach the measured position. Figure 3 yields a small sample of this data plotted for a primary beam normally incident on the sample. Electrons are tracked based on incident particle trajectory angles ranging from 0^o to 90^o in increments of 0.5^o and initial energies typical for true secondary electrons (typically between 1 eV and 20 eV). Only select energies are displayed in Fig. 3. The jagged portion of each of the curves presented are due to the discrete presence of the wire grid. It should be noted that because this is a 2-D code, the wire grid is assumed to have only a two dimensional nature. It appears that the grid plays a significant role in backing out initial conditions based on final conditions.



(a)



(b)

Fig. 1 Preliminary secondary electron studies with beam normally incident on the niobium sample. The detector bias conditions are: grid 250V, MCP front voltage is 300 V, and the MCP back voltage is 2.6 kV. All voltages are referenced to ground. The niobium sample under test is grounded. The top of the niobium sample is 1 inch from the grid. The figures displayed shows (a) the spectrum dark current resulting with the electron gun is off (dark count rate ~ 3,000/s), (b) the sum of the spectrum dark current and secondary electron emission when the electron gun is in continuous mode generating 500 eV with a filament current of 1.3 A, emission current of 55 μ A and a sample current of 3.15 nA (overall count rate ~ 14,000/s).

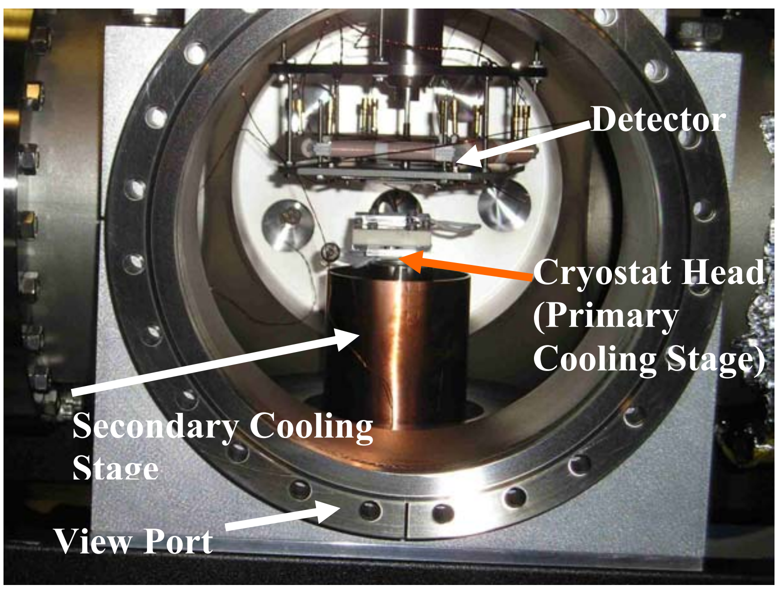


Fig. 2. View of the electron gun, beam tube, detector, manipulator arm, cryostat and thermal shield. The thermal loads as viewed by the top of the cryostat head are identified.

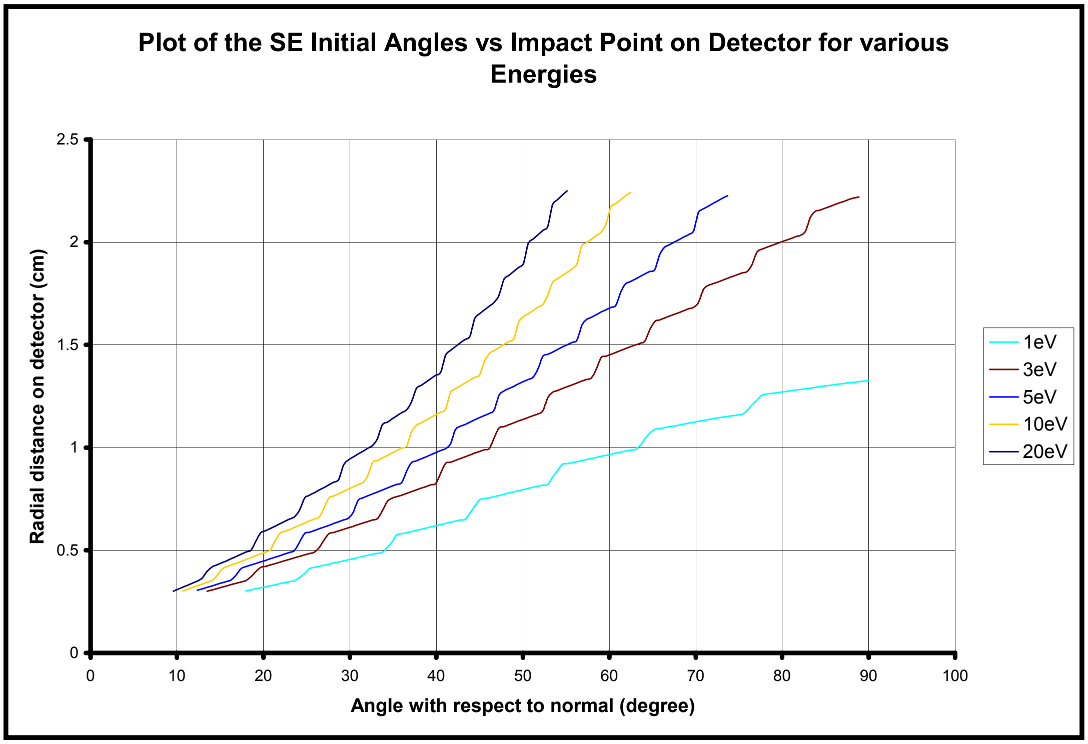


Fig. 3. Particle trajectory mapping on the detector surface for secondary electrons released from a flat niobium surface based on a distribution of incident trajectory angles and energies.