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BLACK GUN TECHNOLOGIES FOR DC PHOTOINJECTORS*

E. Montgomery†, J. Butler, C. Jing, S. Poddar, Euclid BeamLabs LLC, Gaithersburg, MD, USA
S. Zhang, Jefferson Laboratory, Newport News, VA, USA

Abstract

Euclid Beamlabs is developing a new "Black Gun" concept in direct current (DC) photoinjectors. To reduce electron-stimulated desorption indirectly influenced by stray photoemission, we are testing advanced optical coatings and low-scattering optics compatible with the extreme high vacuum (XHV) environment of modern DC photoinjectors. Stray light in DC photoinjectors (in proportion to the photoemitted charge) causes off-nominal photoemission, initiating electron trajectories which intercept downstream surfaces. This causes electron-stimulated desorption of atoms, which ionize and may back-bombard the cathode, reducing its charge lifetime. Back-bombardment is key for high average current or high repetition rate. First, we report on progress developing optical skimmers based on Butler baffles to collimate both incoming and outgoing laser beams. Second, we describe candidate coatings for reduction of scattered light. Requirements for these coatings are that they be conducting, optically black at the drive laser wavelength, conformally applied to complex geometry, and XHV-compatible with negligible outgassing.

INTRODUCTION

The "Black Gun" DC photoinjector concept, first suggested by Matt Poelker at Jefferson Lab (JLab), is intended to reduce back-bombardment of sensitive photocathodes in DC electron guns. We follow a two-pronged attack to identify a feasible appproach: physical collimation of the laser beam, and blackening of internal surfaces.

Physical collimation is hampered by the need to place any collimators after the last scattering optical element (a Kodial glass viewport) - an extreme high vacuum (XHV) environment. Among all-metal XHV-compatible collimating apertures, the design which presents the minimal amount of forward scattering is the Butler baffle, a thin conical funnel with a knife-edge entrance [1]. These are not commercially available and we have re-developed the manufacturing expertise to produce and test them for Black Gun applications. A sharp knife edge minimizes forward scatter during skimming. In the forward direction, the beam is collimated and stray light eliminated. In the counter-propagating direction after cathode reflection, small angular spread in the beam glances through and exits.

Blackening of internal surfaces is a challenge in existing DC guns at JLab, in part because non-evaporable getter (NEG) coatings cover gun internal surface area [2]. These microns-thick coatings are optically gray. Therefore selective blackening is at the cost of some pumping speed, and must not increase total gas load significantly. In addition, charging is unacceptable, therefore the coating must be conducting. The coating must be applied conformally (chemical vapor deposition, or CVD, is one such technique). Finally, broad spectral absorption is not required but the reflectance at the drive laser wavelength (typically about 780 nm for spin-polarized GaAs) must be very low.

EXPERIMENTAL PROGRESS

Fabrication of Butler Baffles

Fabrication of a Butler baffle starts with a mandrel to be later electroformed. We have prepared stainless steel mandrels with two step lathe turning. First a conical point is cut into a 1" diameter rod. Next, using a radius cutter mounted to the lathe tool holder, the cone is turned concave, to achieve a tip diameter about 1 mm as the radius cutter is tangential to the turning axis.

Electroforming of copper and nickel has been completed on these mandrels, approximately 200 microns thick. The outer surface is polished, and then the electroformed layer is pressed off the mandrel. Once separated, the baffle can be more gently adhered to the mandrel and the tip abrasively removed from the baffle without damaging the mandrel using fine grit paper and then an ink eraser. Fabricated baffles are currently undergoing testing at Euclid. We intend report upon performance of these baffles as a function of metal (copper or nickel), aperture, and mechanical design in an upcoming publication. The prototypes are shown in Fig. 1.

Figure 1: Butler baffles on mandrels (L) and after polishing, blackening, and mounting for optical testing (R).

Black Coatings

Table 1 describes our comparison of commercially available black coating technologies for use in DC photoinjectors. One material met all criteria: Acktar™ Vacuum Black® [3]. We have characterized Acktar™ Spectral Black®, a related coating, using electron dispersive spectroscopy (EDS), confirming it is comprised of vacuum-safe materials, primarily aluminium and aluminium oxides.

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† e.montgomery@euclidtechlabs.com

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Table 1: Selected Black Coating Candidates

Blackening Method	Merits	Drawbacks
Anodization	bakeable conducting conformal	higher gas load
Diamond-like carbon	bakeable conducting conformal XHV compatible	w/implantation
MoS_2	Bakeable 400ºC conducting conformal UHV compatible	not XHV
Acktar™ Vacuum Black® [3]	bakeable 380ºC conducting conformal XHV compatible: 10^{-13} Torr-L/s/cm^2	

Scanning electron microscopy taken at the Argonne Center for Nanoscale Materials shows micron-scale texture (Fig. 2) but no honeycombs as in anodization which could lead to outgassing problems.

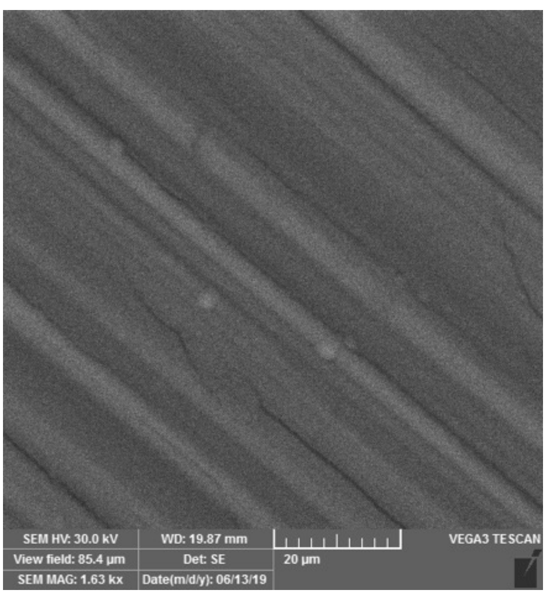

Figure 2: SEM showing texture of Acktar Spectral Black material; scale bar is 20 microns.

Future Work

Characterization of the bidirectional reflectance distribution function (BDRF) of both baffles and black coatings remains. Plugging that into non-sequential scattering simulations, we plan to identify which regions of the black gun can most benefit from surface blackening. We will also be engineering a steerable Butler baffle mount to allow laser scanning across the cathode surface without cutoff of the beam. Incorporation of proven technologies into gun-type testing at DC photoinjector facilities should follow.

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