PROPOSED DARK CURRENT STUDIES AT THE ARGONNE WAKEFIELD ACCELERATOR FACILITY

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Abstract

A study of dark currents has been initiated at the Argonne Wakefield Accelerator Facility (AWA). Emission of dark current is closely related to a breakdown. Breakdown may include several factors such as local field enhancement, explosive electron emission, Ohmic heating, tensile stress produced by electric field, and others. The AWA is building a dedicated facility to test various models for breakdown mechanisms and to determine the roles of different factors in the breakdown. An imaging system is being put together to identify single emitters on the cathode surface. This will allow us to study dark current properties in the gun. We also plan to trigger breakdown events with a high-powered laser at various wavelengths (IR to UV). Another experimental idea follows from the recent work on a Schottky-enabled photoemission in an RF photoinjector that allows us to determine in situ the field enhancement factor on a cathode surface. Monitoring the field enhancement factor before and after can shed some light on a modification of metal surface after the breakdown.

INTRODUCTION

In high gradient structures, in addition to the electron beam, dark current is also present. The physics of the formation of the dark current may vary: field emission, secondary emission, photoemission, etc. Typically, the characteristics of this dark current are quite reproducible from pulse to pulse. Images of the emitters do not change unless a breakdown happens. In the event of a breakdown, some emitters disappear and some are created. Several theories have been proposed to understand this process [3, 5].

Dark current has exponential dependence with surface electric fields. Experimental data are usually analyzed with the Fowler-Nordheim model [1] with two adjusted parameters: emitter area and field enhancement factor β. If this factor is multiplied by the maximum surface field reached in the structure (β•E_{max}), the result is approximately 1 volt per angstrom (*10 GV/m*). This value appears to be a common level in many high-gradient structures when breakdown is initiated. Relation between dark currents and breakdown is not well-understood. It is not known whether β•E_{max} value is related to the trigger or the result of RF breakdown.

PROPOSED STUDIES

Following the Fowler-Nordheim model, this experimental β gives some average information about the field emitters. However, the number and distribution of the emitters are not known. Large experimental values of the β currently do not have a pure geometric explanation. The “hairs” on surface of conductors, which would provide large geometrical values of β, are not observed from the experiment especially for high vacuum multi-megawatt RF structures.

We plan to conduct experiments using a high gradient RF gun with removable cathode to observe dark currents and breakdowns in a controlled environment. We will try to identify the emitters from the dark current data and compare their location with the SEM image of the cathode. This study is devoted to understanding the physical nature of Fowler-Nordheim β and its dependence on the cathode material and surface preparation. This information should provide clues for understanding the relationship between the dark current and the breakdown.

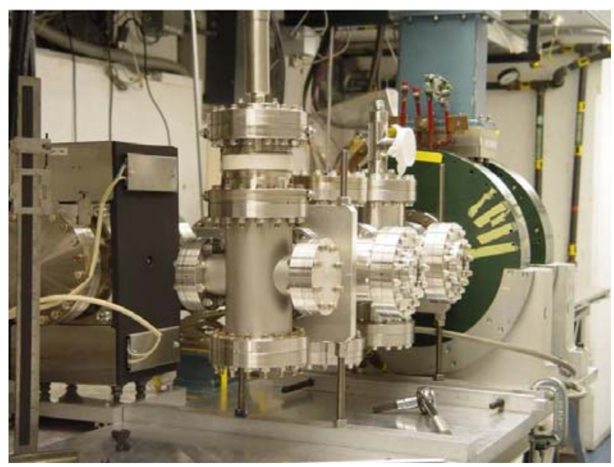

Figure 1: ½ cell, 1.3GHz electron injector with diagnostics chamber.

The Fowler-Nordheim fit (Fig. 2) results in $\beta = 84$, which agrees with one volt per angstrom figure of merit (β•$E_{max} = 10.08$ *GV/m*).

The beamline will contain various diagnostics. It includes RF monitoring, ion gauge, and a spectrometer for energy measurements. In the event of a breakdown, there will be a significant increase of reflected power, accompanied by a fast degradation of the vacuum level. We intend to capture and record this event in several ways. There will be a YAG screen for the measurement of the dark current distribution, a Faraday cup for an absolute charge measurement, and an RF pickup probe or a streak camera for time structure of the current and bunch length measurements. We have a gated ICCD camera which can be used to observe the breakdown process as it is triggered by IR or UV laser.

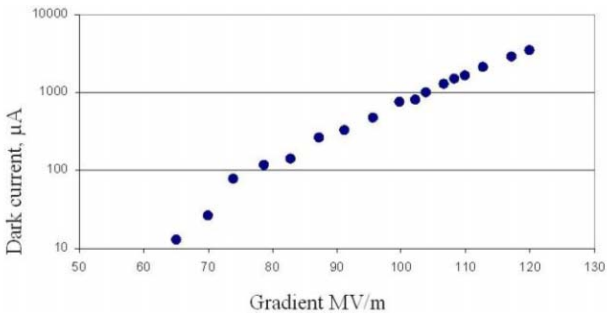

Figure 2: Dark current measurements of the gun [2].

DARK CURRENT SIMULATIONS

We are also looking into a method to trace the dark current image back to the emitter site. It is well known, that dark current image on the YAG screen contains so-called streaks – line traces. This happens because the dark current is emitted over the different phases of RF.

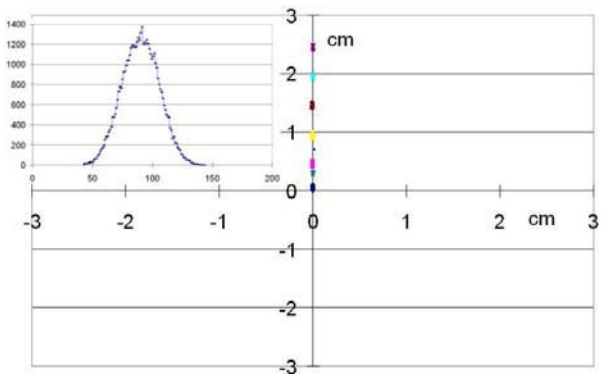

Figure 3: Initial color-coded distribution of emitters on the cathode surface. Particle distribution by emission phase.

We perform simulation which traces dark current from the cathode surface (figure 3) to the YAG screen down the beamline. We observe streaks (figure 4).

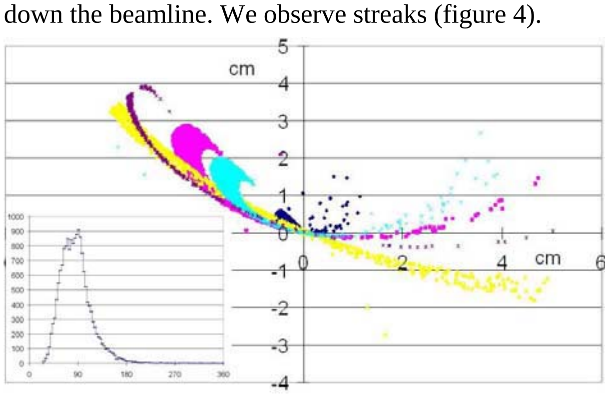

Figure 4: Color-coded distribution of dark current at the YAG screen location down the beamline. Particle distribution by emission phase is also shown.

The inverse problem is practically impossible to solve, because there are too many emitters on the cathode. We are developing experimental procedures which can switch on only part of the emitters. One idea comes from our work on Shottky-enabled photoemission [4]. Low energy photons from the laser and cavity RF field turn on the emitters in the laser spot. This way we can probe a small area of the cathode and the dark current image will be less busy.

SUMMARY

We have developed a program for dark current and breakdown studies. A dedicated facility for this project is being built. It is an L-band electron gun with a diagnostics chamber. We intend to study the dark current emission and its relationship to the RF breakdown and physics of RF conditioning. In particular, we are going to take 'before' and 'after' the shots of the cathode to see if we can identify emitters and understand the nature of field enhancement.

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