Čerenkov Mirror Reflectivity Test Results

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Abstract

In this report we present the final reflectivity measurement results for the Heavy Gas Čerenkov (HGC) detector mirrors of the Super High Momentum Spectrometer (SHMS). The measurements were obtained used the reflectivity measurement setup at the Free Electron Laser (FEL) facility at Jefferson Lab.

1 Introduction

The Heavy Gas Čerenkov (HGC) detector, as part of the Hall C Super High Momentum Spectrometer particle identification detection system, was recently constructed at the University of Regina [1]. The detector is equipped with four 5″ Hamamatsu[1] R1584 PMTs which collect Čerenkov radiation reflected by four aluminized mirrors. The dimensions of the HGC mirrors are 60 cm $\times$ 55 cm.

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[1] HAMAMATSU Photonics K.K. [IR] 325-6, Sunayama-cho, Naka-ku, Hamamatsu City, Shizuoka Pref., 430-8587, Japan. Website: www.hamamatsu.com

Based on the simulation study of the HGC detector, the wavelength region of interest ranges from 180–600nm. The aluminized mirrors are anticipated to have reflectivity of 70% at 200 nm and 90% beyond 400 nm wavelength.

In our previous report [1], we concluded that our aluminization vendor ECI[2] meets the reflectivity requirement based on the results obtained from the reflectivity measurement setup at the Free Electron Laser (FEL) facility of Jefferson Lab. Since then, the remaining six mirrors were sent to ECI and aluminized. In this report, the final HGC mirrors reflectivity results are documented. The test results from ECI are attached in App. A.

2 Čerenkov Mirror Reflectivity Results

2.1 Measurement Methodology

The methodology and setup used to obtain the mirror reflectivity can be found in the previous reflectivity report [1]. The calibration and usage of the reflectivity setup can be found in the reflectivity setup manual [2].

Each of the six mirrors was measured at six different locations; each measurement ranges from 195-400 nm in 5 nm steps. Fig. 1 shows the schematic diagram of the measurement locations for all six mirrors. A Reference Mode measurement was taken before every Measurement Mode measurement for the purpose of computing the systematic uncertainty. The measurement duration for each mirror is around six hours; the lamp stability was studied and confirmed to be less than 0.5% fluctuation over this period.

The lock-in amplifier settings were 3 s time constant and 5 mV sensitivity, the monochromator dwell time was set for 30 s.

[2] Evaporated Coatings, Inc. 2365 Maryland Road Willow Grove, PA 19090 USA. Phone: 215-659-3080

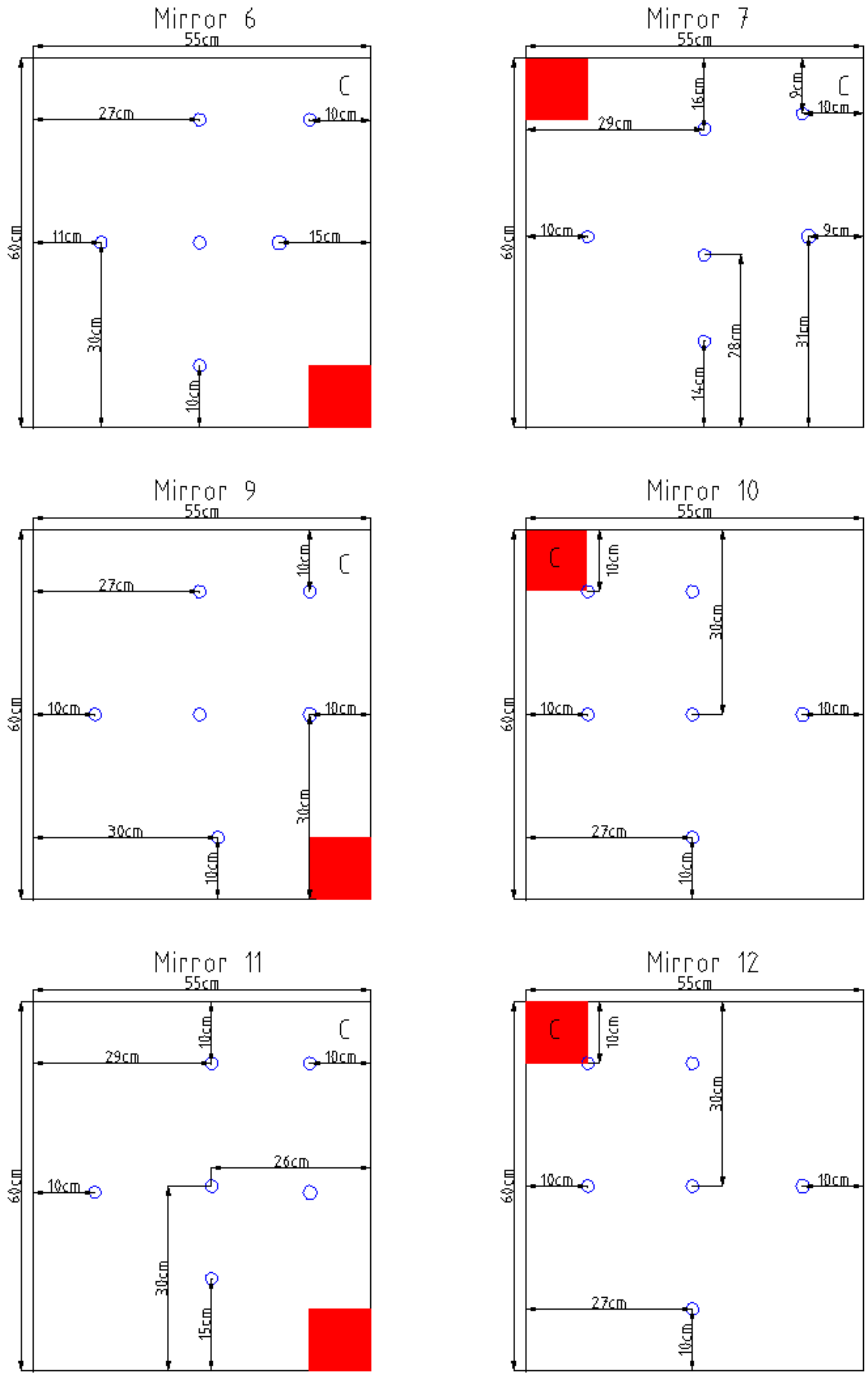

Figure 1: Reflectivity measurement locations on the mirrors (front view). The red shaded corners indicate the number mark locations on the backside mirrors. "C" indicates the interleaved corner in the HGC detector.

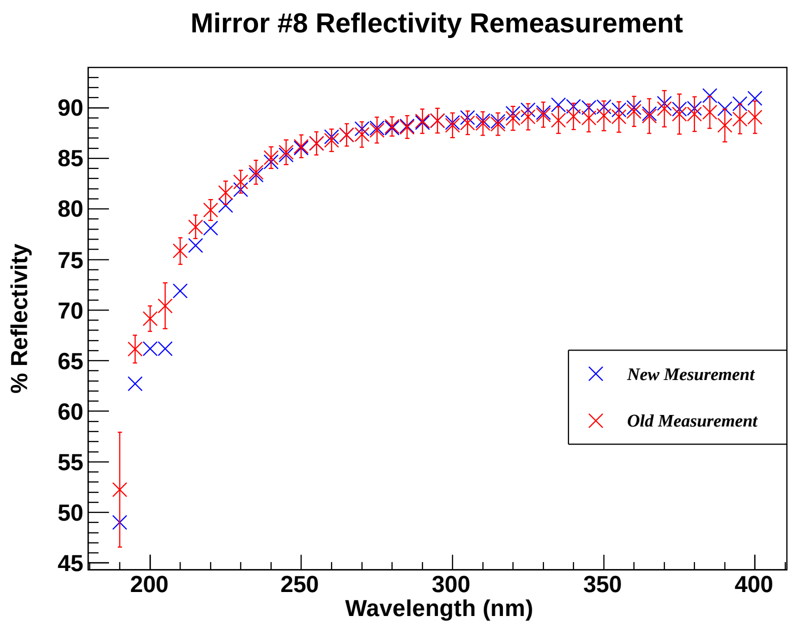

Figure 2: Plot shows the initial and repeated measurements of the mirror #8 reflectivity. The measured location was 10 cm from edges.

2.2 Repeated Measurement of Mirror #8

In order to confirm the measurement reproducibility in this second set of measurements, the reflectivity of mirror #8 was remeasured and compared with our previous result [1]. The two measurements were 7 months apart and system had been re-aligned since the initial measurement. The initial and repeated measurements were made at 10 cm from the mirror edges and the center of the two measurement positions were a maximum of 2 cm apart.

Fig. 2 shows the initial and repeated measurements of mirror #8. Despite the fact that the mirror positions and angles might differ slightly due to the system realignment, most of the new measurement points are within the uncertainties of the previous measurement. The RMS deviation across all measured wavelengths is 1.48%, thus confirming the reliability of the measurement.

2.3 Čerenkov Mirror Reflectivity Results

The Reference and Measurement Mode spectra of all tested mirrors are plotted in Fig. 3; the computed reflectivity results are plotted in Fig. 4. During the six hour measurement period, six independent Reference Mode measurements were taken one hour apart. The maximum deviations among the Reference Mode spectra for a given mirror are $\pm 0.5\%$, which signifies the stable performance of the D_2 lamp.

From Fig. 4, mirrors #6 and #12 have the smallest deviation in reflectivity at different locations across the mirror. Between 200-400 nm, the reflectivity across the mirrors remains constant at around 88% with $\pm 2\%$ variation, except a 6% drop recorded at 325 nm on the mirror #6 'Right' reflectivity spectrum. One possible cause of such a discontinuity in the reflectivity curve might be localized contamination during the aluminization and protective coating process; this could result in a narrow photon absorption band near 325 nm.

From our previous reflectivity result [1], we learned that the measured reflectivity values in the low wavelength region (200-250 nm) are 5-10% lower than those which were extrapolated theoretically by the manufacturer. A realistic expectation based upon the initial reflectivities results was 70% at 200 nm. The averaged reflectivities for mirrors #6 and #12 at 200 nm are very close to the expected value, with small variation, as indicated in Fig. 3. Between 200-250 nm, the reflectivity curves rise rapidly to around 86% as wavelength increases, which correlates with our expectation.

All criteria indicate the aluminization quality of mirrors #6 and #12 are better than our expectation. The dip in the mirror #6 measurement may indicate the possibility of small local contamination, however, such insignificant variation in reflectivity at such narrow band is unlikely to result significant impact to the mirror performance, and only one set of data recorded such dip indicates such contamination is not widely spread.

The reflectivity results for the mirrors #7, #9, #10 and #11 show larger deviations among different positions across the mirrors, especially for the shorter wavelength region below 250 nm. At 200 nm, the deviation can be as large as 10-18%, with the lowest being 58% on mirror #11. On the other hand, the averaged reflectivity for most mirrors are between 65-70%, and the reflectivity curves of all mirrors show an expected rapid increase between 200-250 nm and reach reflectivity above 80%. At the longer wavelength region (300-600 nm), the reflectivity steadily increases towards 90% without any indication of discontinuity.

Although mirrors #7, #9, #10 and #11 have lower averaged reflectivities than the expected value (70%) by 5-10%, with larger deviations at 200 nm, the general shapes of the reflectivity curves are as expected and their performances between 225-400 nm are comparable to those of #6 and #11. From our Monte-Carlo study, the number of photo-electrons decreases as wavelength decreases. This indicates good reflectivity at longer wavelength region (above 300 nm) is more critical. In addition, the poor PMT quantum efficiency at wavelength below 200 nm trivializes the 5-10% difference in mirror reflectivity, thus lower than expected reflectivity between 180-210 nm would not result any significant impact to the overall detector performance. We believe mirrors #7, #9, #10 and #11 have sufficient aluminization quality to be used on the HGC detector.

2.4 Measurement and Error Analysis

The uncertainty analysis method used here is different from that of our previous reflectivity result [1]. For each of the six measurements across the mirror, the Reference Mode spectra were measured first, followed the Measurement Mode spectra. The measurement took 5-6 hours per mirror and the condition of the condition for each of the Reference Mode measurements should have been identical. There were six sets of measurements taken 1 hour apart. The differences among these measurements should take into account all systematic uncertainties such as: lamp stability, background noise and setup vibration, etc.

We computed the reflectivity used for all six sets of Reference Mode spectra against the Measurement Mode spectra at any single location. The average among the six reflectivity values were

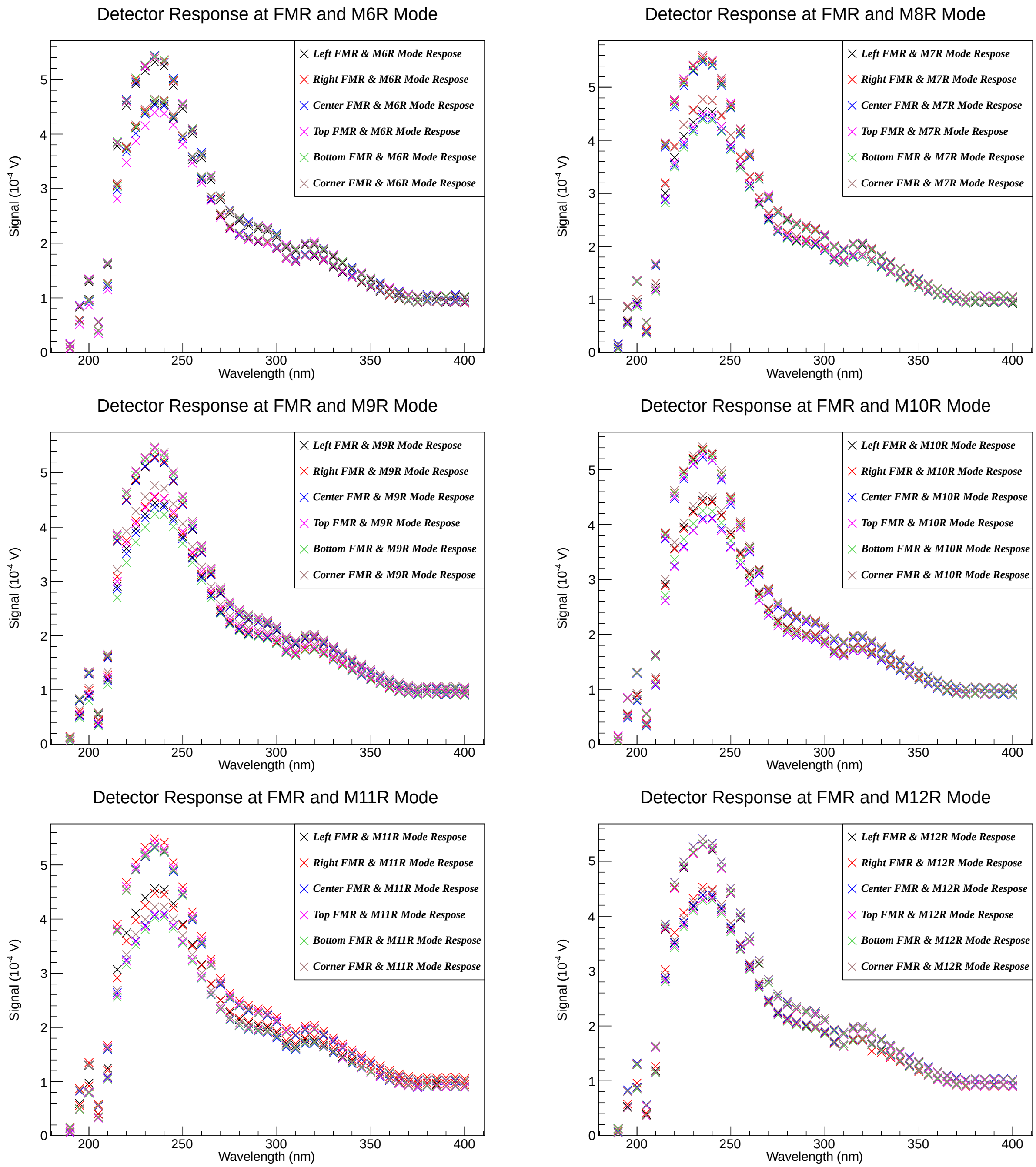

Figure 3: Plots show the Reference Mode measurement and Measurement Mode spectra for the HGC mirrors at wavelength of 190-400 nm at 5 nm steps. Each mirror is measured at six different locations.

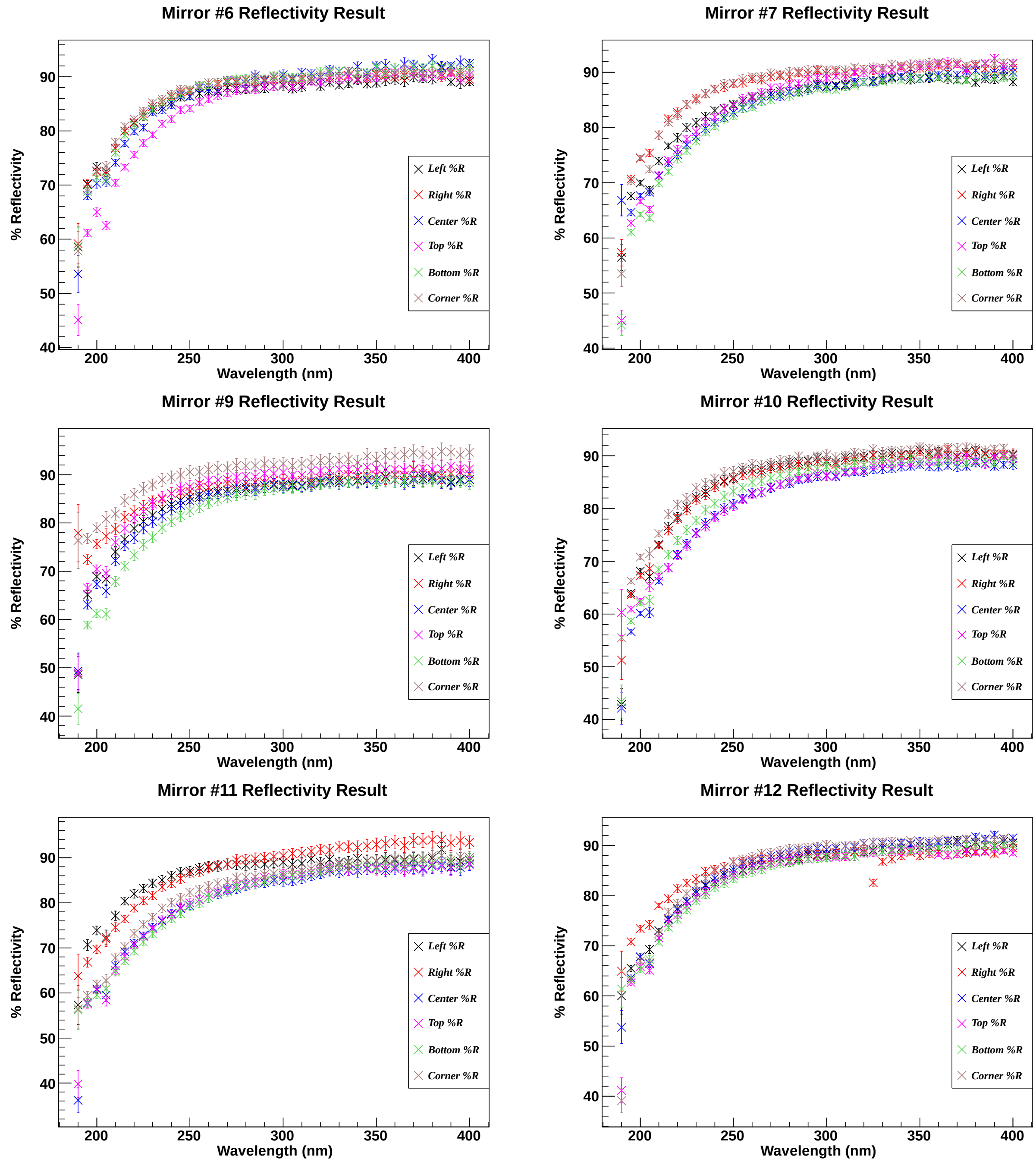

Figure 4: Reflectivity results for the HGC mirrors at wavelength of 190-400 nm at 5 nm steps. Each mirror is measured at 6 different locations.

taken as the reflectivity, the standard deviation was used as uncertainty.

3 Conclusion and Outlook

In this report, we determined that mirrors #6 and #12 have the best overall aluminization quality, and mirrors #7, #9, #10 and #11 have acceptable aluminization quality. Despite the fact that most of the mirrors have 5-10% lower reflectivity than the expectation (70%) at 200 nm, and there are possible indications of localized contamination to the aluminized surfaces, these are unlikely to significantly impact the pion identification efficiency of the HGC detector.

We are confident that the aluminized HGC mirrors by ECI are capable of delivering the performance as expected, and would strongly recommend ECI to be considered as a reliable candidate for oversize mirror aluminization for other JLab detector projects.

It is a common understanding that the reflectivity of aluminized mirror will decrease over time due to the usage and oxidation. We strongly recommend to remeasure the reflectivity of the HGC mirrors some years after usage, in order to recalibrate the detector efficiency as well as to gain knowledge on the reflectivity variation over a long period of time.

A ECI Reflectivity Measurements

The reflectivity measurements by ECI are attached. These measurements look like a combination of actual measurements and extrapolation. The witness samples which were placed during the aluminization process were returned late by ECI, and with no information on their positions. It is also unclear which witness sample corresponds to which data sheet.

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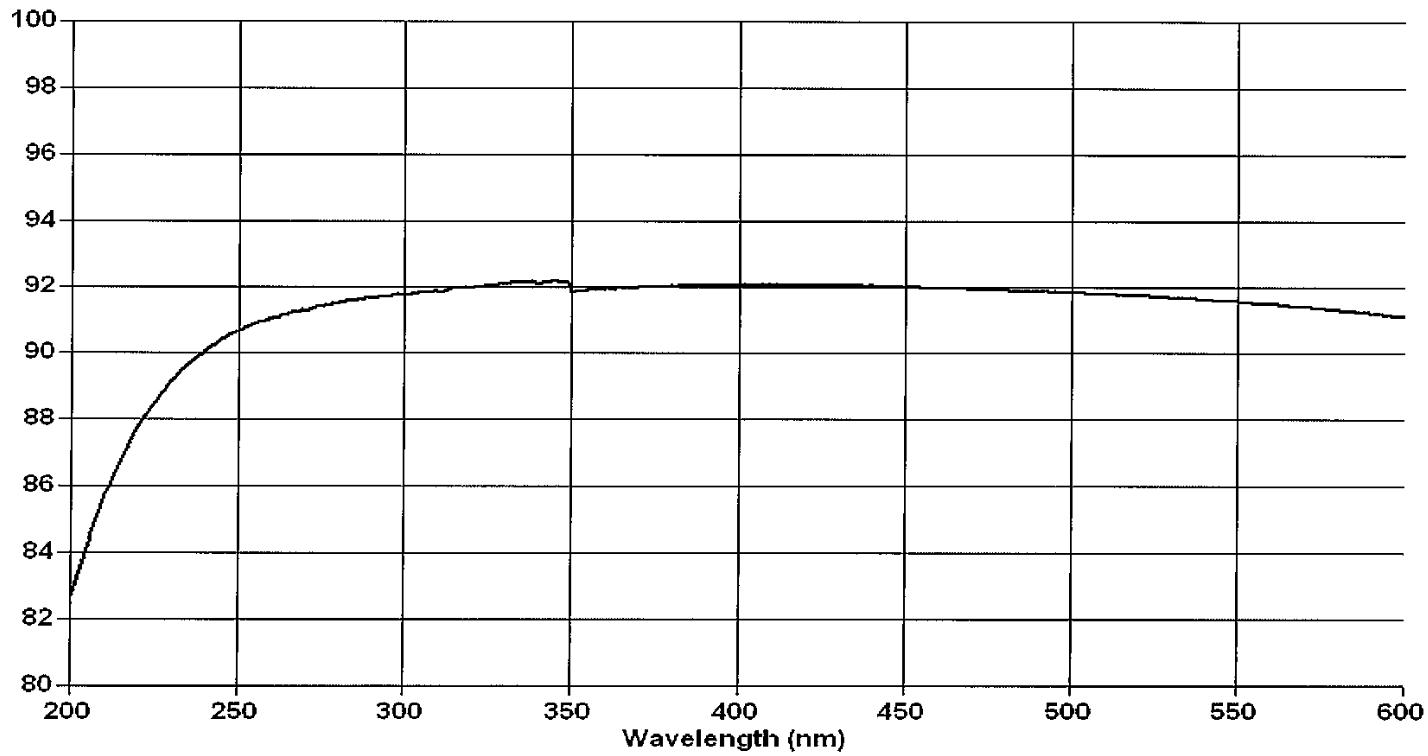
Customer: Jefferson Laboratory **Date:** 8-02-12 **Angle 8°** **Analyst: KH**

P.O. #: **12-P2025** **Run #: 1-185** **Polarization:** **Remarks: HGC Mirror**



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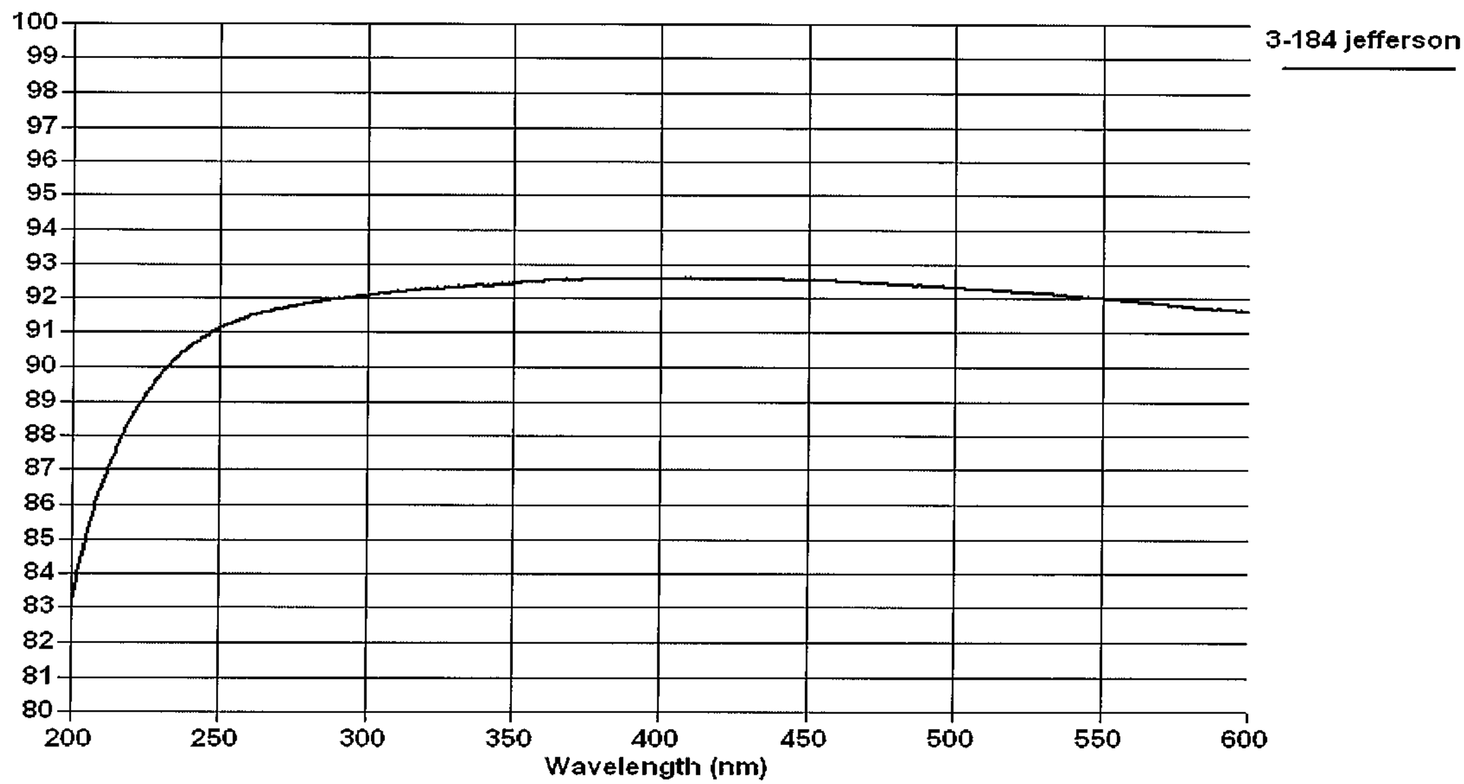

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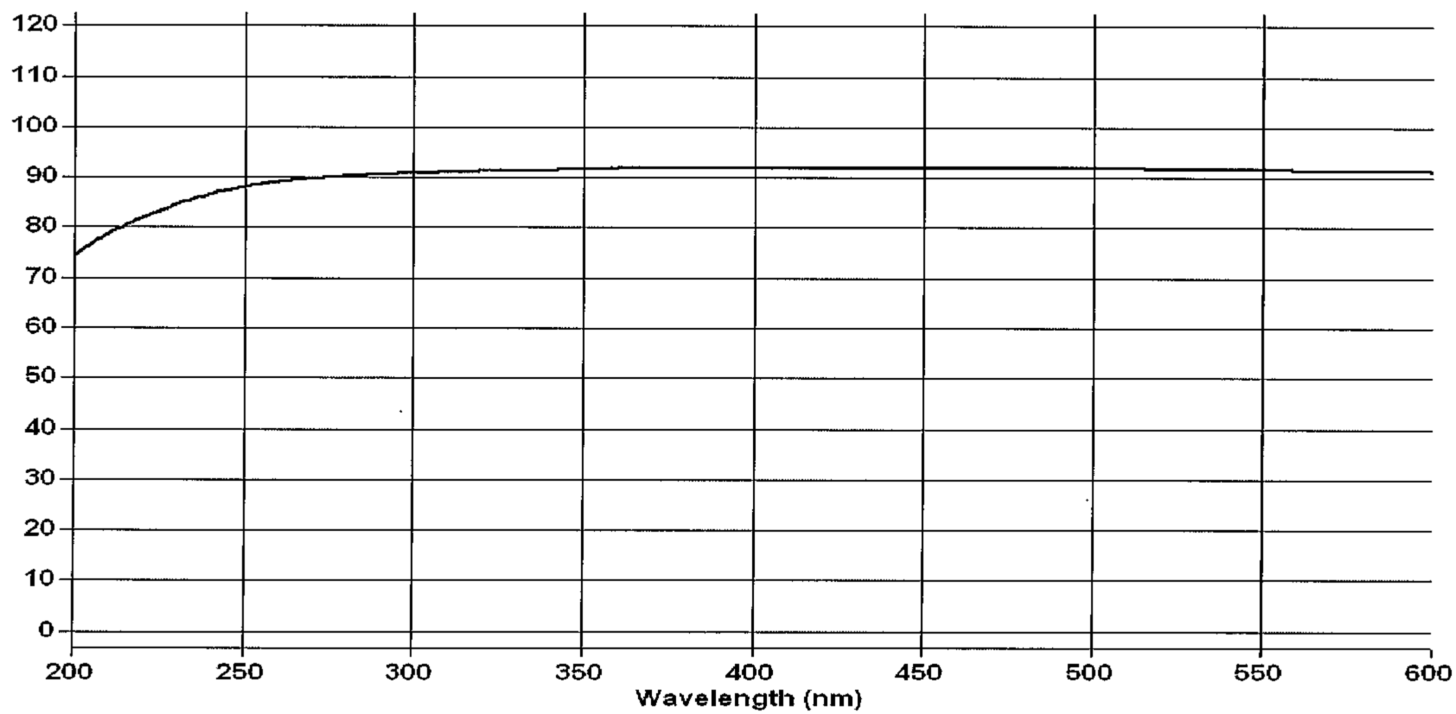

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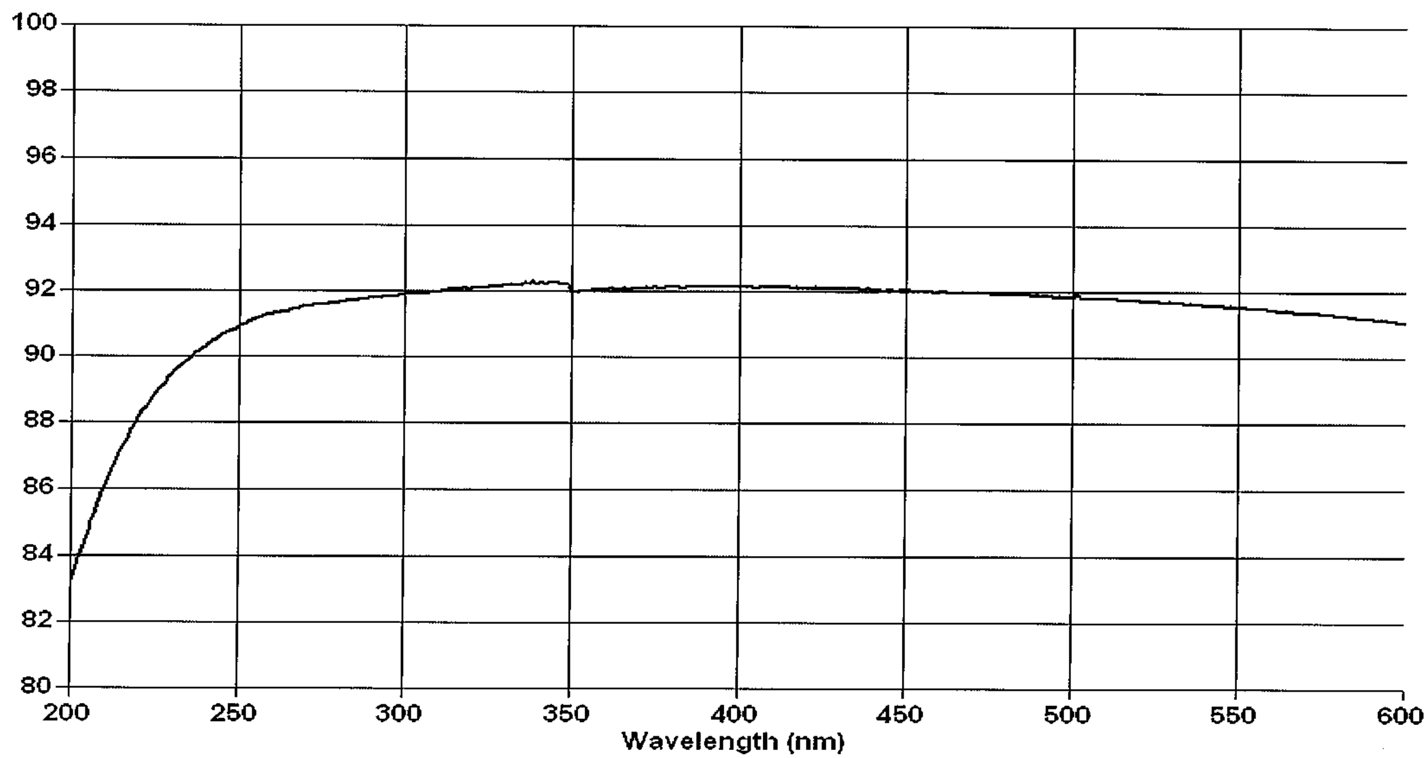
Customer: Jefferson Laboratory **Date:** 8-06-12 **Angle** 8° **Analyst:** KH

P.O. #: 12-P2025 **Run #:** 1-187 **Polarization:** **Remarks:** HGC Mirror



References

[1] W. Li, G. Huber, et. al, *Heavy Gas Cerenkov Mirror Reflectivity Measurements*", HallC-doc-735-v1.

[2] W. Li, *Operation Manual for Reflectivity Measurement Setup of Free Electron Laser Facility at Jefferson Lab*, HallC-doc-754-v1.