

IMPROVED DC GUN INSULATOR ASSEMBLY*

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Abstract

Many user facilities such as synchrotron light sources and free electron lasers require accelerating structures that support electric fields of 10-15 MV/m, especially at the start of the accelerator chain where ceramic insulators are used for very high gradient dc guns. These insulators are difficult to manufacture, require long commissioning times, and often exhibit poor reliability. Two technical approaches to solving this problem will be investigated. Firstly, inverted ceramics offer solutions for reduced gradients between the electrodes and ground. An inverted design will be presented for 350 kV, with maximum gradients in the range of 5-10 MV/m. Axial symmetry is important to minimize emittance growth of the beam, but the replacement of the photo-cathode, in a gun with an inverted ceramic base, presents a significant mechanical engineering problem. Also, any field emission at all from the gun will ionize gases and poison the cathode. Secondly, novel ceramic manufacturing processes will be studied, in order to protect triple junction locations from emission, by applying a coating with a bulk resistivity. The processes for creating this coating will be optimized to provide protection as well as be used to coat a ceramic with an appropriate gradient in bulk resistivity from the vacuum side to the air side of an HV standoff ceramic cylinder. Example insulator designs are being studied through computer modeling, and insulator samples are being manufactured and tested.

INTRODUCTION

It is very important to prolong the operating lifetime of High gradient DC photoguns used at facilities such as the Cornell ERL Injector, Daresbury VUV-FEL, and JLab's CEBAF and FEL facilities. Each of these facilities has experienced reduced operations due to field emission, which has often caused catastrophic failure of the ceramic insulator used to bias the photocathode. The low reliability of the photogun and resulting downtime of the injector significantly increase the operating costs of synchrotron radiation light sources and free electron lasers.

TECHNICAL APPROACH

At the present time, the development of very high DC-voltage (> 300kV) GaAs-based photoguns is being carried out by a number of groups worldwide, including JLab, Cornell, Daresbury and JAEA/KEK. Current developmental efforts to improve on traditional large bore ceramic insulators include the following strategies:

- Strategy 1. An "inverted" ceramic insulator that extends into the gun high voltage chamber.

- Strategy 2. Insulators with bulk resistivity which serve to bleed-off field-emission electrons that accumulate within the ceramic insulator.

Strategy 1 consists of the development of a photogun with an "inverted" ceramic insulator that extends into the gun high voltage chamber. The inverted insulator approach does not require a large electrode support structure and therefore reduces the number of high gradient regions inside the gun that contribute to field emission. This current work builds on the earlier development at CEBAF of an inverted gun that has already been in use for almost a year [1].

Strategy 2 addresses the bleedoff of energetic electrons to ground before there is sufficient charge buildup to puncture the ceramic. Additional manufacturing issues developed as a result of brazing connecting flanges to the lossy bulk ceramics that can withstand bakeout temperatures. New large bore ceramic assemblies have been constructed by CPI with a "bookend" braze or "backing ceramic" and have been delivered to Cornell [1]. However, to provide the same charge dissipating feature, we have continued our development of a thick resistive coating to be applied to a standard, large-bore ceramic insulator whose braze joint is not at issue.

STUDIES OF INVERTED CERAMIC INSULATOR DESIGN

The existing design

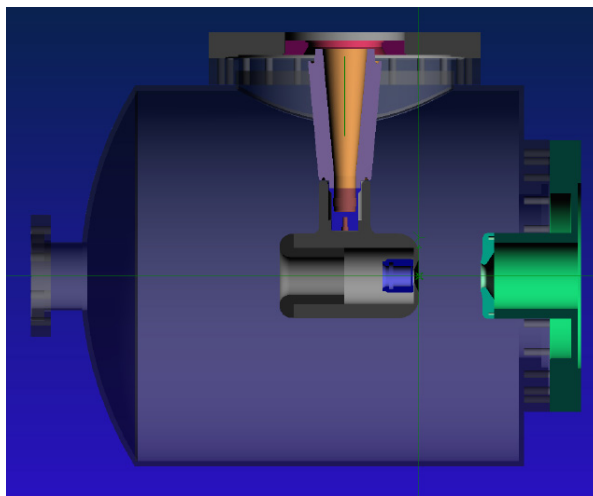


Figure 1: The existing JLab gun design.

In this paper, we describe an extension of the earlier development at CEBAF, the goal being to reduce field emission at gun voltages considerably higher than the 100 kV achieved in the current CEBAF design. The inverted gun design represents a reasonable R&D program that

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complements the bulk resistivity approach and the segmented insulator approach now being pursued at other laboratories.

We modelled the existing JLAB CEBAF gun which uses the inverted ceramic. At 250 kV the region where the inverted ceramic is attached to the gun electrode has electrical gradients far in excess of 10 MV/m. The reason for the non-symmetrical support is to allow photocathode replacement through the back of the gun electrode through a load-lock system. The problem with this non-symmetrical gun electrode is that it produces an asymmetrical field around the gun axis, which in turn deflects the beam at an angle relative to the center-line of the gun. For the existing gun design, we calculated that the beam would be deflected 7.4 milliradians, as it travels from the center of the photo-cathode to the anode region (neglecting space charge forces).

Optimum diameter of the gun electrode

In general, the optimum gun electrode would be a sphere in the center of the grounded vacuum chamber. We modelled this geometry and varied the size of the sphere. The bathtub curve of Figure 2 shows the minimum is achieved when the diameter of the sphere is half the diameter of the can. On the left side of the bathtub curve, the surface gradient is dominated by the curvature of the ball, on the right side the surface gradient is dominated by the proximity to the chamber wall.

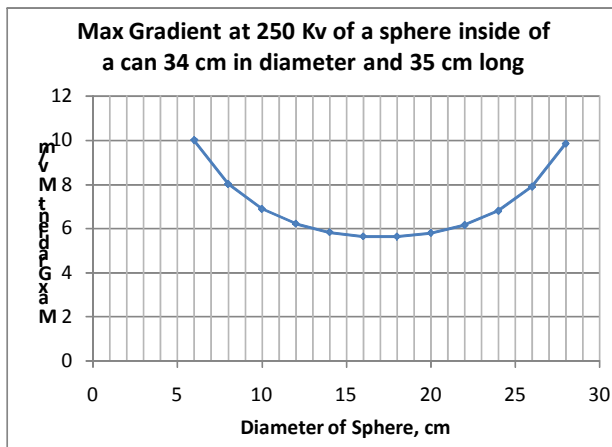


Figure 2: The minimum gradient of a sphere inside of a can is when the sphere diameter is half the diameter of the can.

Spherical Electrode with corona ring

The best design for the non-symmetrical support of the gun electrode in the vacuum chamber is a sphere, with the region around the triple junction being protected with a corona ring and the region in the back of the gun optimized for replacing the photocathode.

The corona ring that protects the triple junction location of the ceramic also produces a slight deflection of the beam, calculated to be 0.6 milliradians as it enters the anode region. The gradients in the region of the triple junction are 3.2 MV/m at 250 kV.

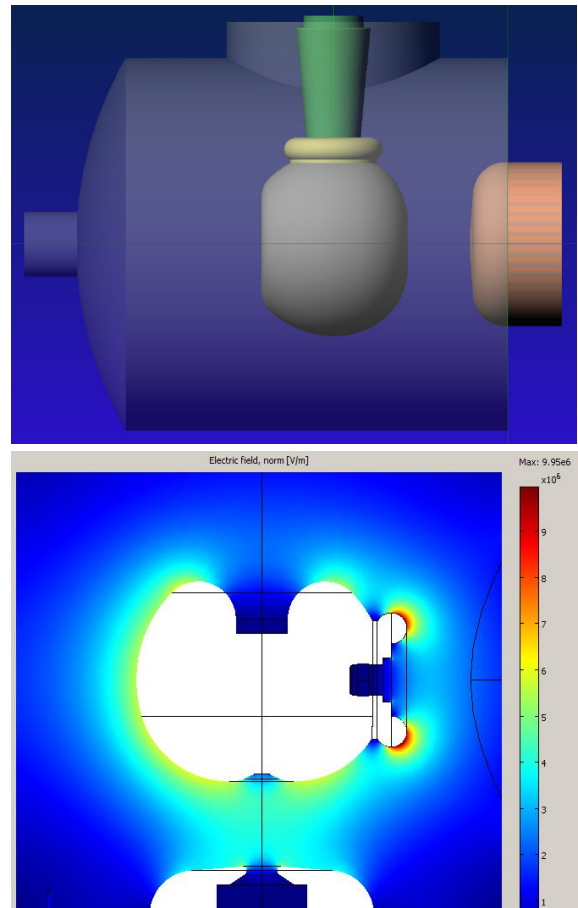


Figure 3: The ball shaped electrode has a corona ring to move the high gradients away from the triple junction point. The maximum gradient is 9.95 MV/m at 250 kV.

CHARGE DISSIPATIVE COATING EXPERIMENTS

We performed several different coating experiments using a glass and nichrome powder mixture. These types of mixtures have been used for thick film resistors [2]. Our goal was to make a resistor that is on the order of 1-2 mm thick with resistance in the 10^9 ohm-cm range.

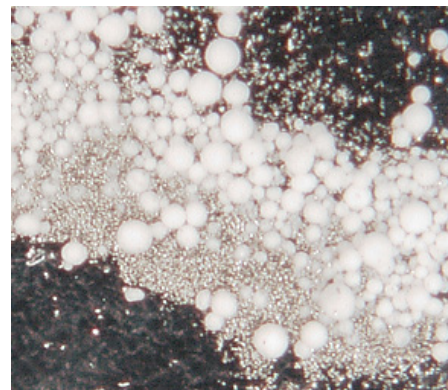


Figure 4: A photo micrograph of the mixture of nichrome and glass powders. The glass powder is the large white particles, the nichrome is the smaller particles, and the black is the slide background.

As shown in Figure 4, the glass particles are approximately 20 to 50 times larger than the nichrome particles. Two different types of glasses were used, and one turned out to work quite well with regards to adhesion to alumina. That glass was material #88 from Elan Technologies [3], and it was selected to adhere well to Kovar.

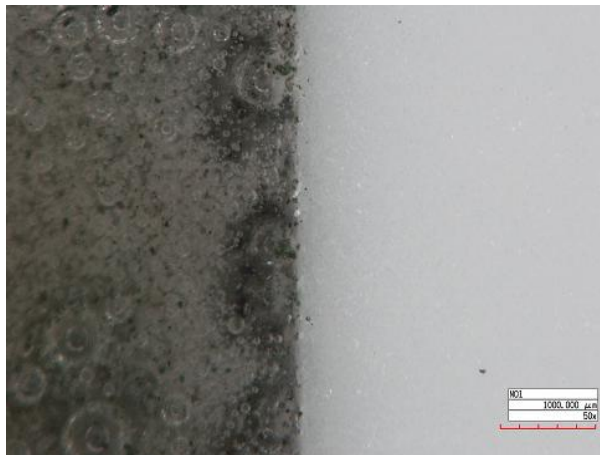


Figure 5: Magnified look at the interface between the alumina and glass-nichrome mixture after melting at 800°C.

In Figure 5 a close-up of the glass-nichrome mixture interface with the alumina is shown. While we did not perform specific stress tests on the interface, we succeeded in examining the cross-section by cutting through the test assembly. The aggressive grinding action did not damage the interface. One of the artifacts we were warned about by Elan Technologies was the formation of bubbles in the mixture during the melting process. This was a result of the glass powder manufacturing process. By special order, other processes can be employed for glass mixture #88, that will prevent the bubbles in the glass. The conclusions of these preliminary experiments with the resistive glass coating are (1) that the particle sizes of the two powders should be more similar and (2) that the glass itself should not be permitted to create bubbles during the melting process.

FUTURE RESEARCH PLANS

Gun Design

An inverted HV ceramic capable of 350 kV operation will be used. The HV connection will be optimized and tested during field emission tests. This project will consist of the design, development, and fabrication of a symmetric 350 kV photocathode electron gun. Surface gradients will be minimized to less than 10 MV/m, and remain below known values for troublesome field emission. The triple point junction will be carefully designed for reduced stress with the use of corona ring. The design objectives will be three-fold.

- (1) To change the present asymmetrically-fed HV design to one with the HV feed and inverted ceramic cathode electrode attachment on-axis, thus

eliminating beam steering from the asymmetric fields.

- (2) Reduce the surface fields on the cathode electrode by utilizing the design principle and preliminary electrode design determined in the Phase 1.
- (3) To create an optics design (focus electrode and anode) that maximizes the active area of the photocathode, thus maximizing the operational lifetime of the cathode.

Ceramic Coating

The project will address the mixing problems between the glass frit and the doping material, which we believe was the primary cause of the non-uniformity and the bubbles in our test mixes. We will address the mixing issue by obtaining frit and powder of similar size, and exploring a wider range of mixing and heating/melting methods. Once a uniform melt is obtained we can easily determine the proper doping percentage to yield a coating resistivity on the order of 1 Gohm-cm. This will be applied to the inner surface of a cylindrical HV ceramic and tested with high voltage. We may also use this mixture in the triple junction region of the inverted ceramic gun design.

REFERENCES

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- [4] Elan Technologies, PO Box 779, Midway, GA 31320, United States (912)880-3526, (912)880-3000 fax, <http://www.elantechnology.com>