DEVELOPMENT AND MEASUREMENT OF STRAIN FREE RF PHOTOINJECTOR VACUUM WINDOWS *

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Abstract

RF photoinjectors produce the highest brightness electron bunches only under nearly ideal illumination by a drive laser [1]. The vacuum window used to introduce the laser beam is an essential element that may potentially degrade the distribution, making it difficult or impossible to know the actual uniformity achieved at the cathode. Because of the necessity to obtain ultrahigh vacuum near the photoinjector, some restrictions are imposed on the fabrication technology available to manufacture distortion-free windows. At the UV wavelengths commonly used for photoinjectors, it is challenging to measure and eliminate degradation caused by vacuum windows. Here, we discuss the initial measurements of a strain-free, coated, UHV window manufactured by Insulator Seal in collaboration with members of Brookhaven and Argonne National Laboratories.

INTRODUCTION

The effectiveness of RF photoinjectors is dependent upon near ideal illumination of the cathode by a drive laser. Much progress has been made in developing laser systems that meet the requirements imposed by photoinjectors and high-brightness experiments. These requirements include precision control of intensity within the active region of the cathode, a necessity for minimizing space-charge-induced emittance growth. Most approaches involve producing a uniform, or other mathematically simple, laser intensity profile. However, laser diagnostics do not typically extend into the vacuum system of the photoinjector, and electron beam measurements to assess the uniformity of the laser intensity distribution provide very complex results. The vacuum window used to introduce the laser beam is an essential element that may potentially degrade any distribution, making it difficult or impossible to know the actual uniformity achieved at the cathode. Because of the necessity to obtain ultrahigh vacuum near the photoinjector, some restrictions are imposed on the fabrication technology available to manufacture distortion-free windows. At the UV wavelengths commonly used for photoinjectors, it is challenging to measure and eliminate degradation caused by vacuum windows. Here, we discuss the initial measurements of a strain-free, coated, UHV window manufactured by Insulator Seal (ISI) in collaboration with members of Brookhaven National Laboratory (BNL) and Argonne National Laboratory (ANL).

THE WINDOW

A class of laser input windows based on a new technological design has been fabricated for use with high-brightness, photocathode-rf gun systems. The ISI-designed window is a special fused silica deep ultra violet viewport with a dual-band or double "V" antireflection (AR coating) coating between 264 nm (<0.15% reflectance from 250-270 nm) and 529 nm (<0.15% reflectance from 515-535 nm for ease of alignment in the visible) mounted on a 2.75" rotatable flange. We chose this bandwidth of coating to accommodate both the ANL Low-Energy Undulator Test Line (LEUTL) photocathode-rf gun drive laser (fourth harmonic of Nd:Glass) [2] and the BNL Accelerator Test Facility (ATF) photocathode-rf gun drive laser (Nd:YAG). The window assembly was designed to be parallel to within 10 arcseconds with a surface quality of 10-5 scratch-dig, and has a flatness of 0.1 wave at 632 nm.

MEASUREMENTS

The first set of measurements was performed at the ATF at BNL using the frequency quadrupled Nd:YAG (266 nm) photocathode-rf gun drive laser operating at 30 microjoules. The laser spot size at the window was approximately 5 mm diameter. The laser profile was imaged at the cathode monument, a fluorescent target which is at the conjugate image plane of the RF photocathode surface, without and with the window in the path. The window, when inserted, was placed unmounted (no vacuum equipment/flanges) perpendicular to the laser at ~ 1 meter upstream of the cathode monument. As shown in Figure 1, there is only a slight change in the beam profile in the comparison of the two cases. Although the window could be installed as close as 0.2 meters from the cathode assembly, we believe this simple experiment and its positive result represents the behavior if this window is mounted in the photocathode-rf

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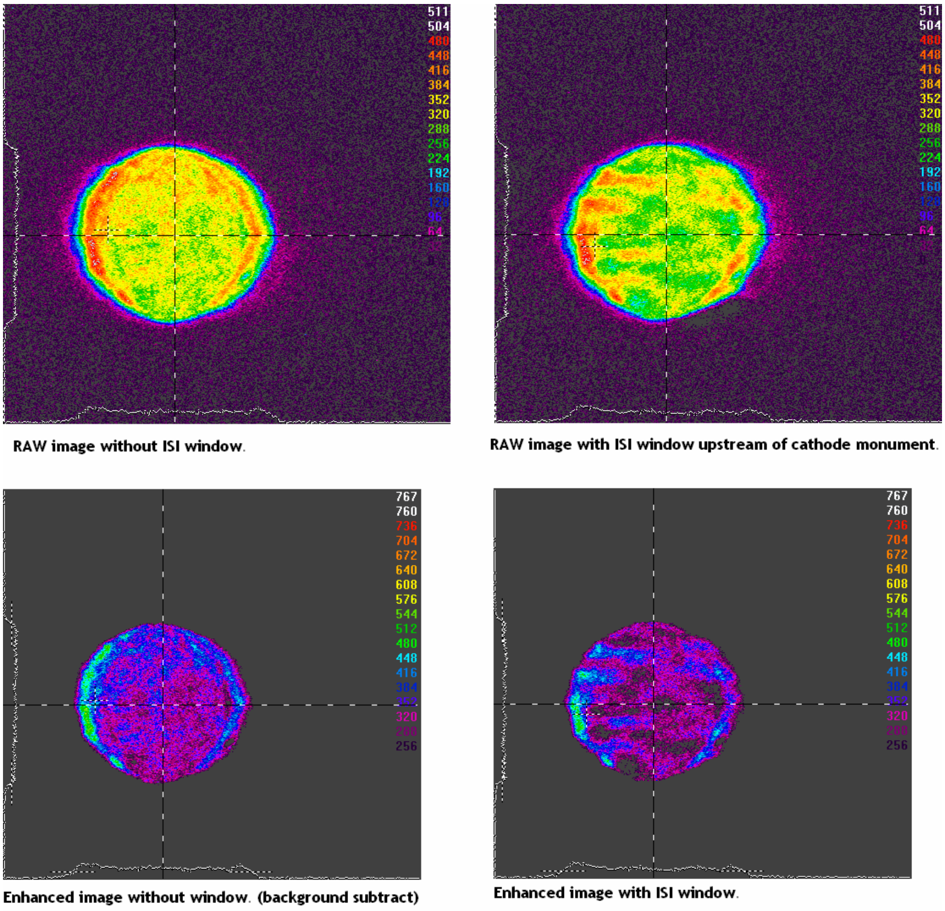


Figure 1: Raw and enhanced laser profile of 30 microjoules of frequency quadrupled Nd:YAG without (left column) and with (right column) the ISI window in its path.

gun assembly. In fact, since the window can be mounted as close to ~0.2 meters from the cathode, any induced phase distortion will not result in an intensity modulation.

The second set of measurements was performed at ANL at the metrology laboratory of the Advanced Photon Source. We measured both unmounted and mounted windows to emulate the effect of the window actually being attached to the photocathode-rf gun assembly. We also measured the flatness profiles and present the raw and best fit, with the spherical aberration removed. The flatness is presented. Note that we refer to Window 1 as that which is mounted on the vacuum cross and Window 2 as the unmounted window. In the case of the mounted window, the laser only passes the window from the most accessible surface. In the case of the unmounted surface, flatness measurements could be taken from laser introduction on either side. The instrument used was a WYKO-6000 interferometer (WYKO Corp., 2650 East Elvira Road, Tucson, AZ 85706, USA) that employs He-Ne (λ=632.8 nm) laser test beam with 150 mm diam aperture. The window measurements were done by zooming onto their surfaces for maximum lateral resolution.

Note that the optical AR coating is a three layer base of SiO_2 with a HfO_2 coating of a proprietary to ISI thickness. The index of refraction for $Si0_2$ is 1.47 and the index of refraction of HfO_2 is approximately 2.25.

In Figures 2 and 3, respectively, the best fit with spherical aberrations removed is presented for the mounted window. In Figures 4 and 5, respectively, the best fit with the spherical aberrations removed is presented for the case of the unmounted window from one side. In Figures 6 and 7, respectively, the best fit with the spherical aberrations removed is presented for the case of the unmounted window for the laser entering from the opposite side. Both windows present very good surface flatness with values below the specification requirement of 0.1 wv rms.

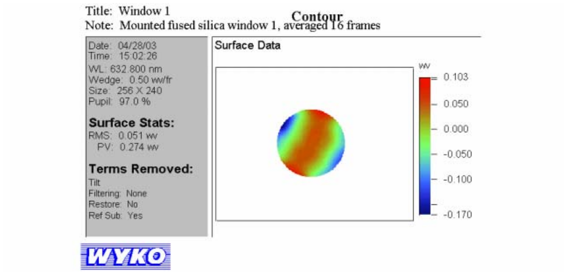


Figure 2: Measured surface profile of the mounted window #1. Here only tilt was removed. Unit: wv.

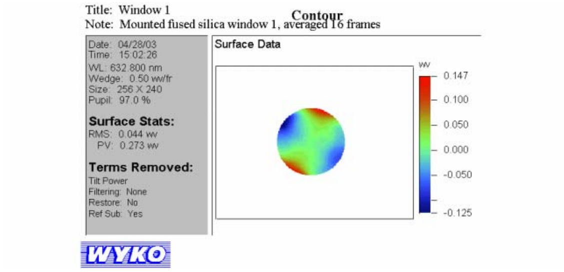


Figure 3. Measured surface profile of the mounted window #1, with both the tilt and power removed. Unit: wv.

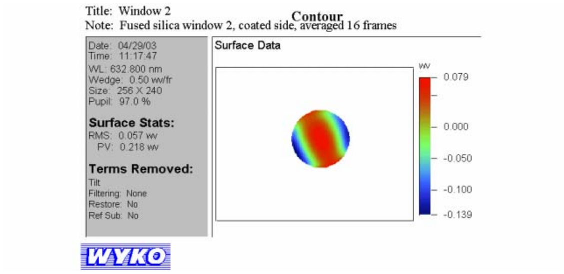


Figure 4. Measured profile of one surface of the unmounted window #2. Here only the tilt was removed. Unit: wv.

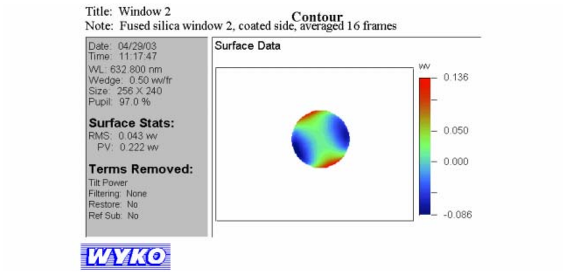


Figure 5. Measured profile of one surface of the unmounted window #2, with the tilt and power removed.: Unit: wv.

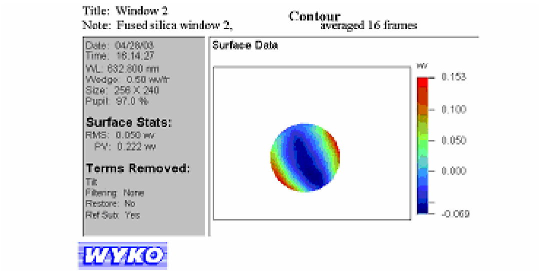


Figure 6. Measured profile of the opposite surface of window #2. Here only the tilt was removed. Unit: wv.

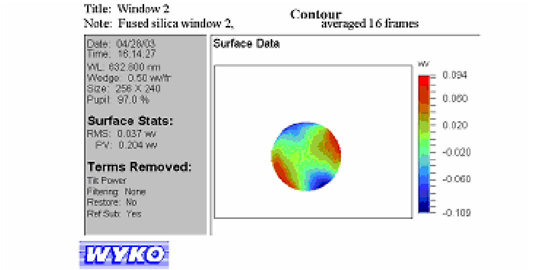
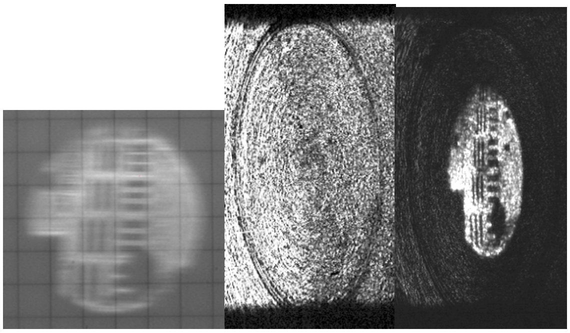


Figure 7. Measured profile of the opposite surface of the window #2, with the tilt and power removed. Unit: wv.



a) b) c)

Figure 8: a) Input laser beam distribution before window as imaged at cathode "monument", b) cathode image from exit port showing 5 mm diameter fiducial ring, c) cathode image with incident laser spot.

The third set of measurements was an experimental test conducted at the ATF at BNL. The new window was mounted on the entrance port of the gun, and the "old" standard style window without flatness consideration on the symmetric port – referred to as the "output" port - on the other side of the gun. There is a camera imaging the cathode on this output port that provides and excellent real-time view of the UV on the cathode that also reveals surface features. To assist with measurements, the ATF has machined a 5 mm diameter fiducial groove onto the surface of the cathode to assist in locating the precise geometric center and provide a scale factor for the beam image. The window appears to have added no distortion to the beam, and with the larger clear aperture, it is expected that the cathode should be able to accept 4 mm uniform laser spots. The cathode image and the laser imaged on the cathode is shown in Figure 8. No downstream measurements have been performed as of yet, as there have been a number of challenges in this replacement gun's commissioning.

CONCLUSIONS

Future plans include testing and characterization of these new technology laser input windows downstream of the gun at the Accelerator Test Facility. Such work will be critical to future photoinjector-based light source projects such as the Linac Coherent Light Source (LCLS) [3] and the high-average power free-electron lasers [4].

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REFERENCES

[1] V. Yakimenko *et al*, NIM A, 483 (2002) 277-281

[2] S.V. Milton et al., "Measured Exponential Gain and Saturation of a Self-Amplified Spontaneous Emission Free-Electron Laser," originally published in Science Express as 10.1126/science.1059955 on May 17, 2001; Science, Vol. 292, Issue 5524 (2001) 2037.

[3] LCLS Design Group, LCLS Design Report, NTIS Doc. No. DE98059292, April 1998 (Copies may be ordered from the National Technical Information Service, Springfield, VA 22162).

[4] G.R. Neil *et al*., Phys. Rev. Lett. **84**, 662 (2000).