# Heavy Gas Cherenkov Mirror Reflectivity Measurement

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Hall C Workshop. August 27, 2012.

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# Project Motivation

- HGC Mirrors must be aluminized to reflect UV Cherenkov photons

- @ Cern
  - High delivery and alumunization cost
  - Uncertain leadtime and delivery time
  - Aluminization quality is certified

- @ Evaporated Coating Inc (ECI), PA
  - Much cheaper cost
  - Very short leadtime
  - Aluminization quality is unknown

- Reflectivity Measurement is needed on ECI aluminizated mirrors to make the final decision

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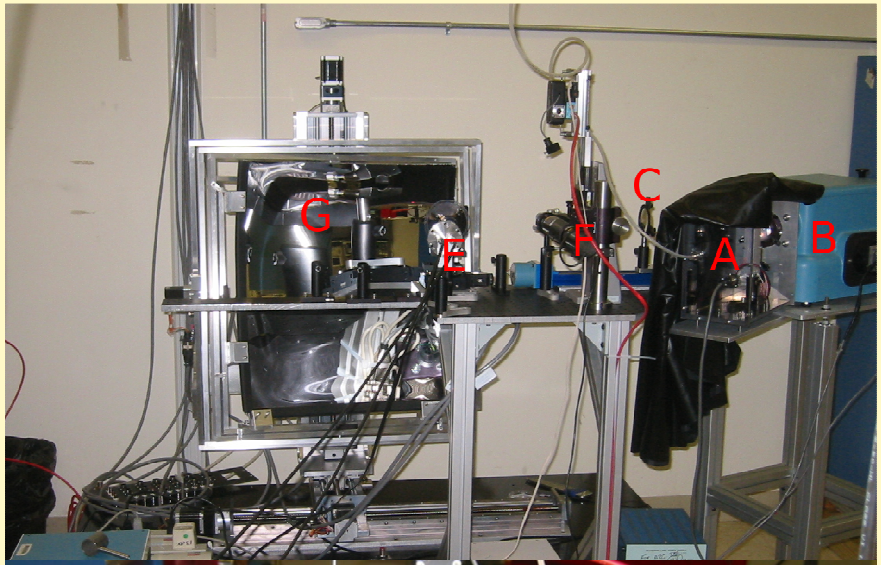
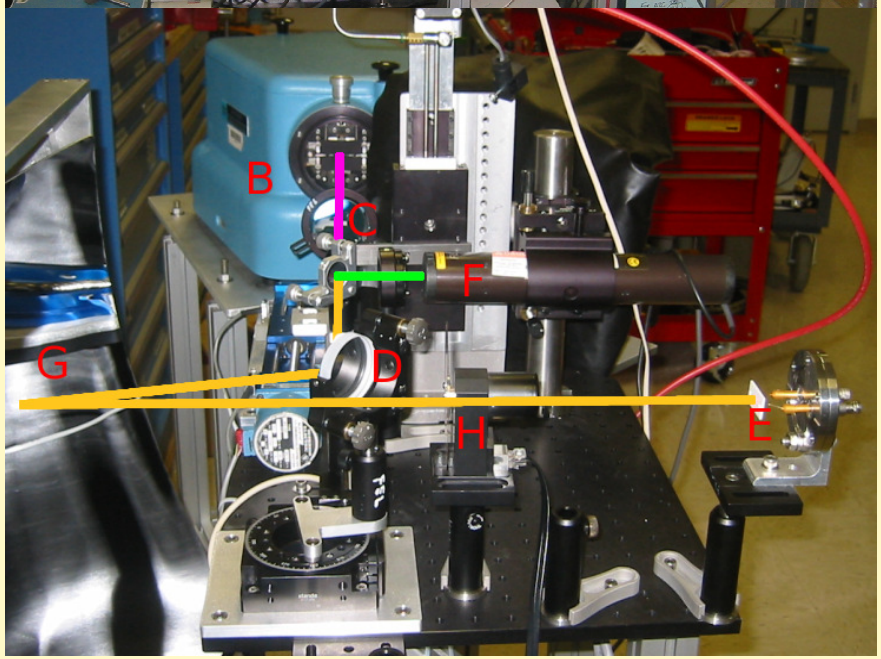
# Introduction

- November, 2011. HGC Mirrors #2 & 8 were sent to ECI for aluminization test
- Hall C, Detector Group and FEL constructed a permanent facility to measure the reflectivity of larger size optics
  - Measure any point on the mirror
  - Lower Wavelength limitation: 165nm
  - Mirror dimension limitation: 60cm x 55cm, radius of curvature: 110 cm)
- HGC and NGC mirrors
  - HGC: 200-400 nm
    - Reflectivity around 70% @ 200 nm
  - NGC: 165-400 nm (Purged N2 environment)
    - Air absorb UV below 190 nm
- Hall A & B are also interested

# Setup (@ FEL, User Lab 3)




- Measurement Equipment:
  - A:  3 Watt Hamamatsu Deuterium Lamp
  - B: MacPherson VUV 218 Monochromator
  - C: PCX 50.8 X 200mm Focusing Lens
  - D: Melles Griot DUV Flipper Mirror
  - E: AXUV-100 Photo-diode
  - F: Alignment Laser Stage
  - G: HGC Mirror # 8
  - H: Thorlab MC100 Optical Chopper
- Black hutch will be installed

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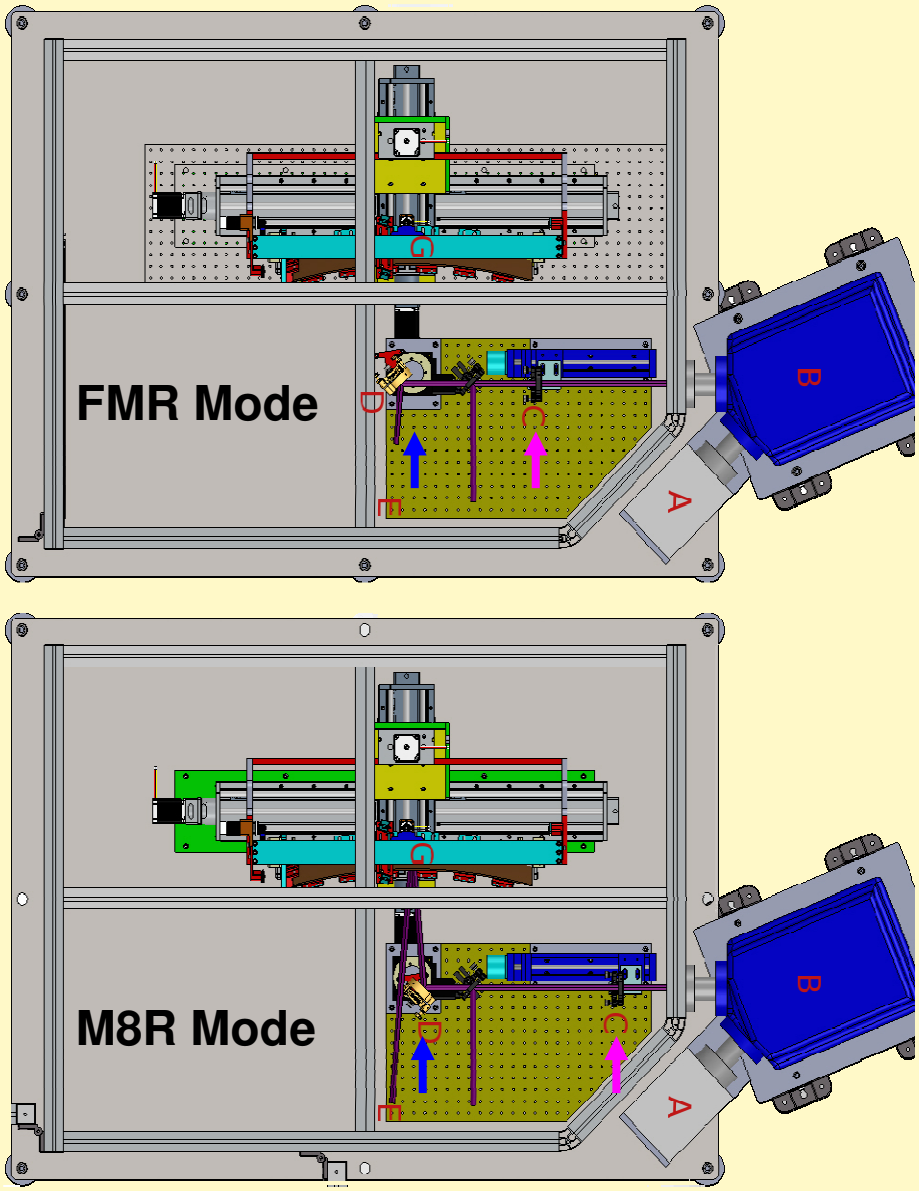
# Measurement Modes




- Wavelength Scan
  - 190-400 nm at 5 nm steps
- 3 Measurement Modes:
  - No Reflection (NR) Mode
    - Light Path: Source → Detector
    - 1 Measurement
  - Flipper Mirror Reflection (FMR) Mode
    - Light Path: Source → Flipper → Detector
    - 8 Measurements
  - Mirror #8 Reflection (M8R) Mode
    - Light Path: Source → Flipper → Mirror #8 → Detector
    - 6 Measurements

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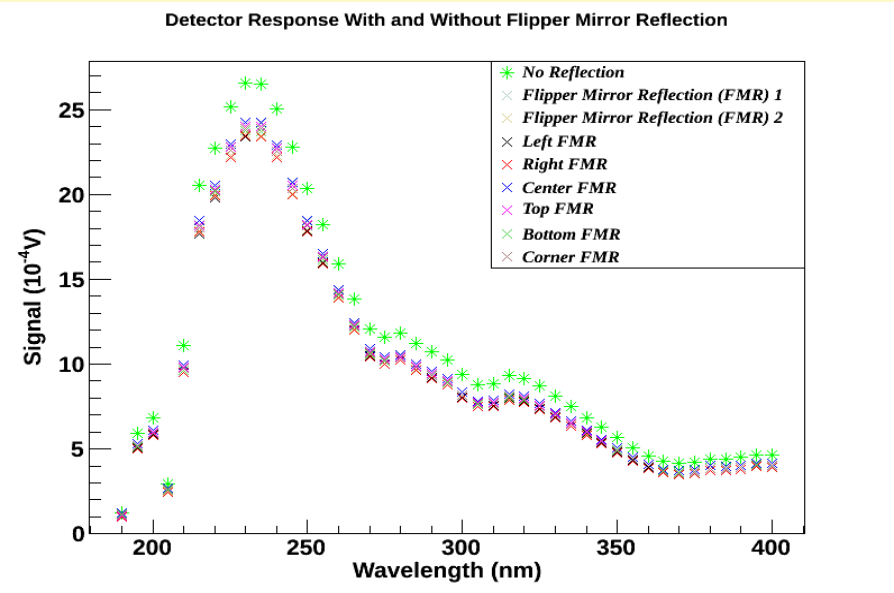
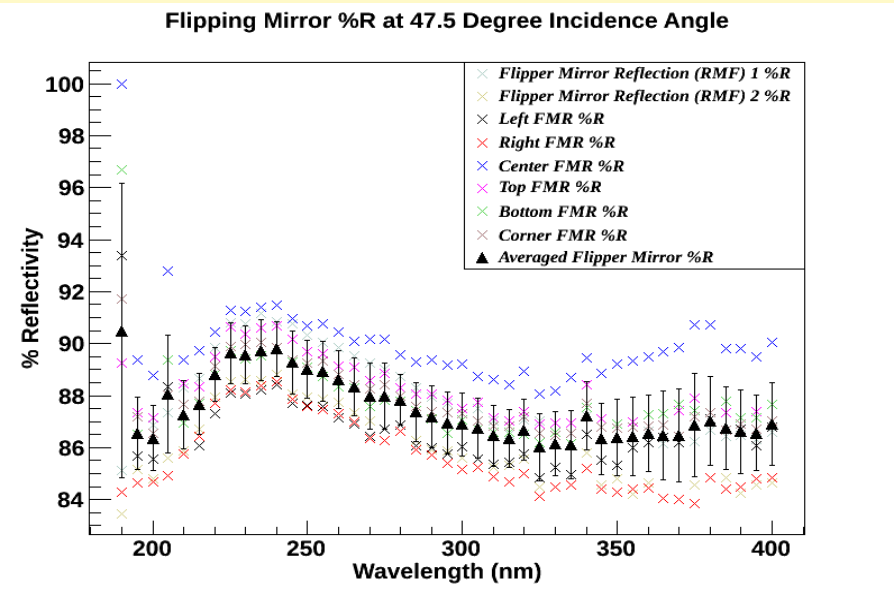
# Flipper Mirror Reflectivity




- NR Mode:
  - Source → Detector
  - 1 Measurement
- FMR Mode:
  - Light Path: Source → Flipper → Detector
  - 8 Measurements (2 After NR, 6 Before M8R)
- Reflectivity:

$$\text{Flipper Mirror Reflectivity} = \frac{\text{Signal (FMR)}}{\text{Signal (NR)}}$$

- Uncertainty: Standard deviation of the reflectivity
- Baseline: 5 x $10^{-5}$V

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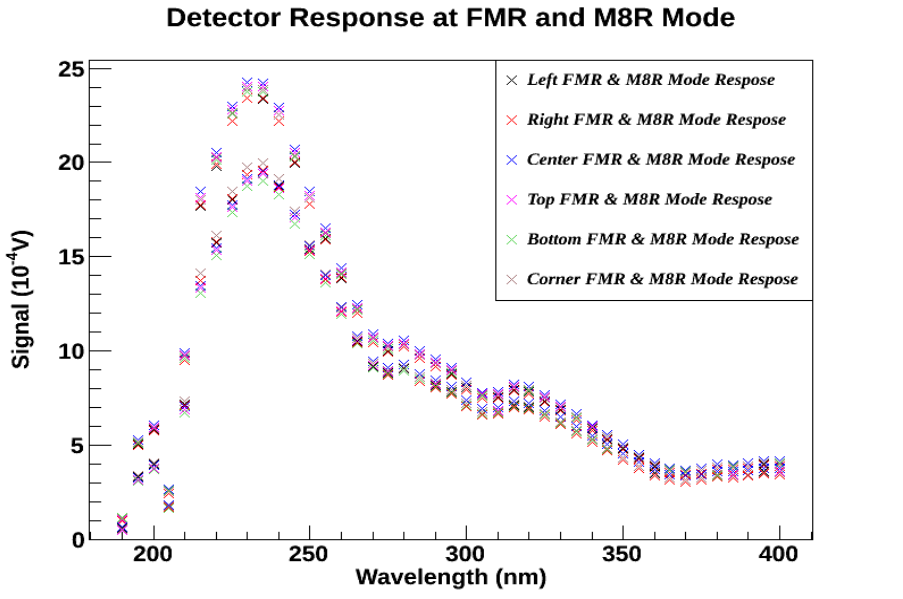
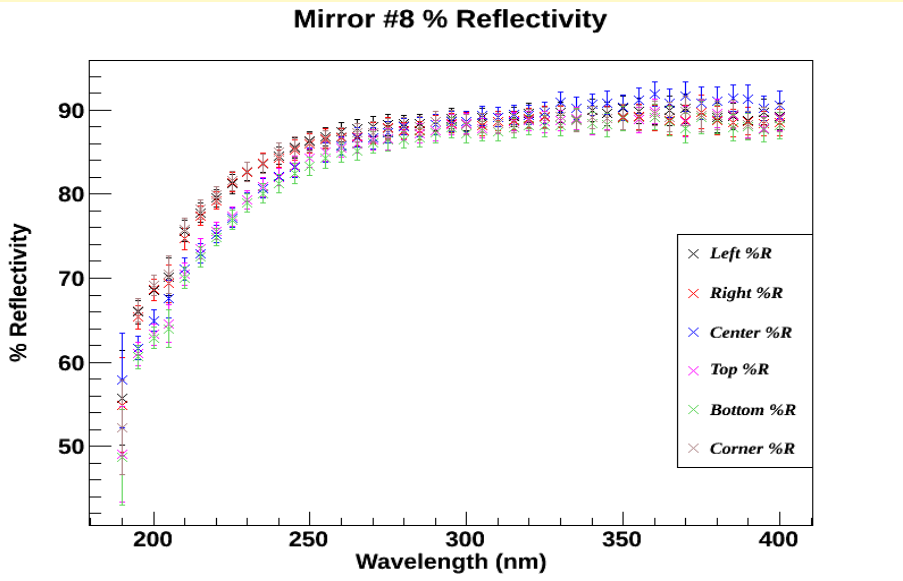
# Mirror #8 Reflectivity




- FMR Mode:
  - Light Path: Source → Flipper → Detector
  - 6 Measurements
- M8R Mode
  - Light Path: Source → Flipper → Mirror #8 → Detector
  - 6 Measurements
- Mirror #8 Reflectivity:

$$\text{Mirror \#8 Reflectivity} = \frac{\text{Signal (M8R)}}{\text{Signal (FMR)}}$$

- Uncertainty is taken as the same as for FMR
- Baseline: 5 x $10^{-5}$V

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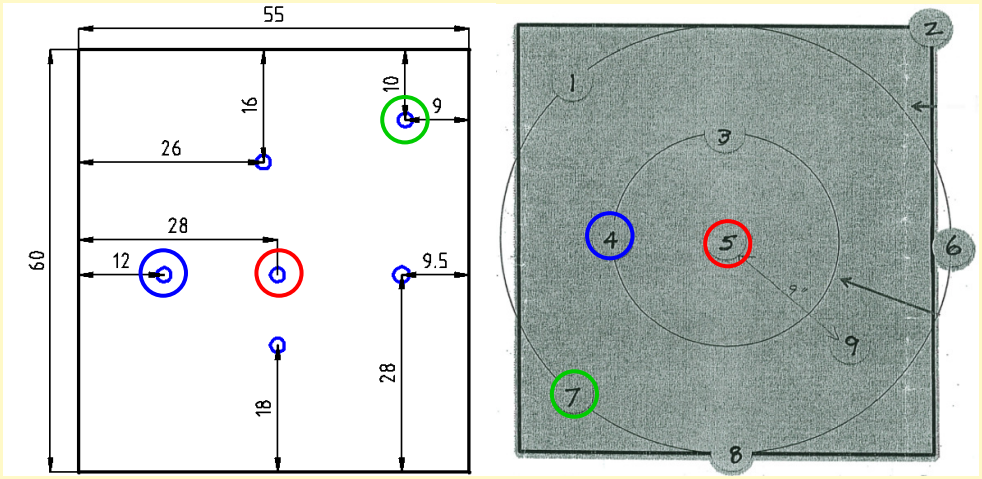
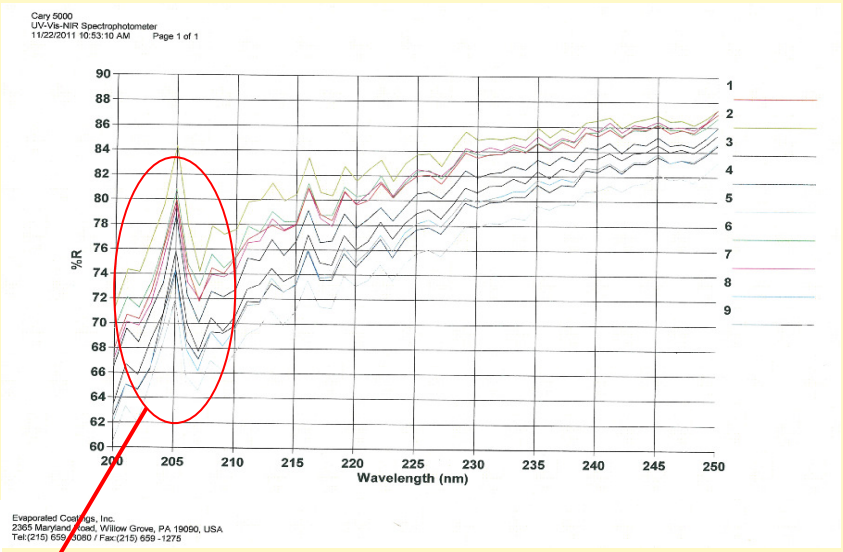
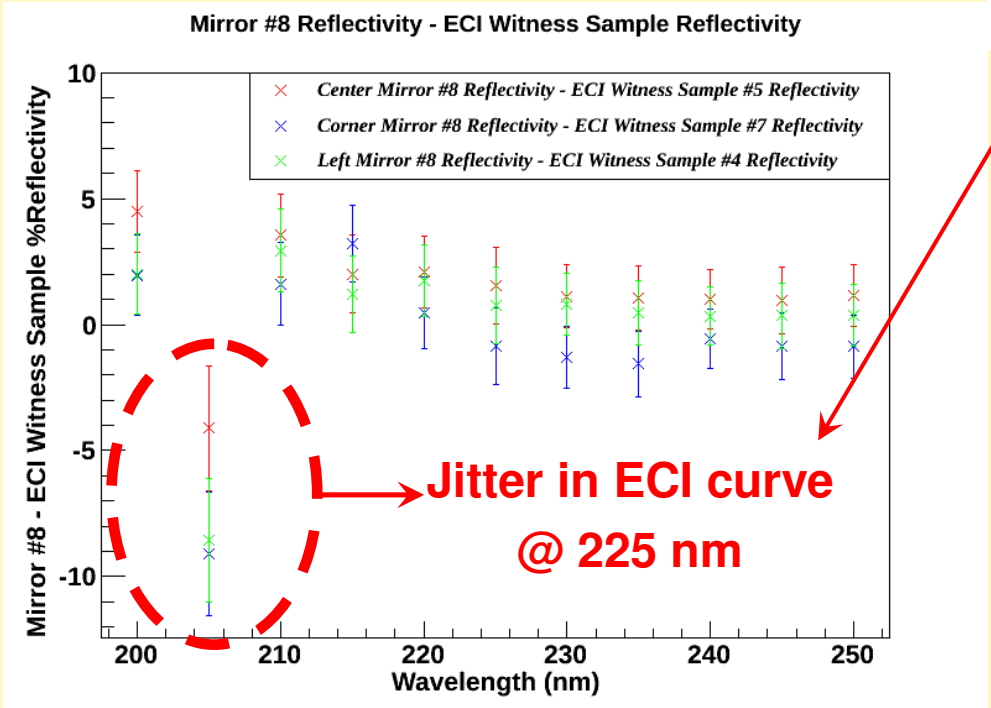
# Measurement – ECI Reflectivity Curve




- Measurement - ECI
  - **Corner - Witness Sample 7**
  - **Center - Witness Sample 5**
  - **Left - Witness Sample 4**
- ECI Uncertainty Estimation:
  - < 230 nm: $\delta(\mathrm{ECI}) = \pm 1\%$
  - > 230 nm: $\delta(\mathrm{ECI}) = \pm 0.5\%$
- Uncertainty Estimation:

$$\delta(\mathrm{difference}) = \sqrt{\delta(\mathrm{measurement})^2 + \delta(\mathrm{ECI})^2}$$

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# Conclusion & Status

- ECI aluminization quality meets our performance specification
- The reflectivity facility at JLab was successful
- Remaining 6 HGC mirrors were aluminized by ECI, and have arrived at JLab in Mid August. Their reflectivities will be measured in Dec, 2012

# Some Future Remarks

- Different Lamp is required to measurement reflectivity down to 165nm
- Alignment cameras are needed for the optical alignment under N2 condition.
- Automation (Coding), but not urgent

# Thank you


- Special thanks go to Wesley Moore and Jim Coleman for setting up the control system. Advice from Bob Legg, Mike Klopf and Tom Powers were absolutely vital for project development.

- Project construction fund and equipment were provided by Hall C, Detector Group and FEL of Jefferson Lab.

# Backups

- Flipper Mirror Reflectivity:

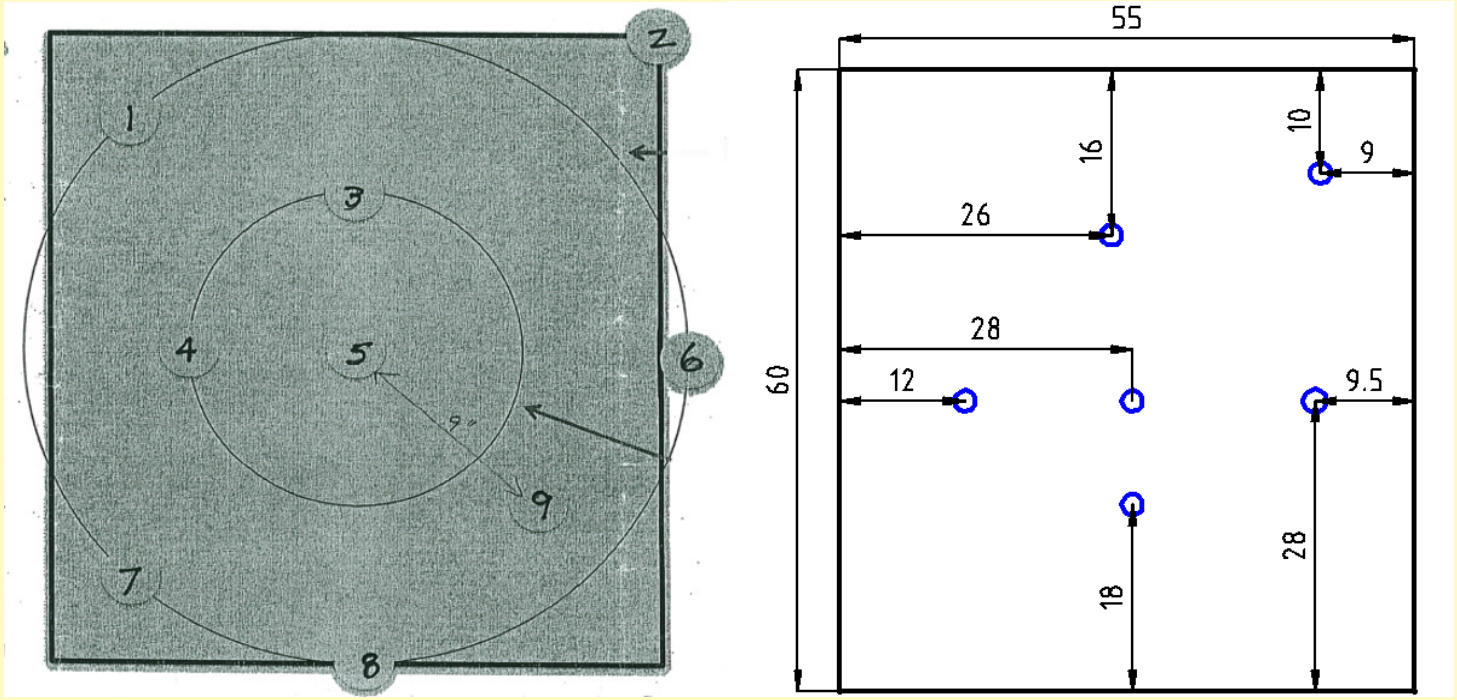
$$\text{Flipper Mirror Reflectivity} = \frac{\text{Signal (FMR)}}{\text{Signal (NR)}}$$

- Mirror #8 Reflectivity:

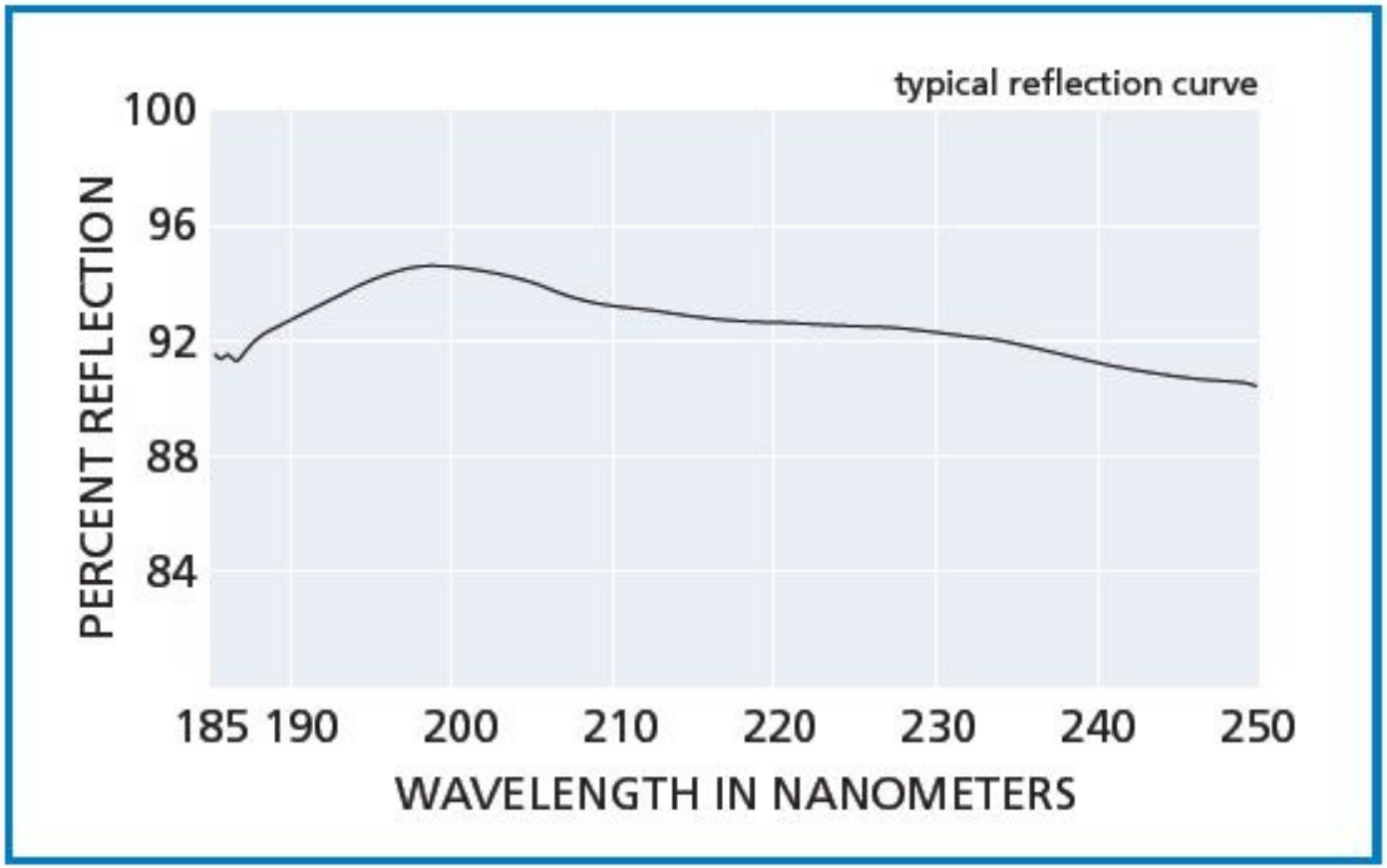
$$\text{Mirror \#8 Reflectivity} = \frac{\text{Signal (FMR)}}{\text{Signal (M8R)}}$$

- Our Measurement and ECI:

# Measurement locations



# DUV Flipper Mirror Typical Reflectivity Curve




**Reflectivity vs wavelength of 193 nm deep UV aluminum coating at 45°**

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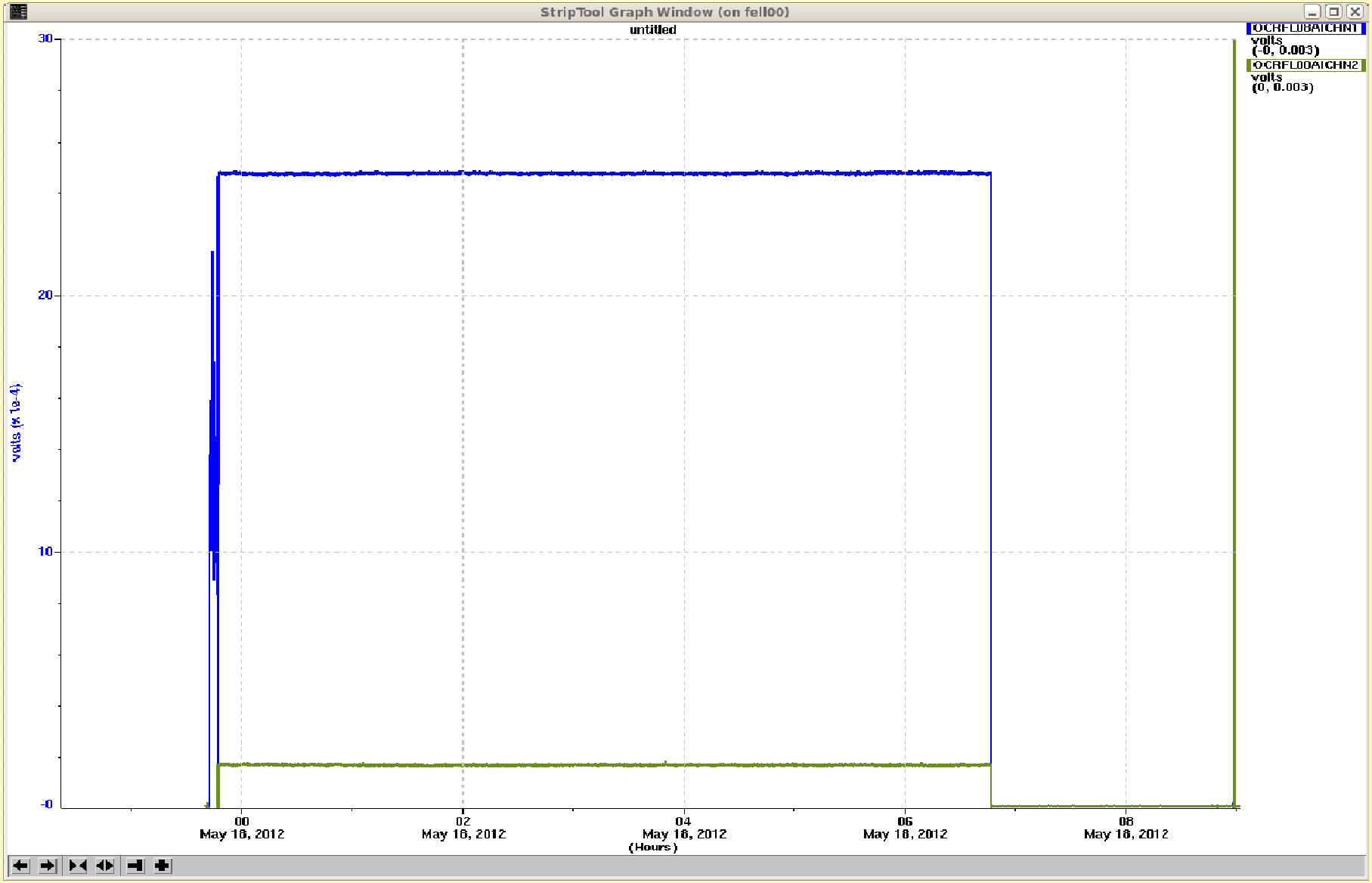
# Thermal Test

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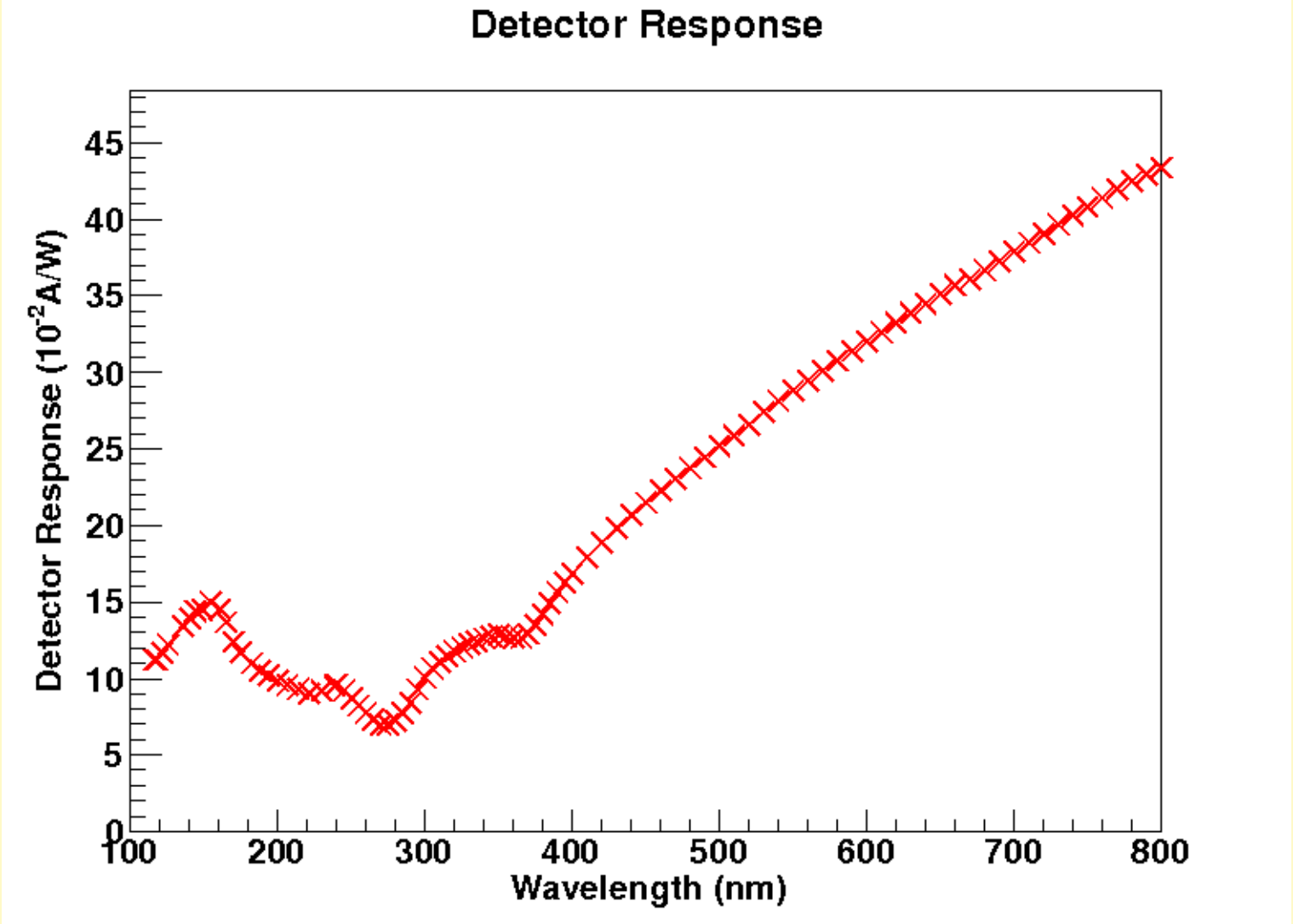
# IRD AXUV-100 Photo-diode Response

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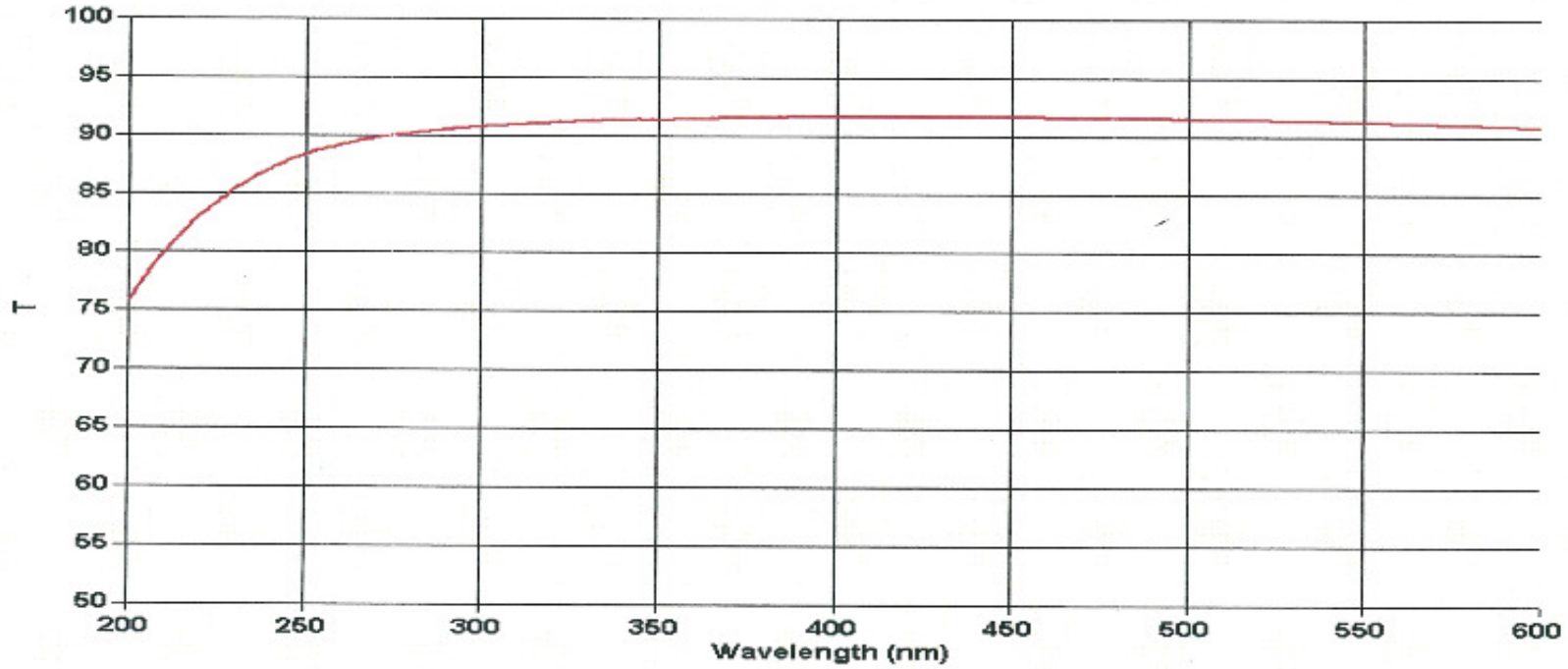
# ECI Theoretical Curve

2365 Maryland Road
Willow Grove, PA 19090 USA
(215) 659.3080
(215) 659.1275 fax
evapsales@evapcoat.com
www.evaporatedcoatings.com

## Coating Spectral Performance

Customer: Jefferson Laboratory Date: 11/22/2011 Angle 8° Analyst: KH

P.O. #: 12-M0245 Run #: 1-65 Polarization: Remarks: HGC Mirror

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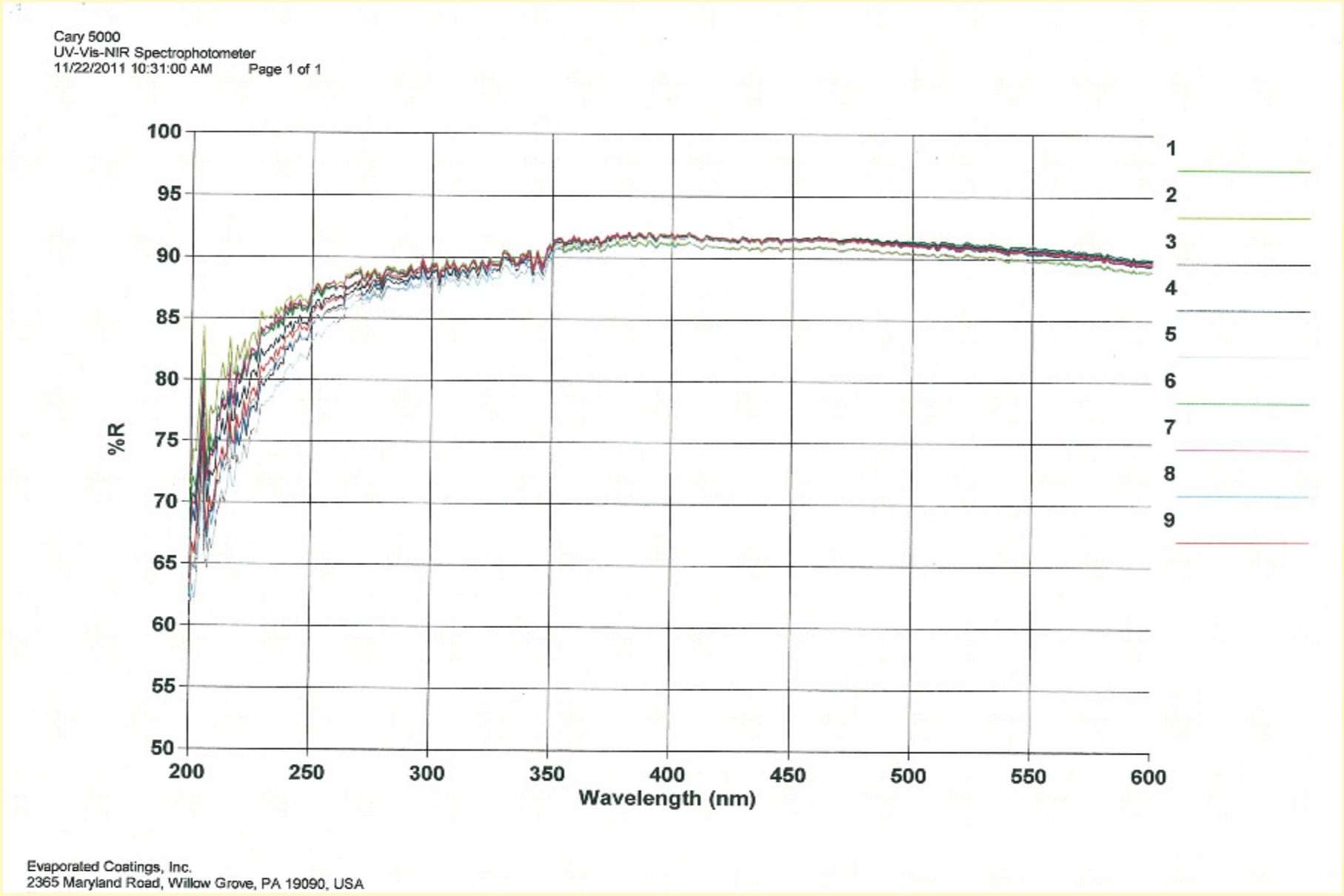
# ECI Witness Sample Reflectivity: 200-600 nm

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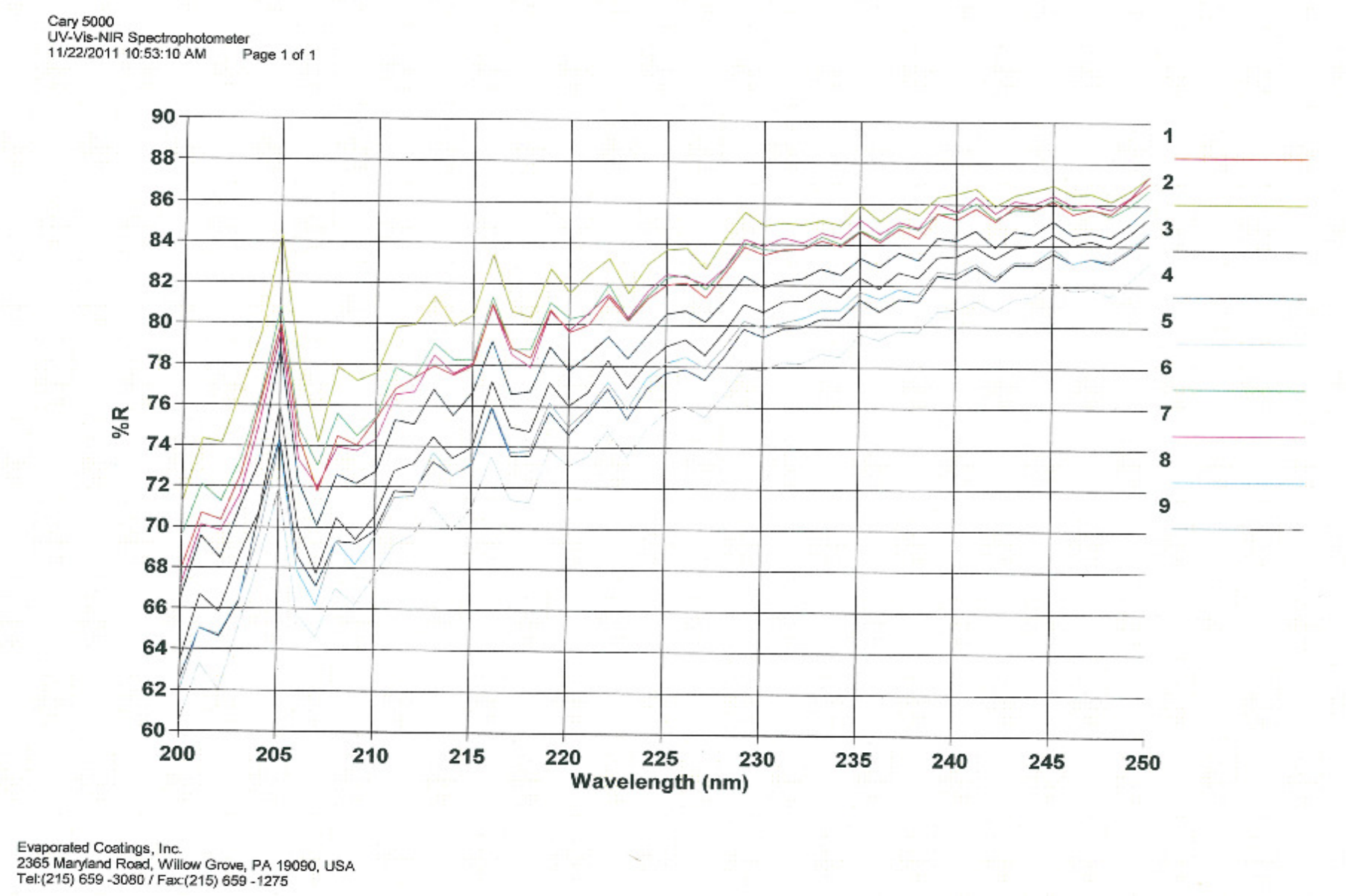


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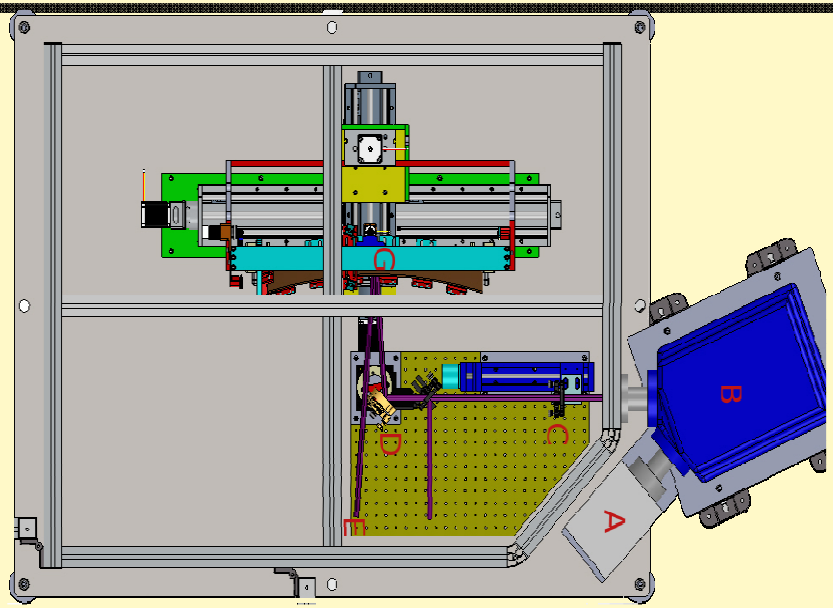
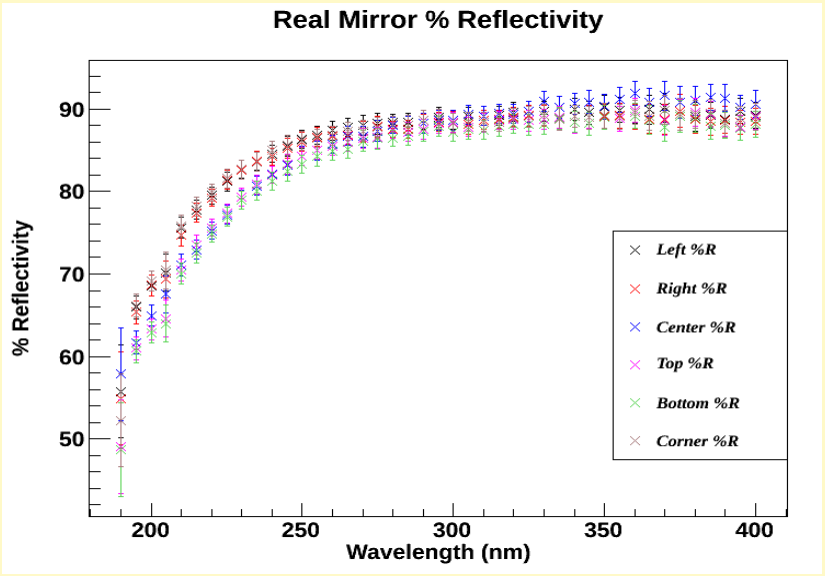
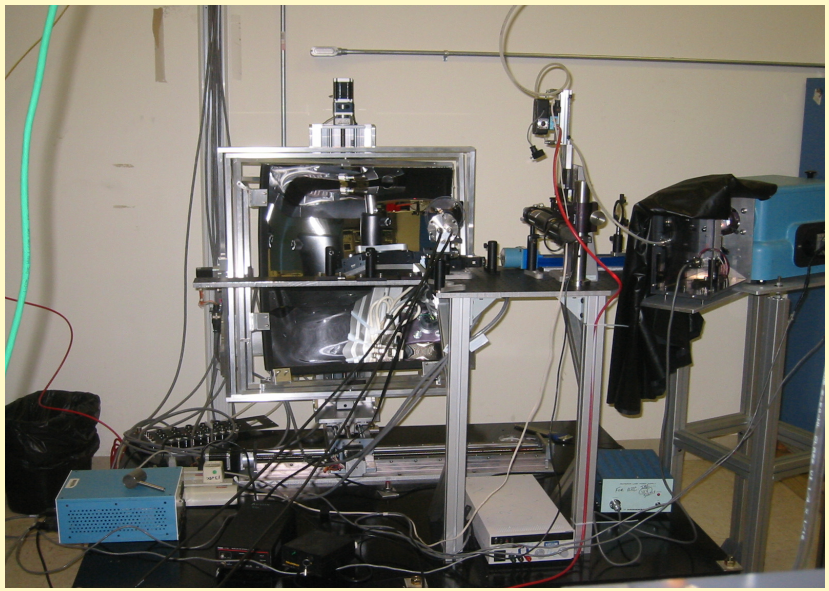
# Quality Control: Mirror Reflectivity Measurement

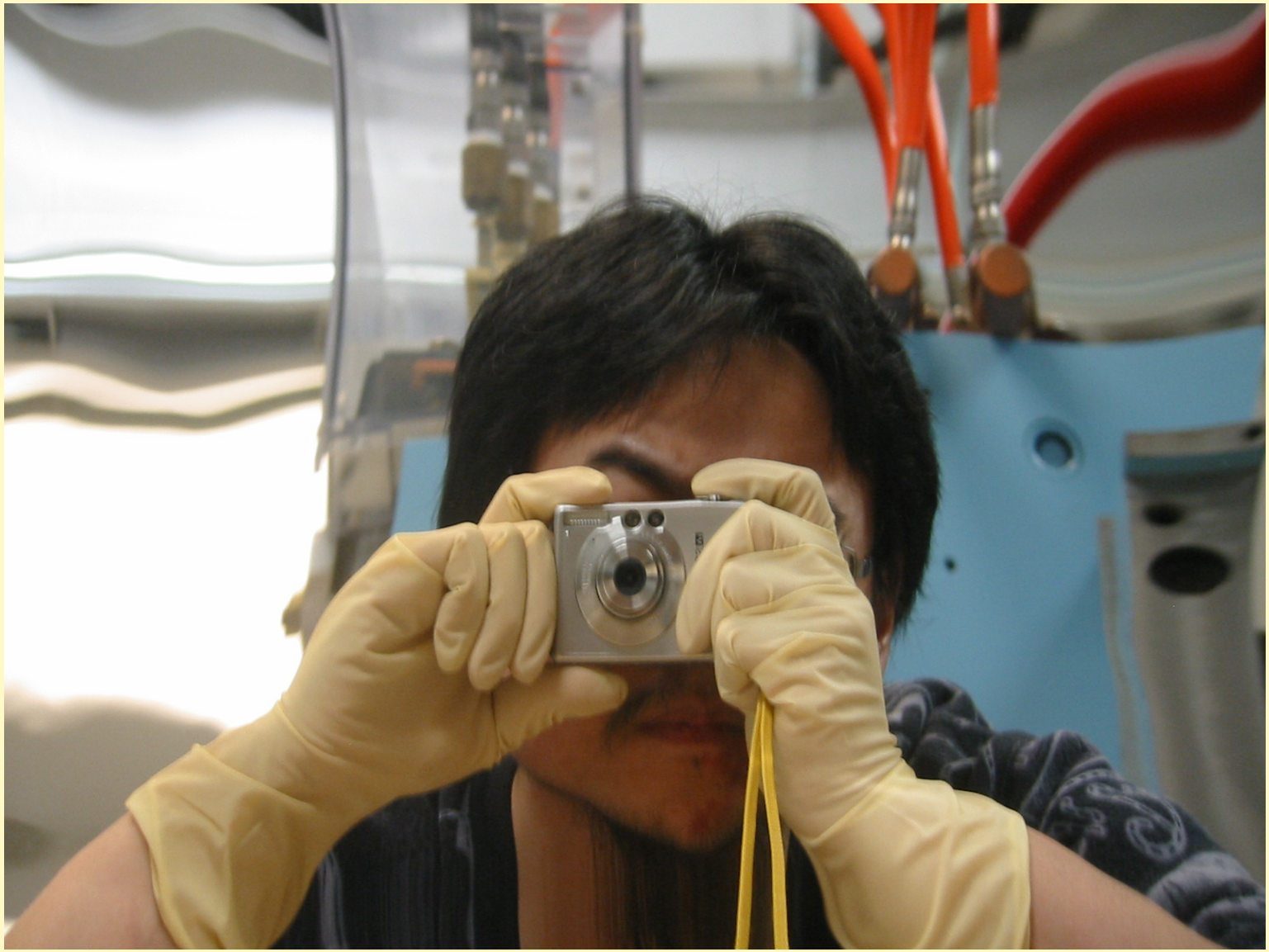
- Permanent Reflectivity Setup at FEL of JLab
- Wavelength: 200-400nm
- 0-3% difference to the vendor's measurement
- **Confirms the vender's coating quality**



# Aluminized Mirror Quality



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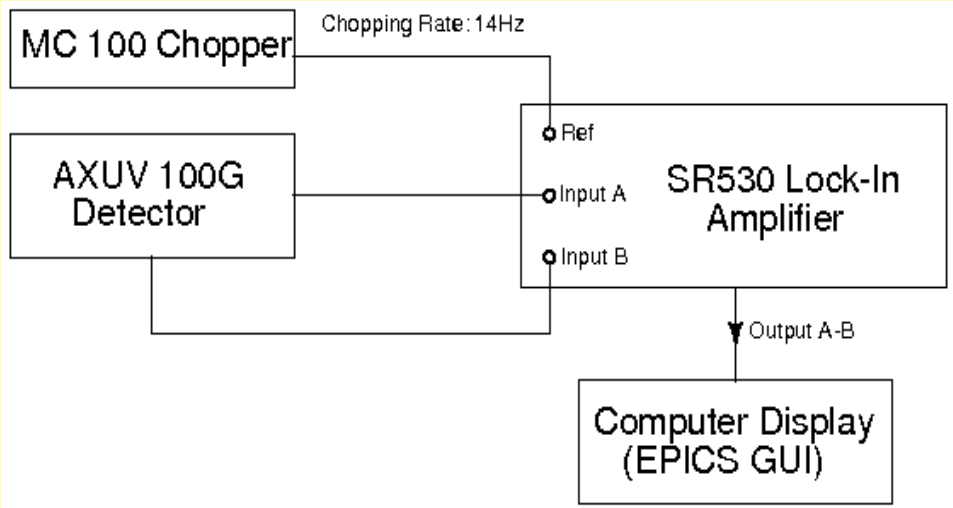
# Lock-in Technique




- **The lock-in technique is used to measure very small AC signals in large background at narrow bandwidth.**

- MC 100 Optical Chopper:
  - Chop the light signal at 14 Hz
  - Generated the gate for SR 530
- AXUV-100 Photo-diode
  - Two signal output: + and -, no bias voltage.
- SR530 Lock-in amplifier:
  - Output: signal magnitude (A-B) and synchronization.

- **Advantages:**
  - **No PMT**
  - **Wavelength Scan: 200-400 nm dark box is not require**
  - **Requires a constant background**