TRIUMF University of Victoria

Dust Migration and Suppression of Field Emission in SRF Cavities

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Overview

Particle acceleration in facilities such as TRIUMF is primarily achieved through the use of SRF cavities, which apply variable electromagnetic fields to particles under cryogenic conditions. The main limitation to the performance of SRF cavities is a phenomenon known as field emission. Field emitting dust particulates have been observed to migrate into SRF cavities due to an unknown mechanism; this project aims to identify and characterize this mechanism and develop a technique to suppress charged particulate migration.

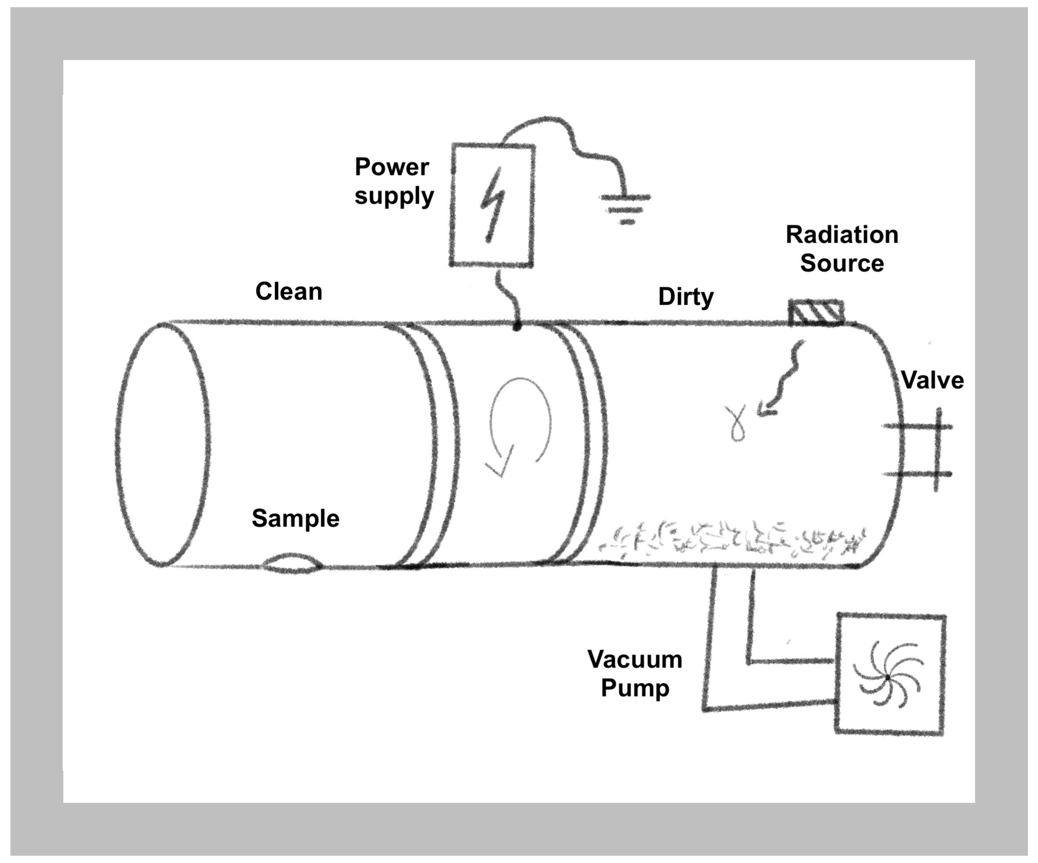

Figure 1: Schematic of envisioned experimental setup.

Field Emission (FE)

FE is a phenomenon wherein electrons are emitted from regions of high surface electric field inside of cavities (Figure 3). This can cause undesired beam trips, decrease the cavity's quality factor (Figure 2), trigger the loss of its superconducting state as well as damage external beamline components. Micron sized particulates have been identified as the main triggers of FE. These particulates are external contaminants found in the beamline, which have a variety of compositions including metals, ceramics and plastics (Figure 4). More stringent assembly procedures and in-situ processing techniques have been developed to mitigate FE, but SRF cavity conditions continue to degrade throughout operation.

Migration of Charged Dust

Prior investigations into particulate contamination at Jefferson Lab (JLab) found the abundance, size and distribution of dust in their cavities to defy expectations. They concluded that these particulates must migrate into the cavities from elsewhere in the beamline via an unknown mechanism [2]. In addition, studies performed at the CERN LHC investigated the time profiles of beam losses caused by particulates. To rationalize the short time scale of these losses, it was concluded that the particles are accelerated into the beam and must therefore be charged [3]. My hypothesis stipulates that the migration of particulates into previously clean SRF cavities is driven by their charge. This project aims to identify and characterize this mechanism and explore the suppression of dust migration using an electrostatic potential barrier.

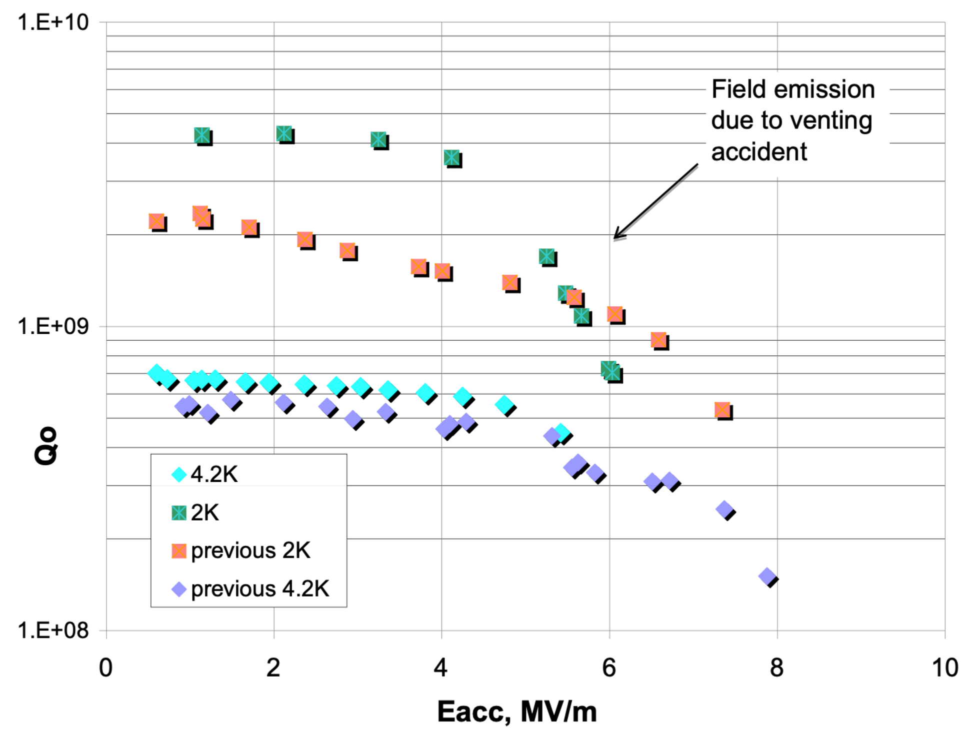

Figure 2: Quality factor as a function of acceleration gradient in a single cell cavity test at TRIUMF. Decrease in quality factor at high gradients due to onset of field emission. [1]

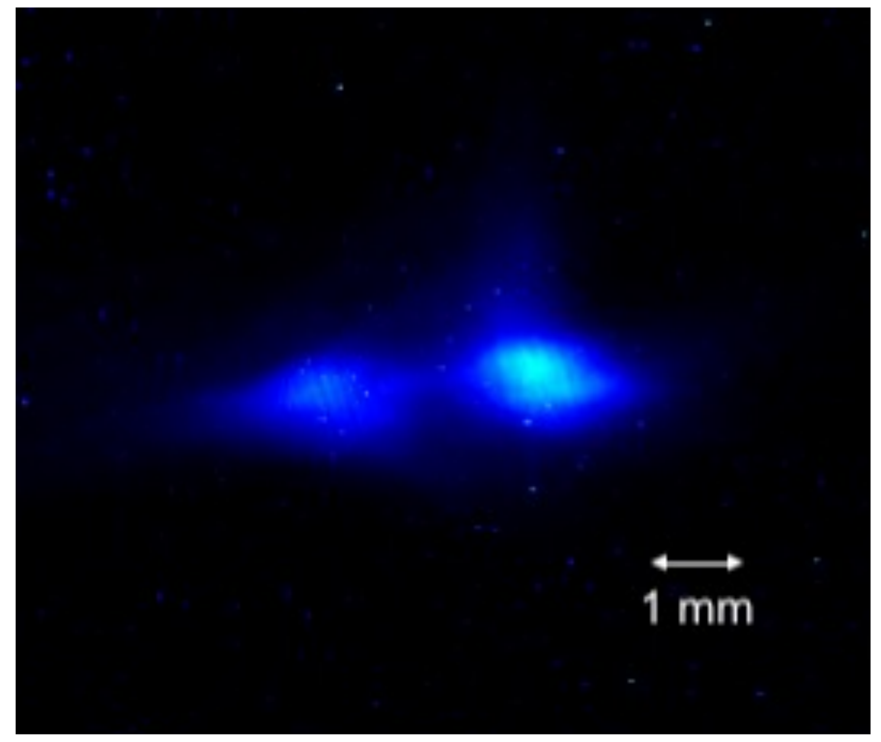

Figure 3: Dark current aka field emission as seen on a TRIUMF e-Linac view screen.

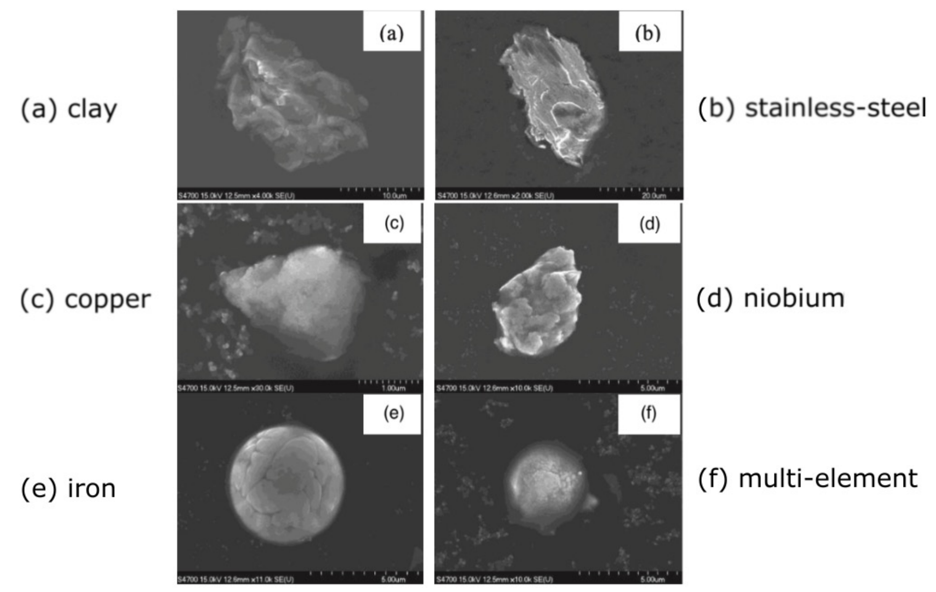

Figure 4: Various particles found in 5-cell CEBAF cavity at JLab: a) clay, b) stainless-steel, c) copper, d) niobium, e) iron and f) multi-element. [2]

Figure 5: Current experimental status in TRIUMF SRF cleanroom

Experimental Setup

The envisioned experimental setup is depicted in Figure 1. One "clean" section of beampipe will be connected via a ceramic break to another "dirty" section of beampipe, with the entire system being held at a vacuum level of ~10^{-5} Torr. A bias voltage of 5-10 kV will be applied, creating a potential barrier between the two sides. Dust particulates will be intentionally introduced on the "dirty" side of the experimental setup along with a radiation source to mimic the active accelerator environment. Using controlled venting, the particles on the dirty side will be forced towards the barrier, and samples will then be collected on the clean side and analyzed via scanning electron microscopy to quantify what effect the potential barrier had in suppressing particulate migration.

Status

The current status of this project is presented in Figure 5. Various beamline components have been collected and have undergone UHV cleaning processes in preparation for assembly.

Bibliography

[1] Zvyagintsev, V., et al. *SCRF Development at TRIUMF.* 2010.
[2] Geng, Rongli, et al. *Nature and implication of found particulates*. 2015.
[3] Goddard, B., et al. *Transient beam losses in the LHC*. 2012.

Discovery, accelerated