

Radiometric Measurement Pitfalls for Far UV-C Optical Radiation

C. Cameron Miller

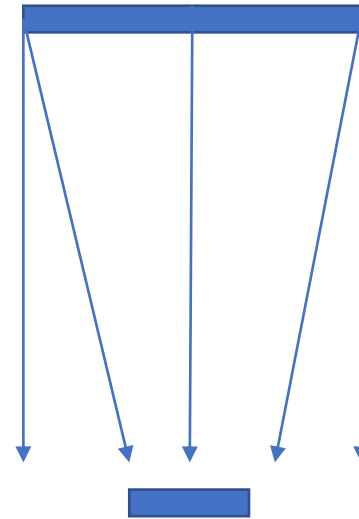
Yuqin Zong, Jeanne Houston, Ellie Gretarsson, Michael Braine, Rob Vest,
Edward Hagley & Howard Yoon
Sensor Science Division

National Institute of Standards and Technology

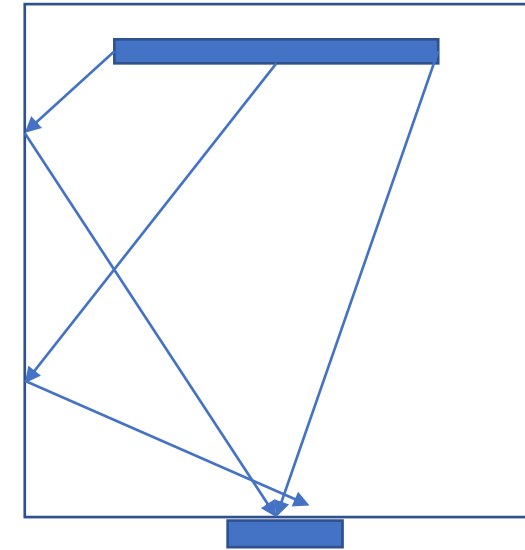
No Radiometers used in UVC – Why?



Barry Hunt, Prescient^x



Collimated



2 π Illumination

CIE 220:2016 – Technical Report – Characterization and Calibration Methods of UV Radiometers

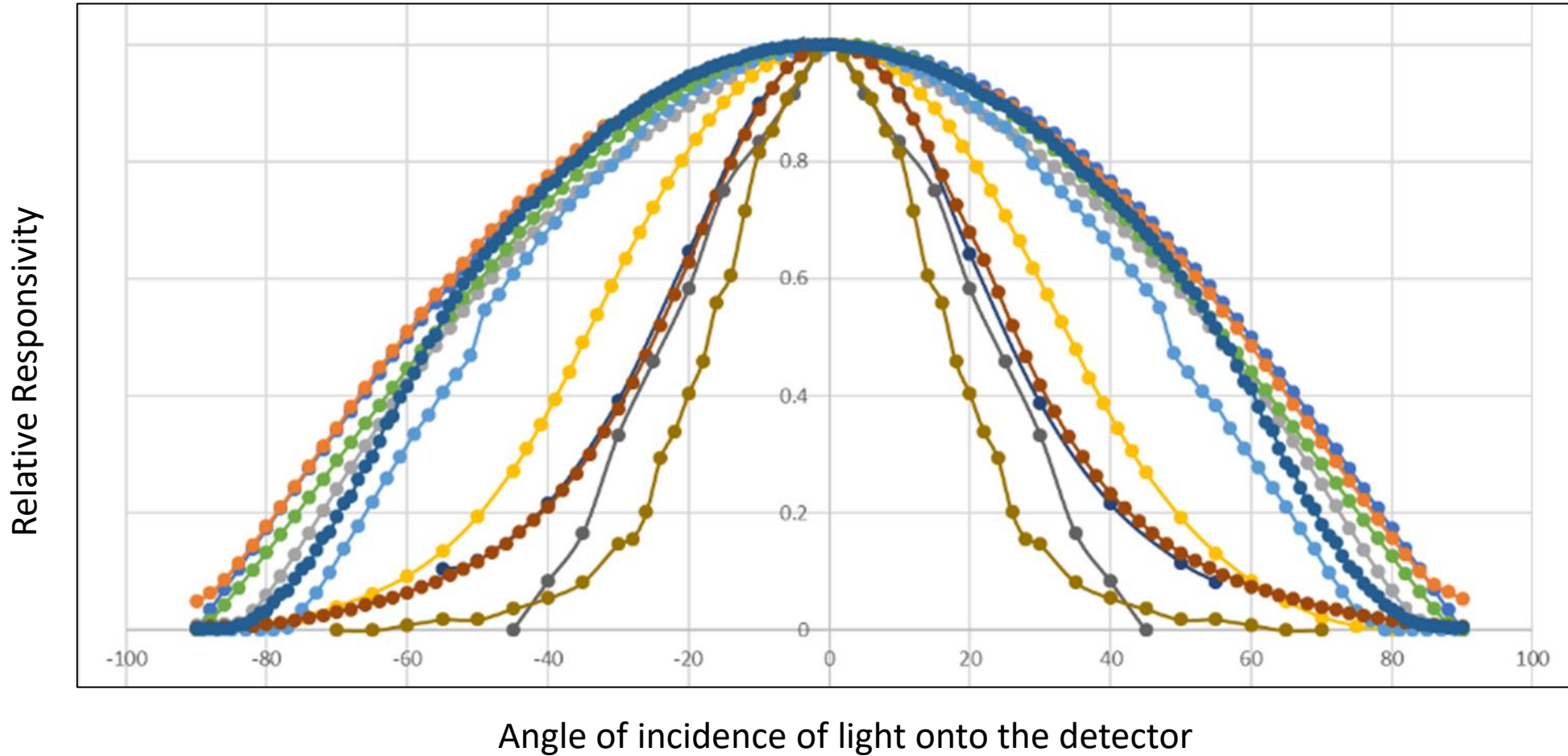
May 2020

Illuminating Engineering Society (IES) & International Ultraviolet Association (IUVA) sign a memorandum of understanding (MOU) to assemble experts in the measurement of ultraviolet C-band (UV-C) emissions to develop American National Standards (ANSI Standards) for the measurement and characterization of UV-C device performance.



- 1 – Approved Method for Electrical and Ultraviolet Measurement of Low-Pressure Mercury Sources – [LM-94-20XX](#)
- 2 – Approved Method for Electrical and Ultraviolet Measurement of Solid-State Sources (LEDs) – [LM-92-2022](#)
- 3 – Approved Method for Electrical and Ultraviolet Measurement of Excimer Sources/Discharge Sources – [LM-93-2022](#)
- 4 – Approved Method for Electrical and Ultraviolet Measurement of UVC Disinfection Products – [LM-95-20XX](#)
- 5 – Calibration & characterization of UVC Detectors

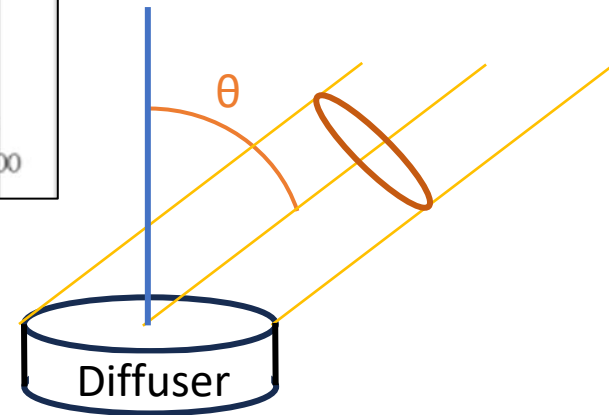
Cosine Correction



Relative Responsivity

Angle of incidence of light onto the detector

Why a cosine correction is required

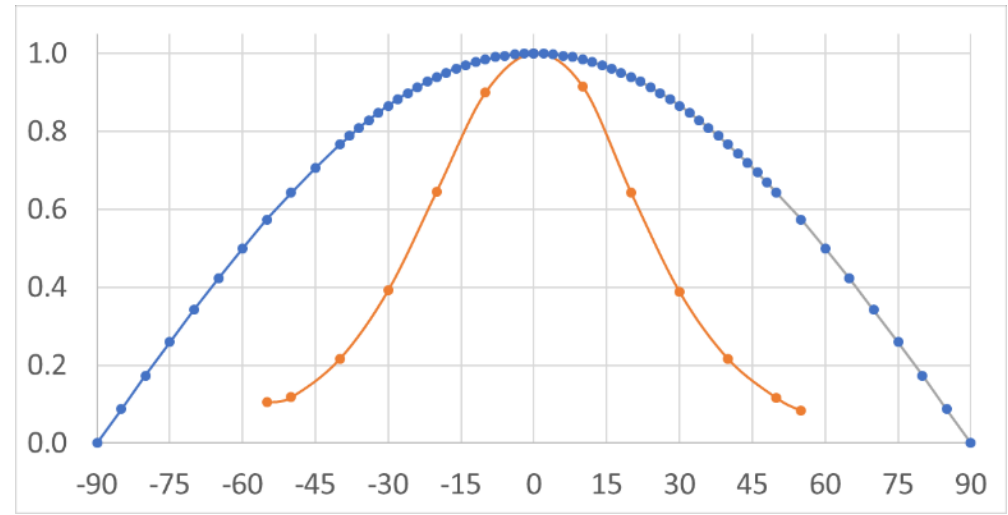
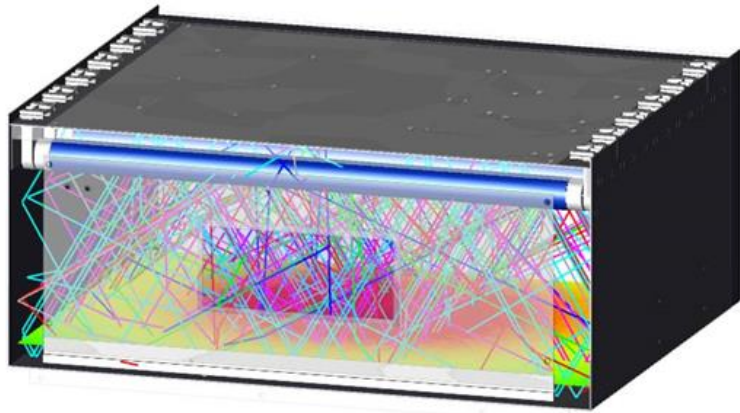


10 different detectors

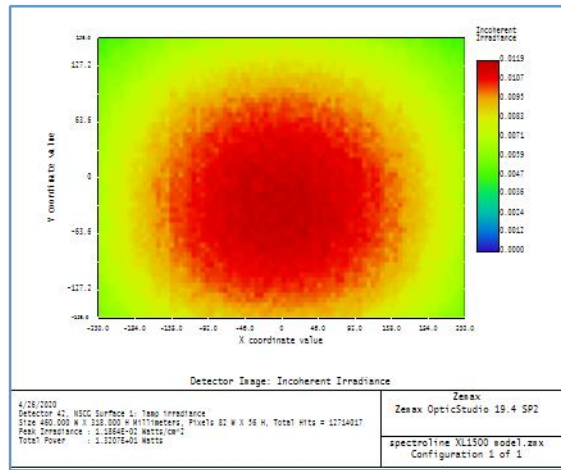
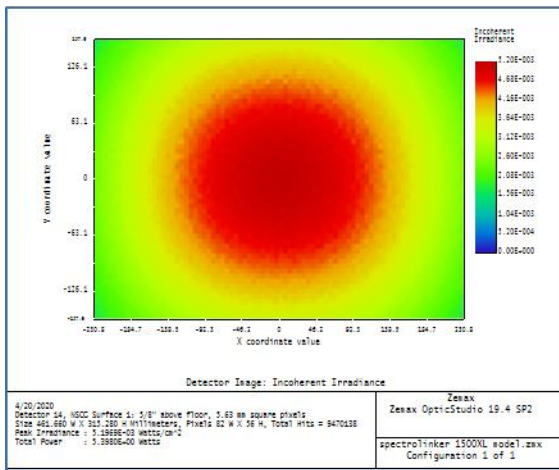
Medium blue dots are a cosine response

Cosine Correction - Application

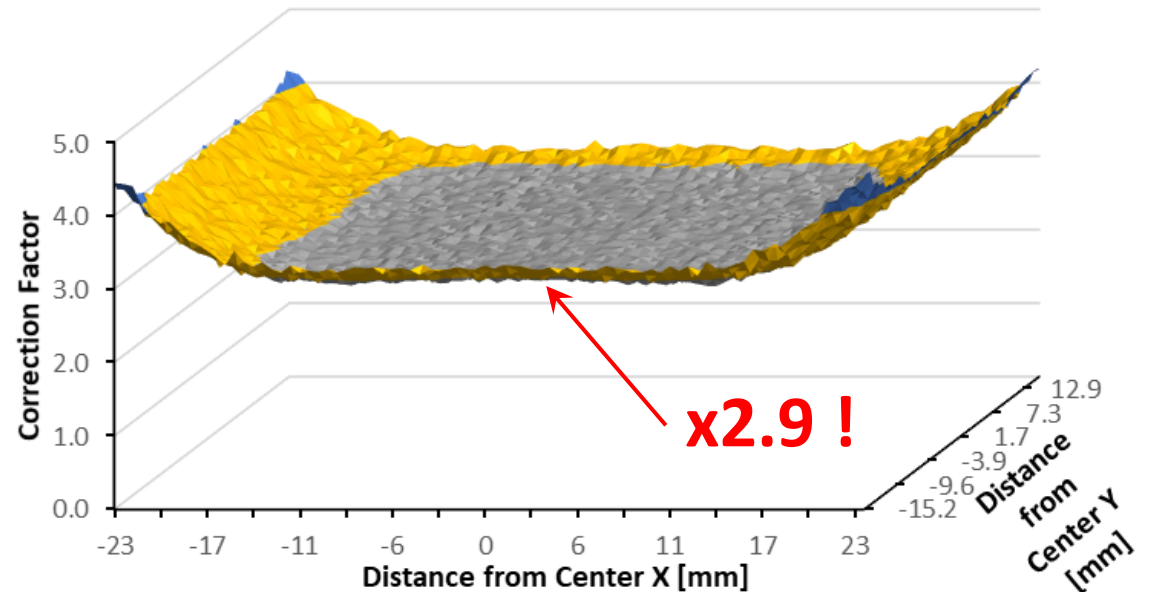
UV 'Microwave' measurement



Sensor Correction Factor

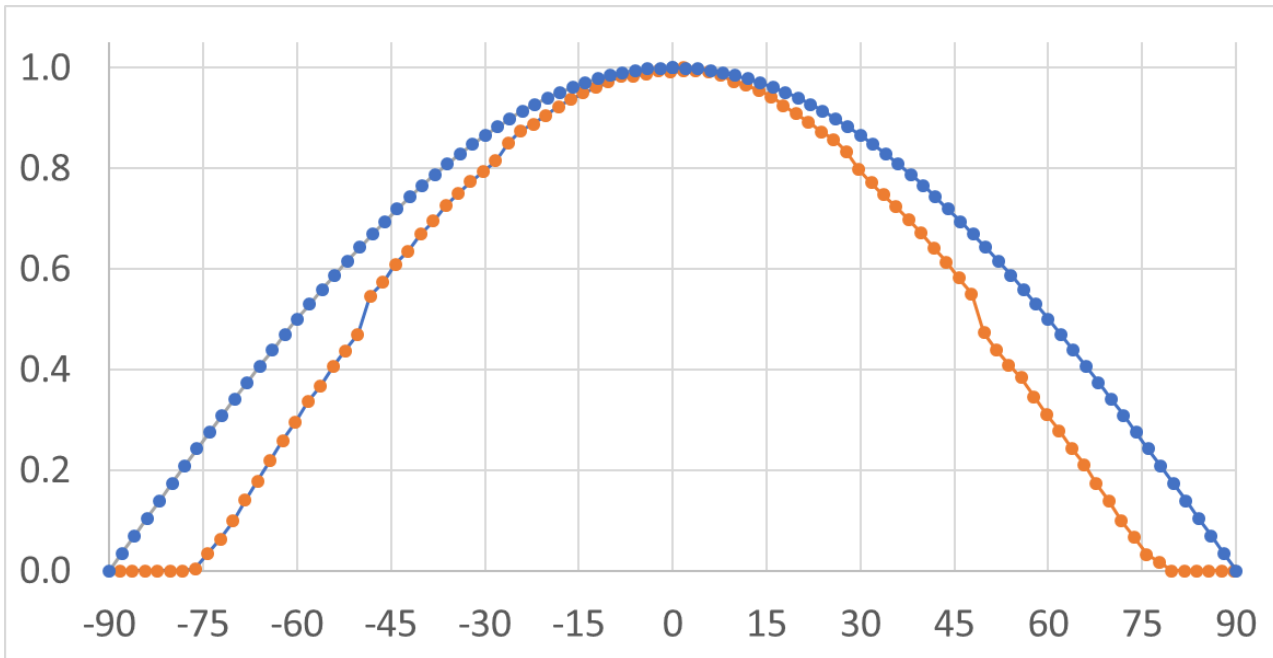


Zarobila, Litorja - NIST

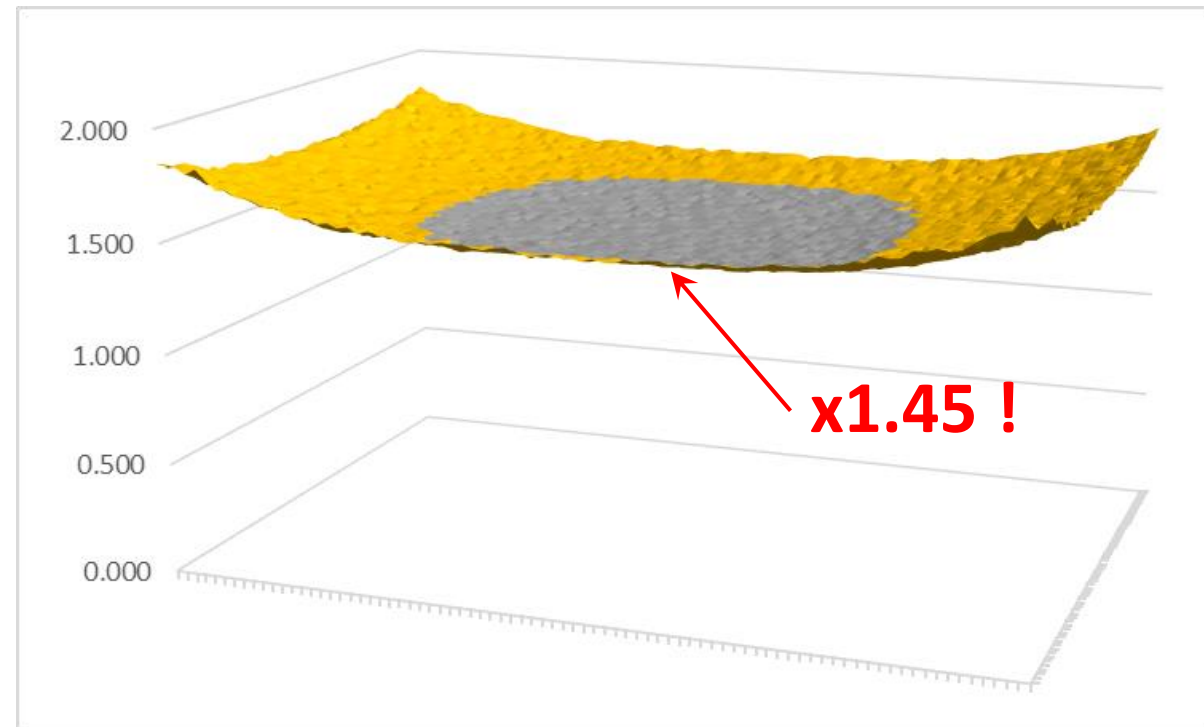
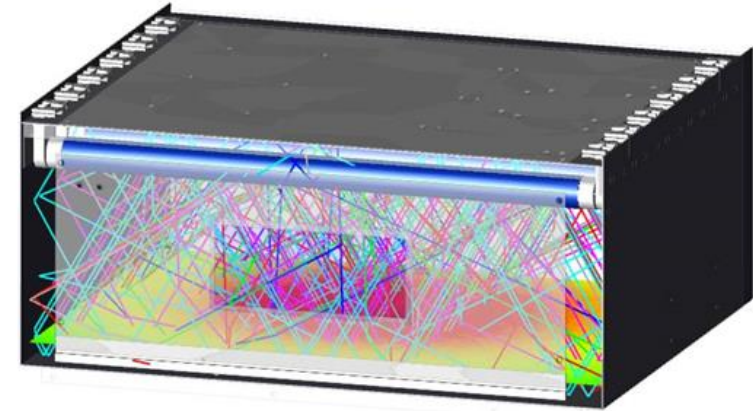


Cosine Correction - Application

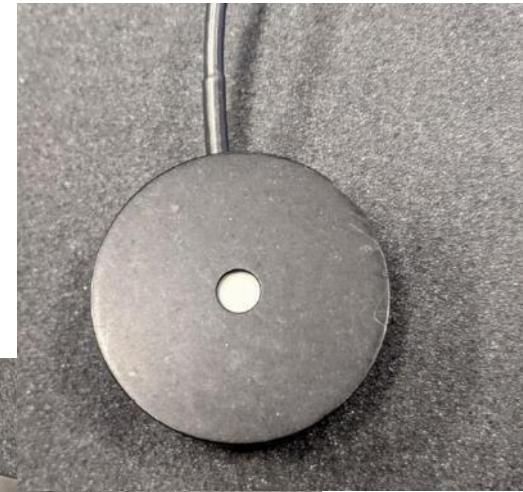
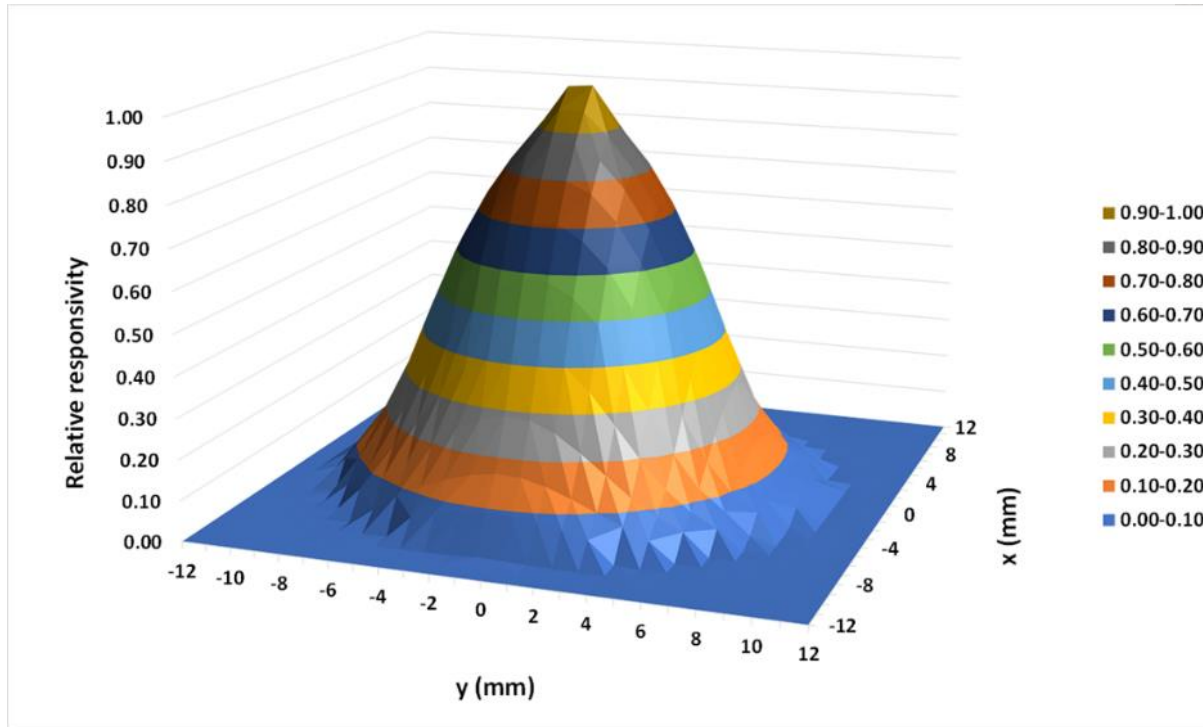
UV 'Microwave' measurement



Zarobila, Litorja - NIST



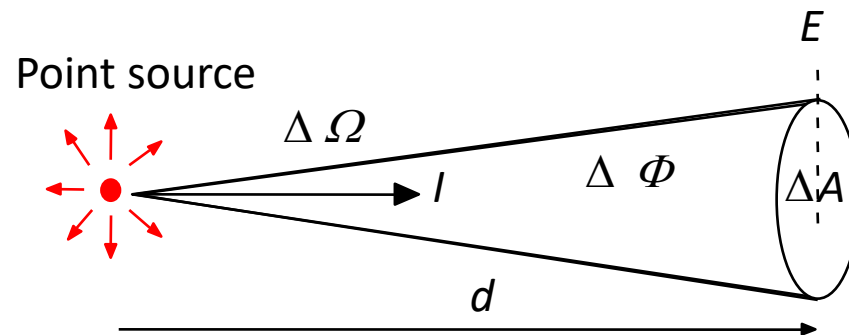
Spatial Non-uniformity



Detector Reference Planes

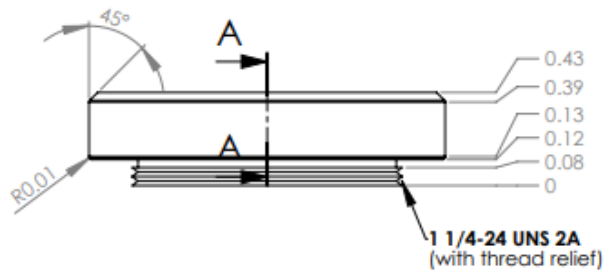


Inverse Square Law

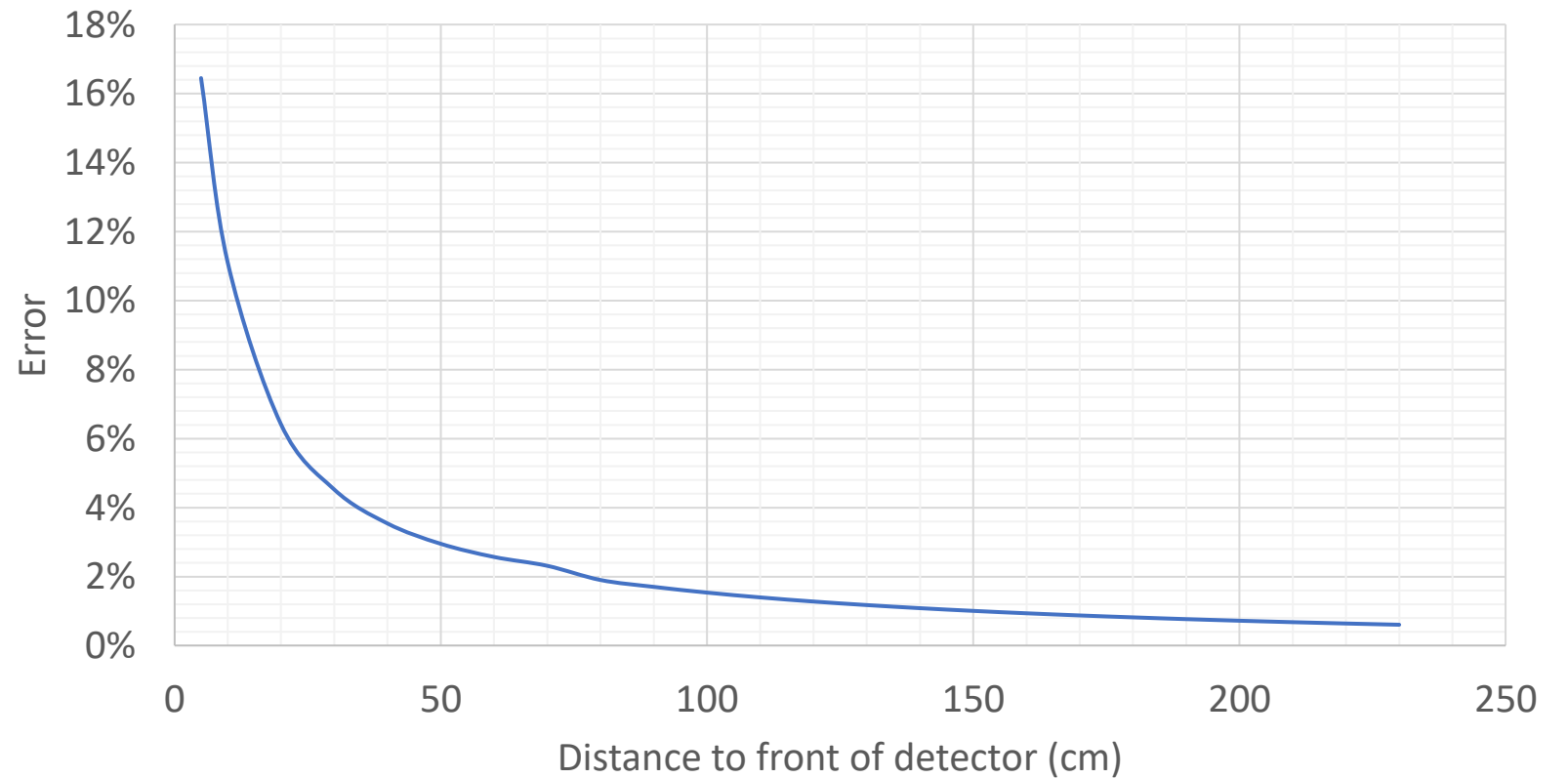


$$\text{Irradiance} \left(\frac{W}{m^2} \right) = \frac{\text{Radiant Intensity} \left(\frac{W}{sr} \right)}{\text{distance}^2 (m^2)}$$

Detector Reference Planes

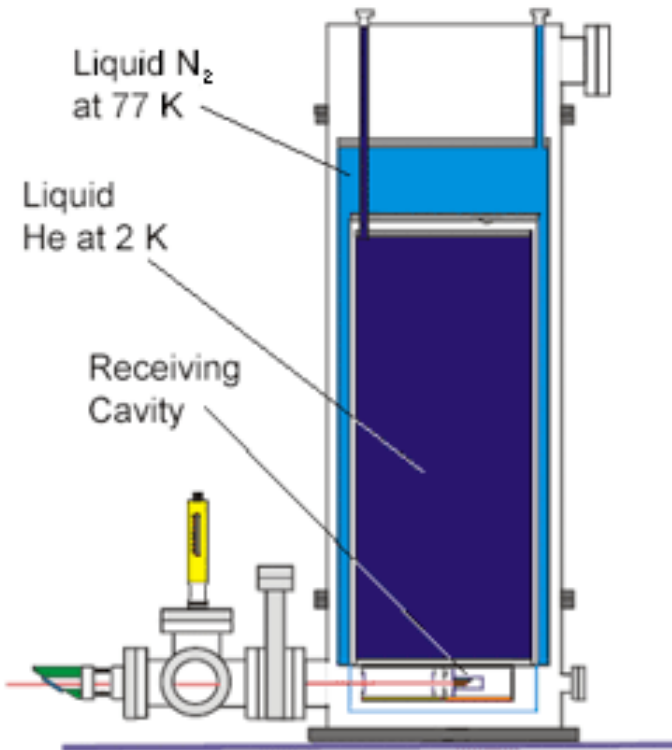


Measurement error with detector reference 0.79cm (0.31") back

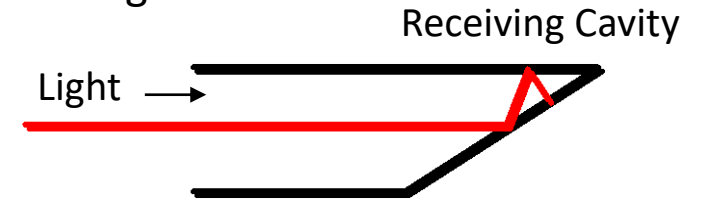


Compliments Holger Clause

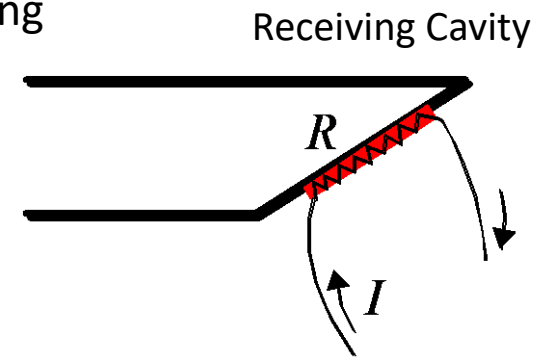
Primary Optical Watt Radiometer (POWR)



Optical Heating



Electrical Heating



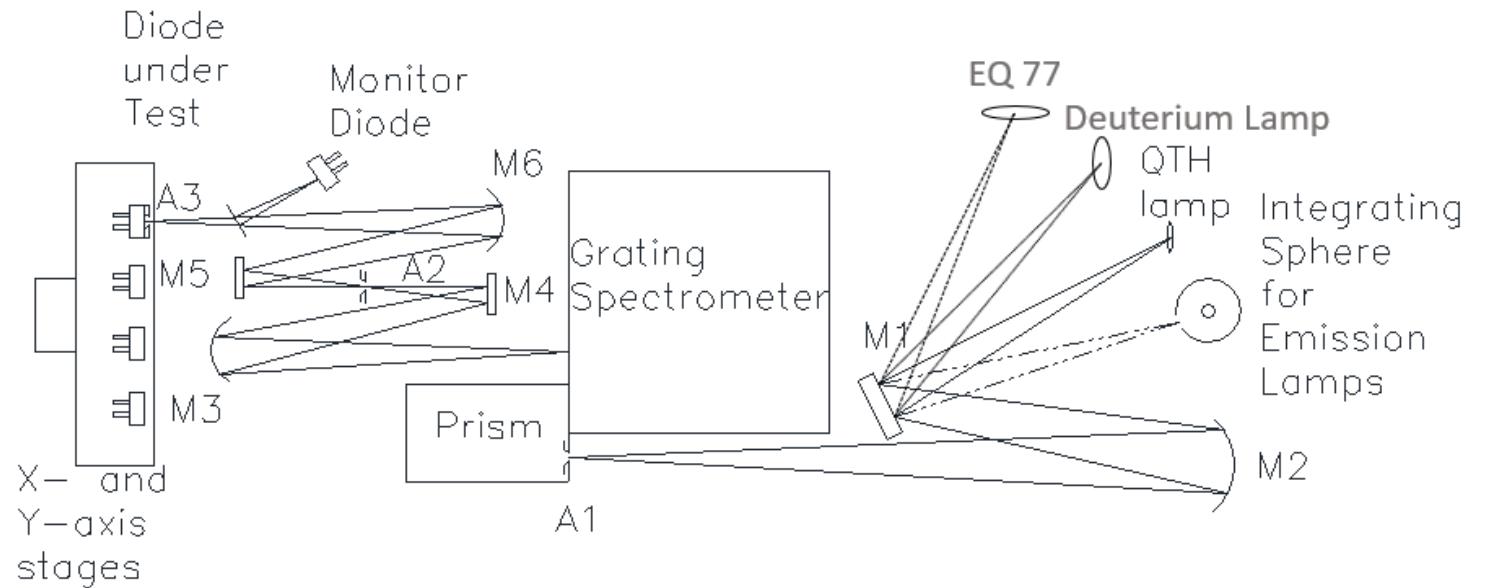
The same ΔT . Thus, $P_0 = P_e = I^2 R$

Therefore, the Optical Watt is measured based on the Electrical Watt.



Ultraviolet Spectral Comparator Facility

- For the Spectral Power Responsivity and Irradiance Calibrations of optical detectors
- Wavelength Range = 200 nm to 1100 nm
- Optimized for the germicidal UV range of 200 nm to 300 nm



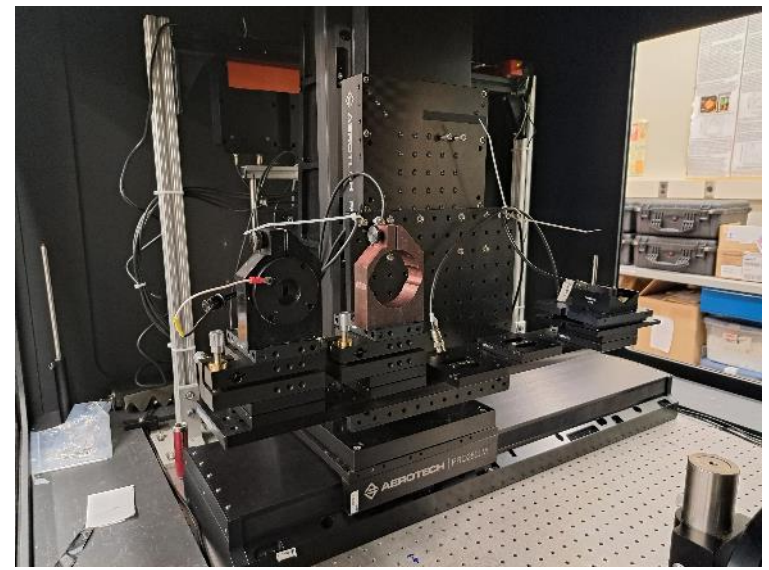
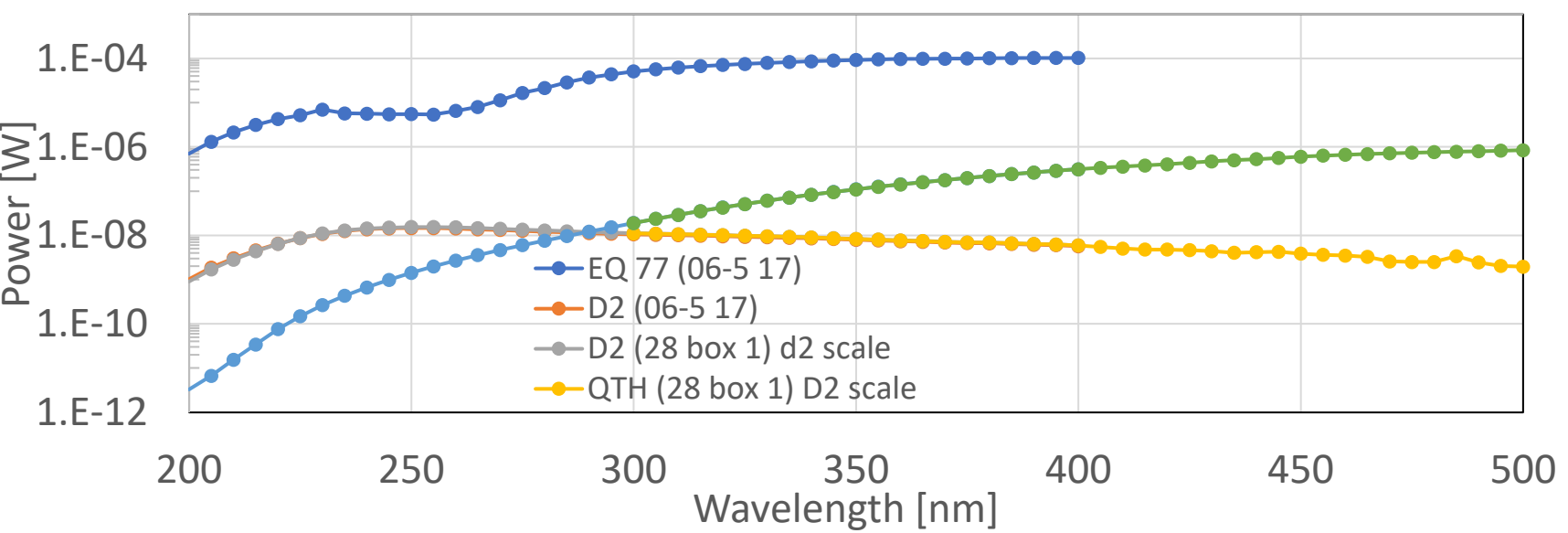
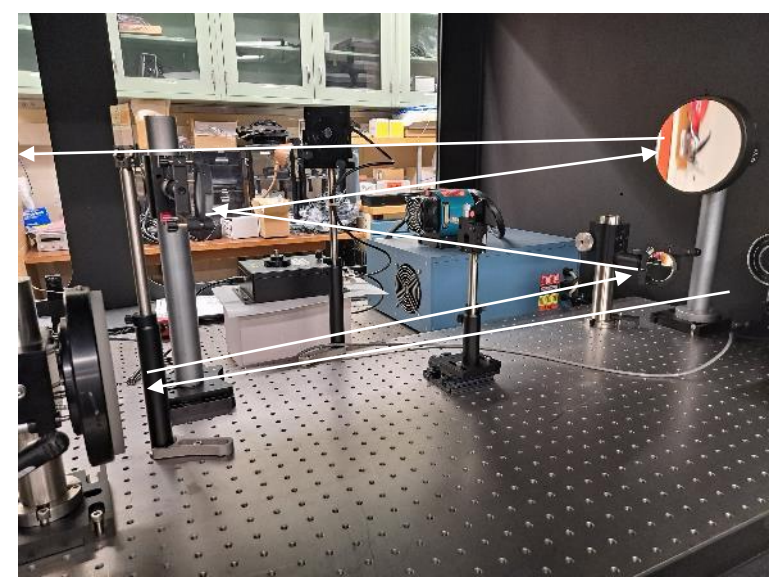
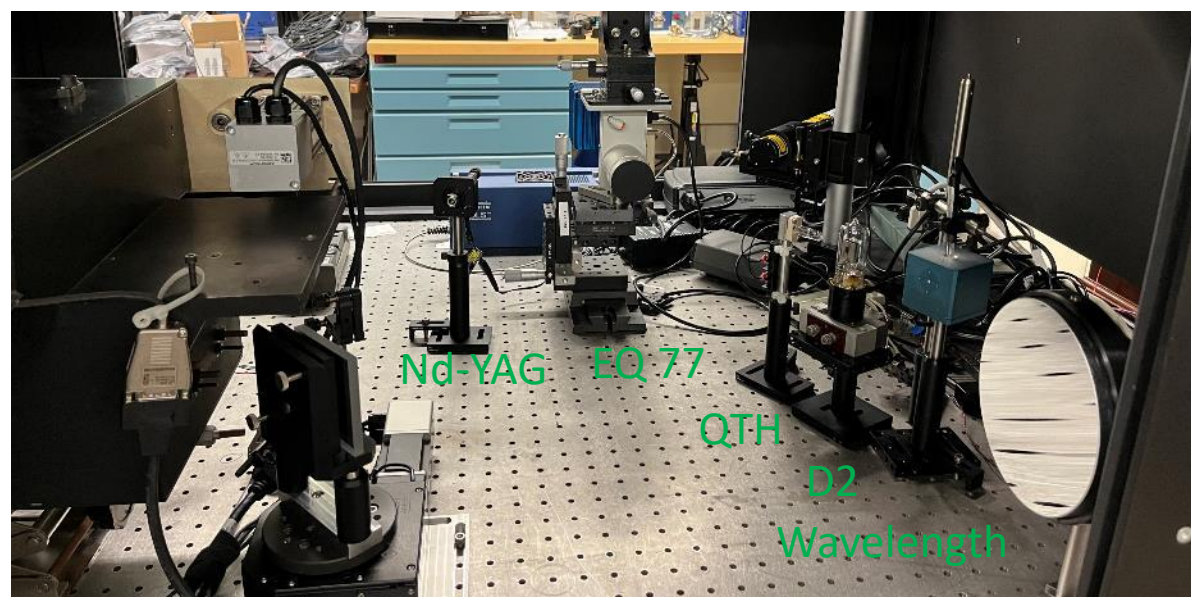
Operational Principles:

- Substitution Method
- 2 beam method

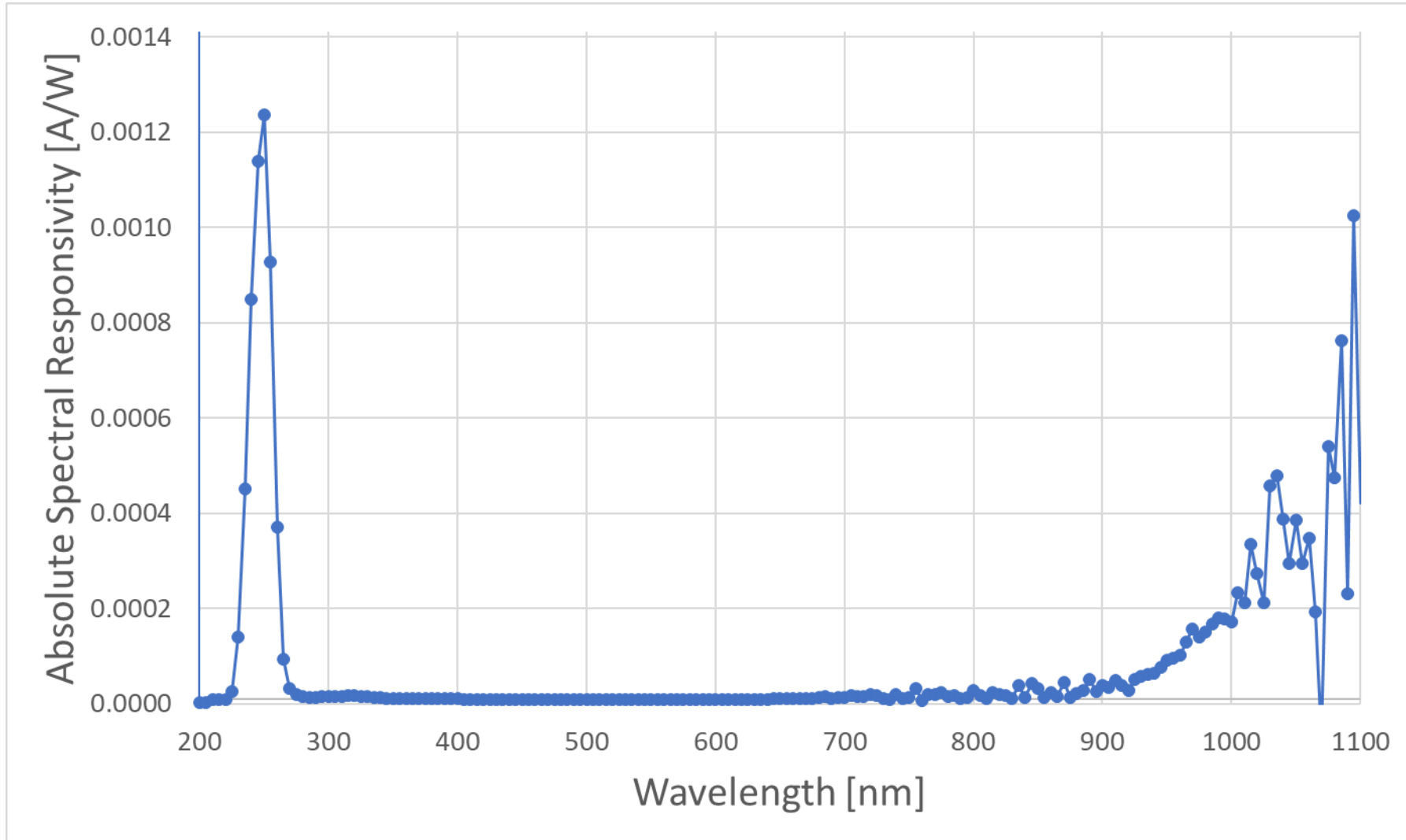
$$S_x = \frac{R_x}{R_s} \cdot S_s = \frac{Y_x / Y_{mx}}{Y_s / Y_{ms}} \cdot S_s = \frac{V_x / V_{mx}}{V_s / V_{ms}} \cdot \frac{G_s}{G_x} \cdot S_s$$



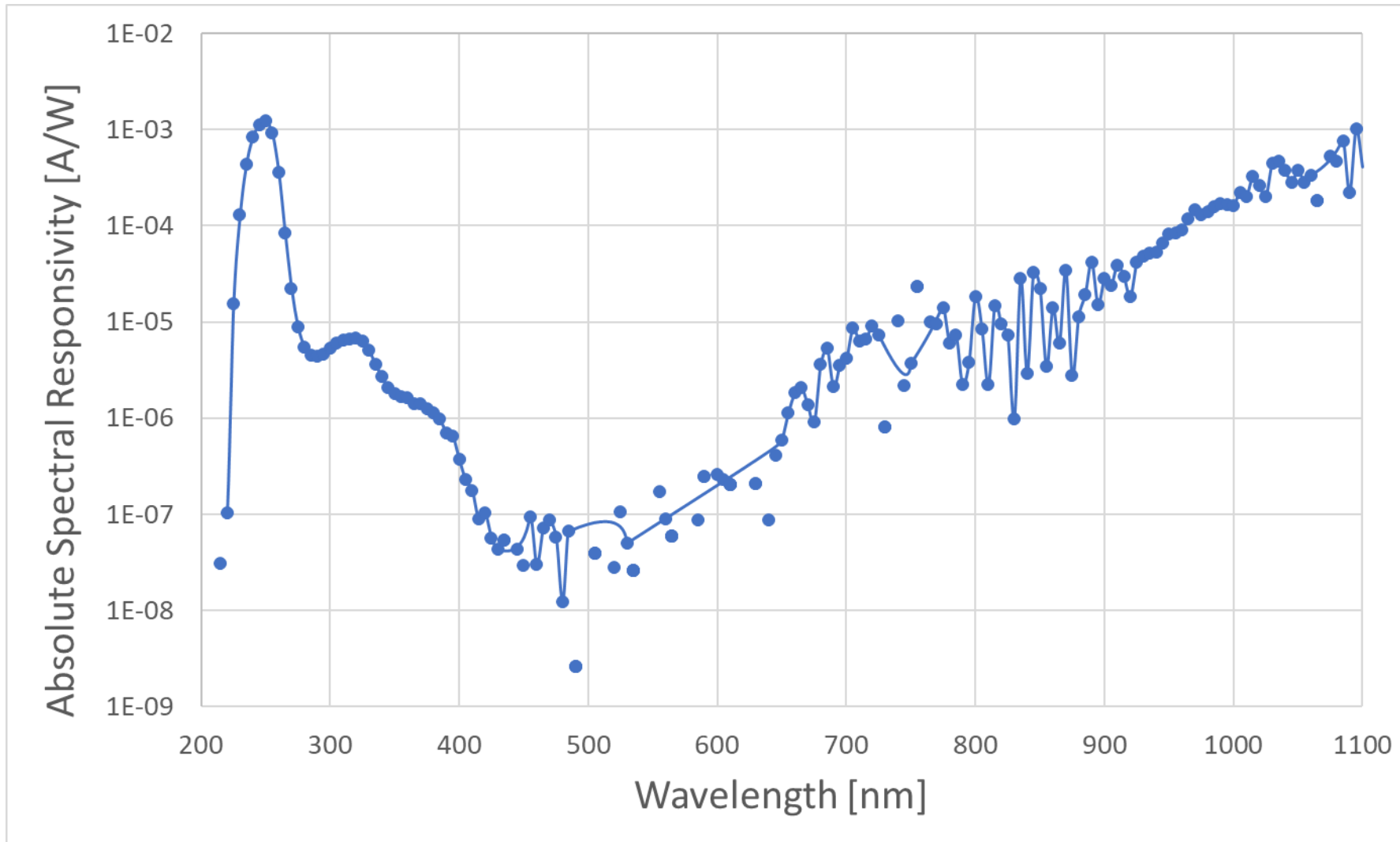
UV-SCF 2nd Generation



254 nm Irradiance Responsivity

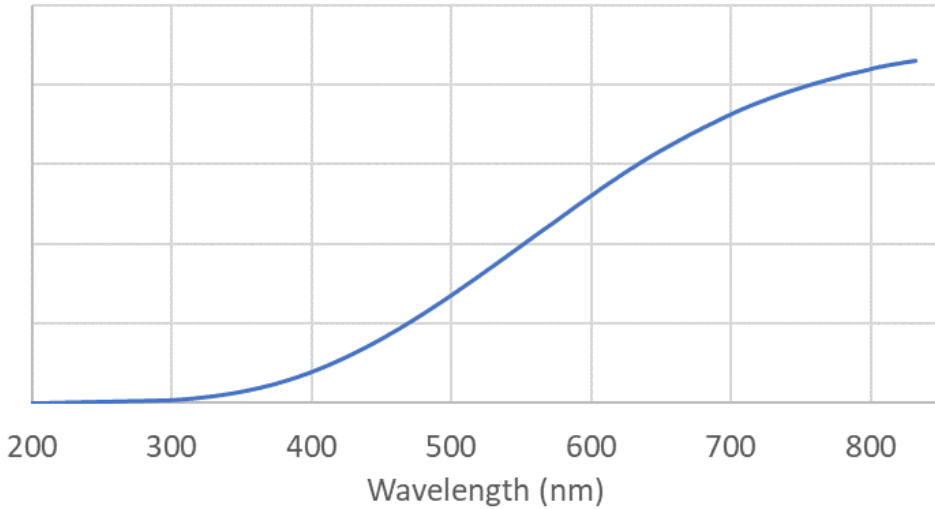


254 nm Irradiance Responsivity - Log



Out of Band Signal

Halogen

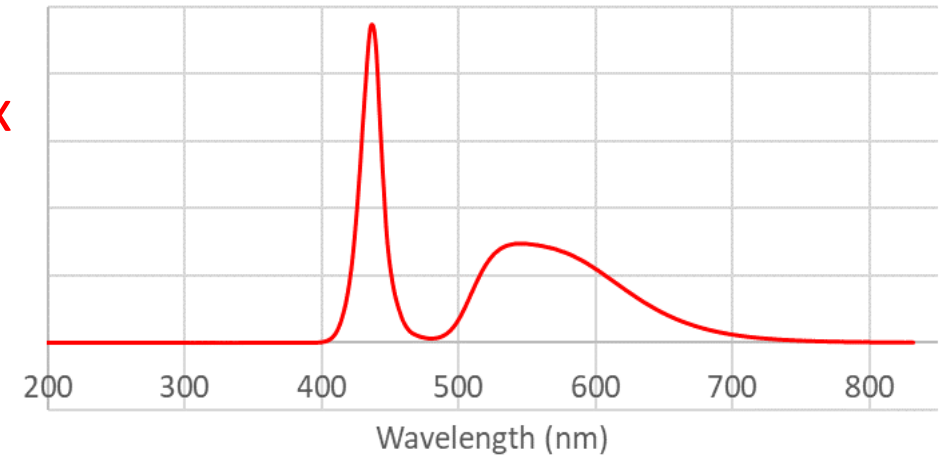


1.73 $\mu\text{W}/\text{cm}^2$
typical room 500 lx

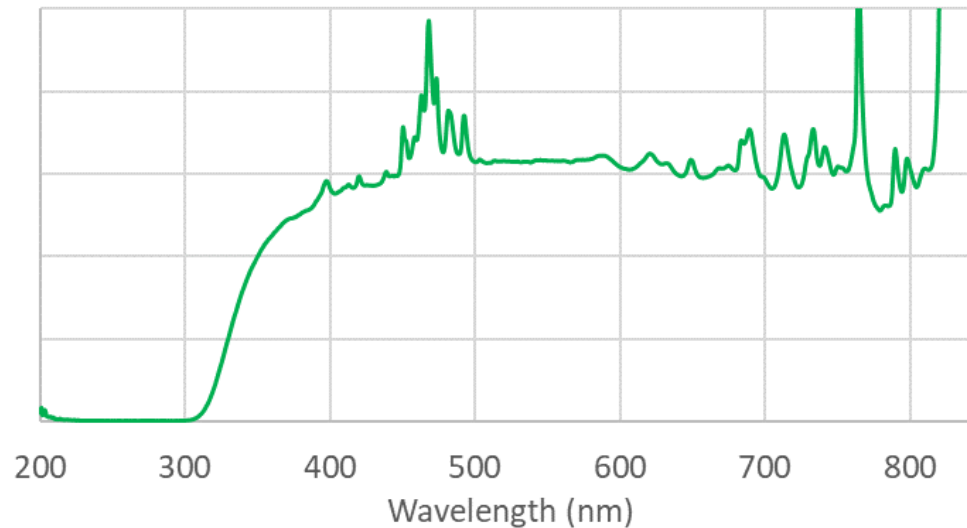
6 mJ/cm^2 over 8 hrs
 $6 \text{ mJ}/\text{cm}^2 / 28800 \text{ s} = 2.1 \mu\text{W}/\text{cm}^2$

White LED

0.0213 $\mu\text{W}/\text{cm}^2$
typical room 500 lx



Xe (glass window)



7.68 $\mu\text{W}/\text{cm}^2$
typical room 3000 lx

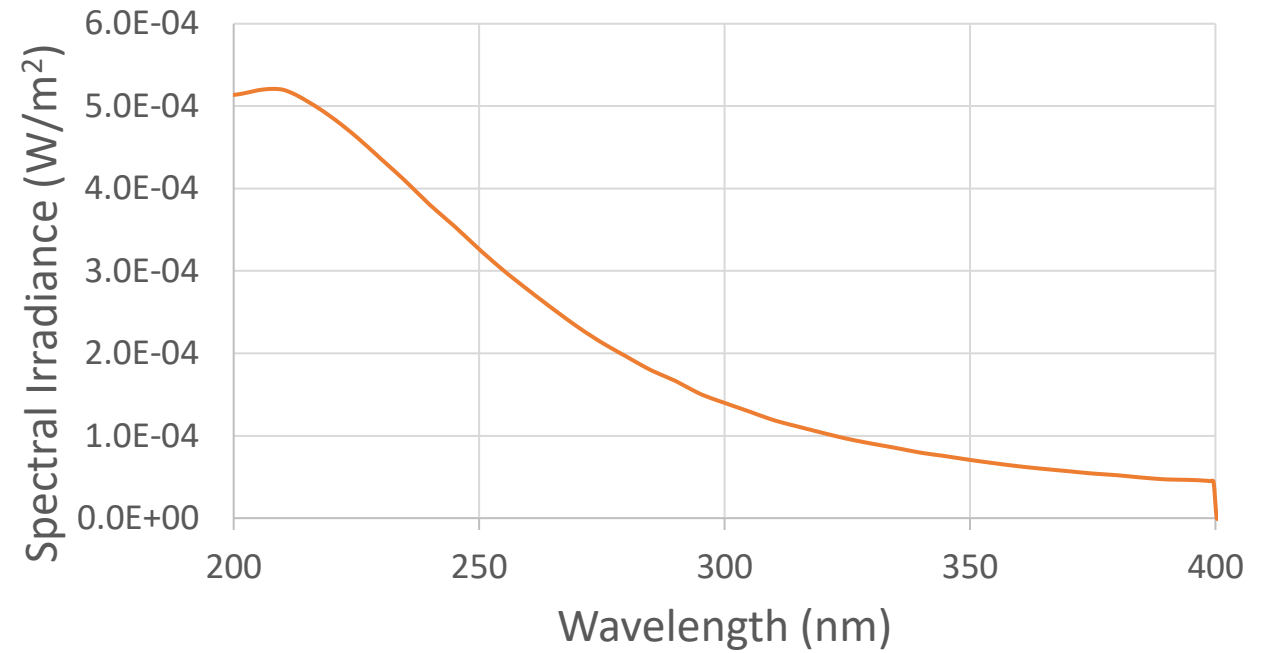
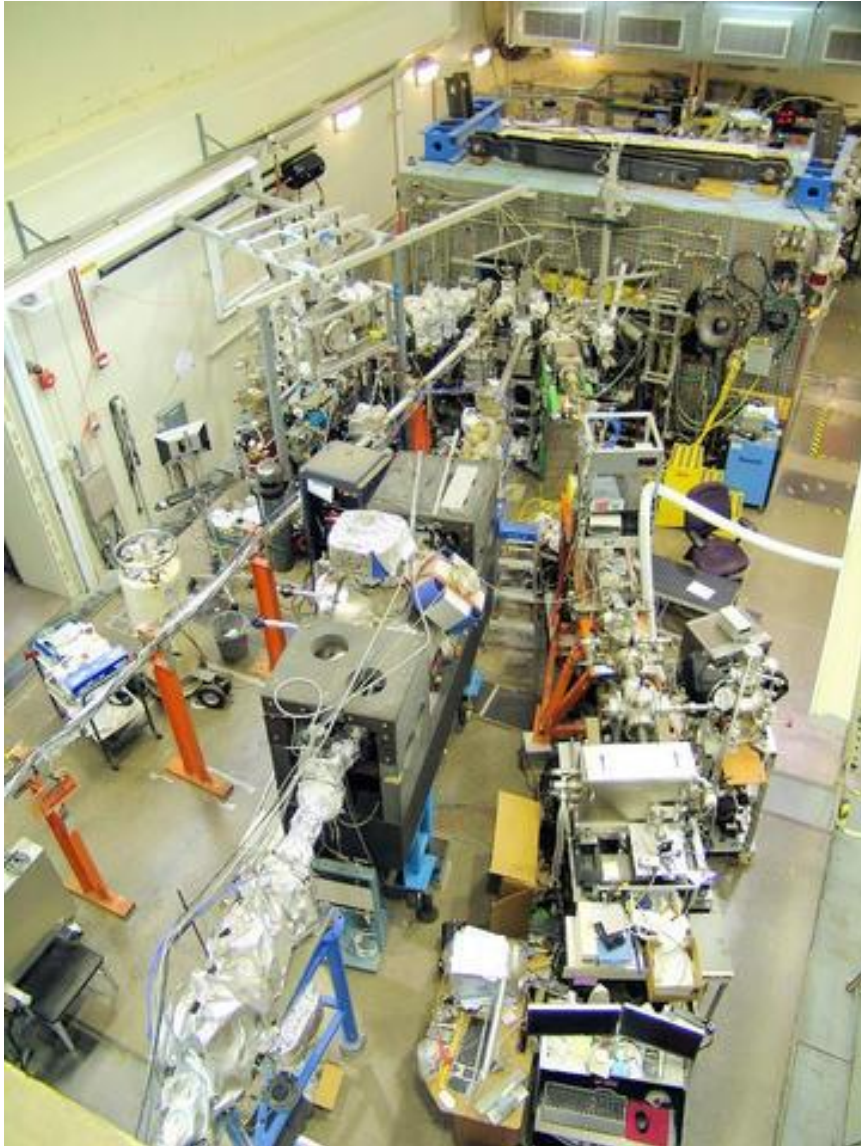
Out-of-band Optical Radiation Sensitivity



222 nm

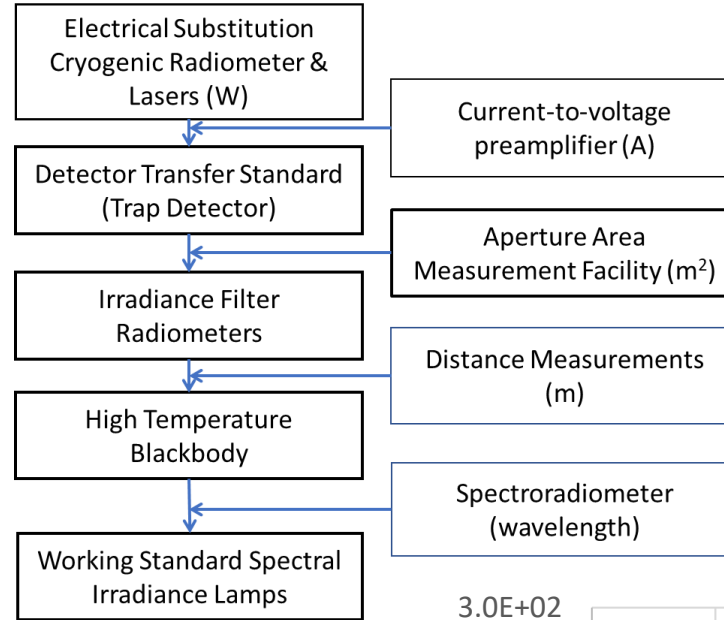
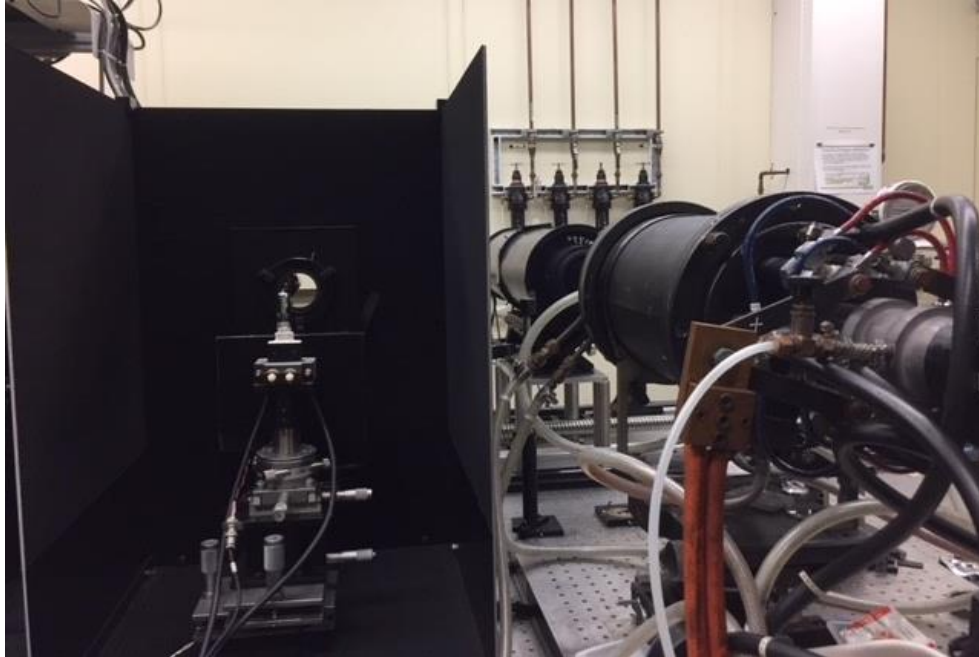
	NIST Scale	Spectro 1 $\mu\text{W}/\text{cm}^2$	Det 1 $\mu\text{W}/\text{cm}^2$	Det 2 $\mu\text{W}/\text{cm}^2$	Det 3 $\mu\text{W}/\text{cm}^2$	Det 4 $\mu\text{W}/\text{cm}^2$
Excimer	51.4 $\mu\text{W}/\text{cm}^2$	51.5	50.6	50.9	48.5	49.4
Quartz Halogen	300 lx, 2856 K	0.0	0.3	4.5	68.1	0.1
Xe/glass	3000 lx, 5690 K	0.0	2.4	388.2	1673.0	0.0
No light	0 lx	0.0	0.0	0.0	0.0	0.0

SURF - Synchrotron Ultraviolet Radiation Facility

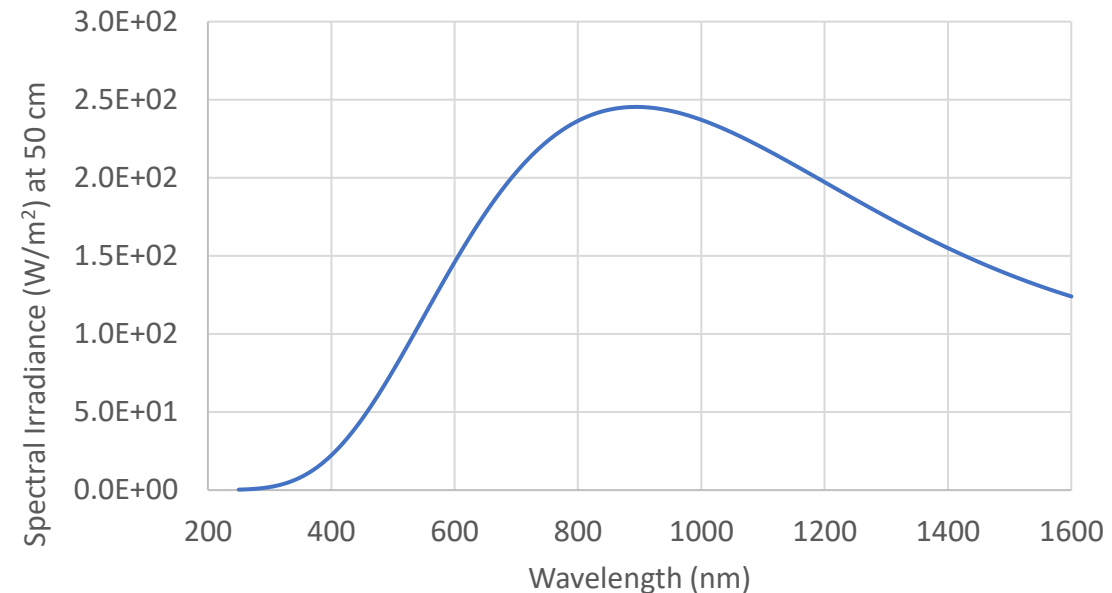


Wavelength (nm)	Expanded Uncertainty ($k=2$) %
200	1.07
250	0.95
300	0.97
350	0.99
400	1.04

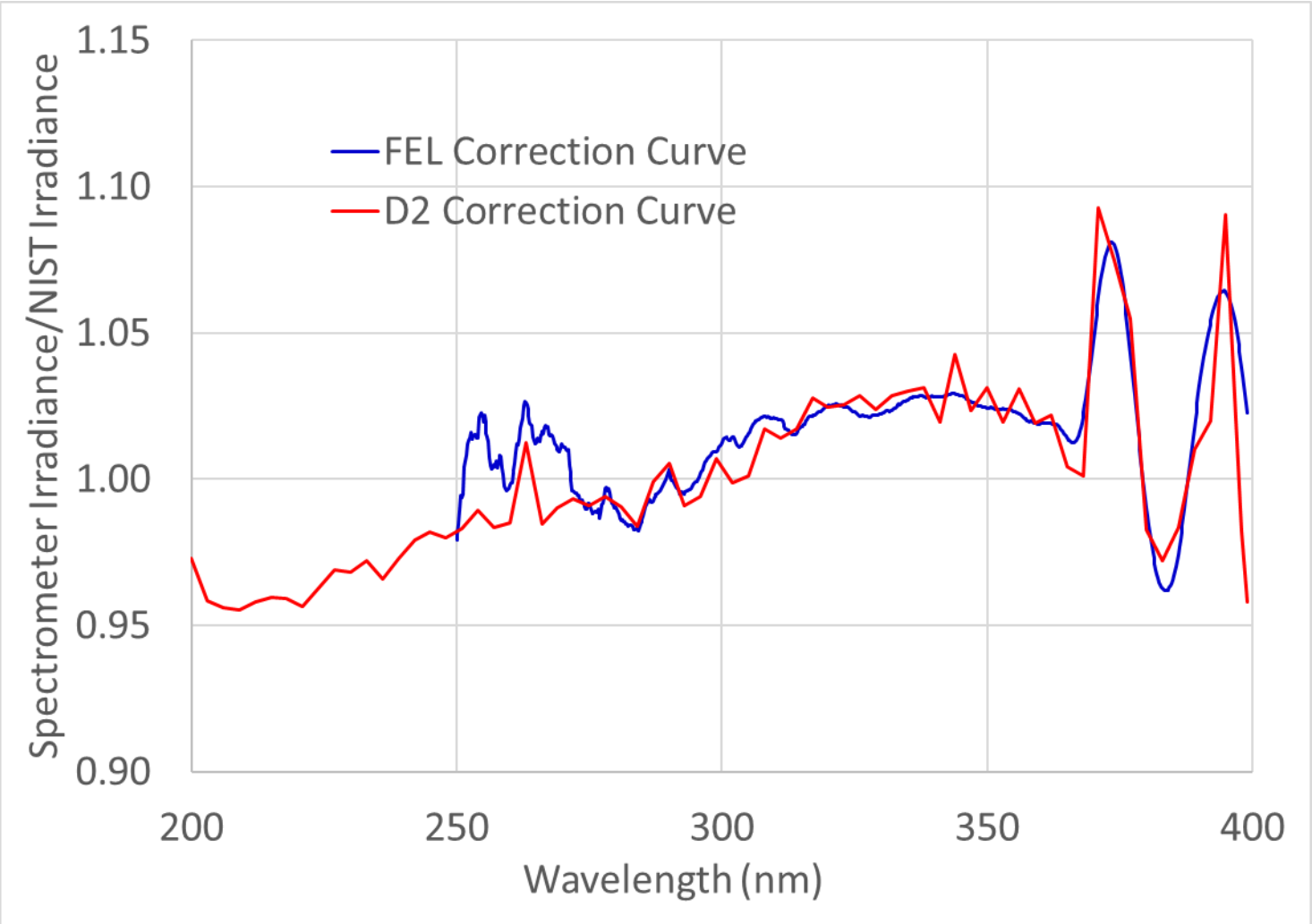
FASCAL II - Facility for spectroradiometric calibrations



Wavelength (nm)	Expanded Uncertainty (k=2) %
250	1.74
350	1.27
450	0.91
555	0.77
900	0.57

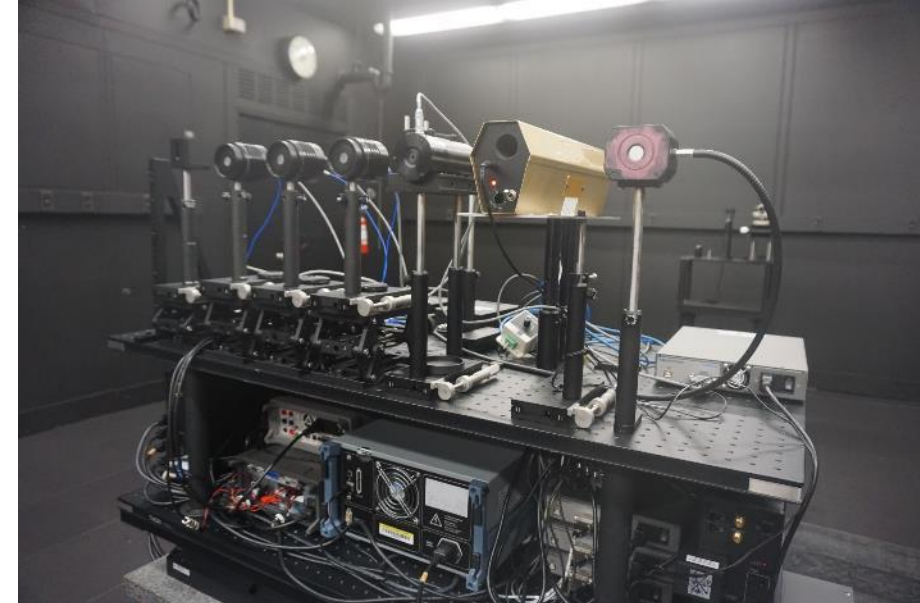
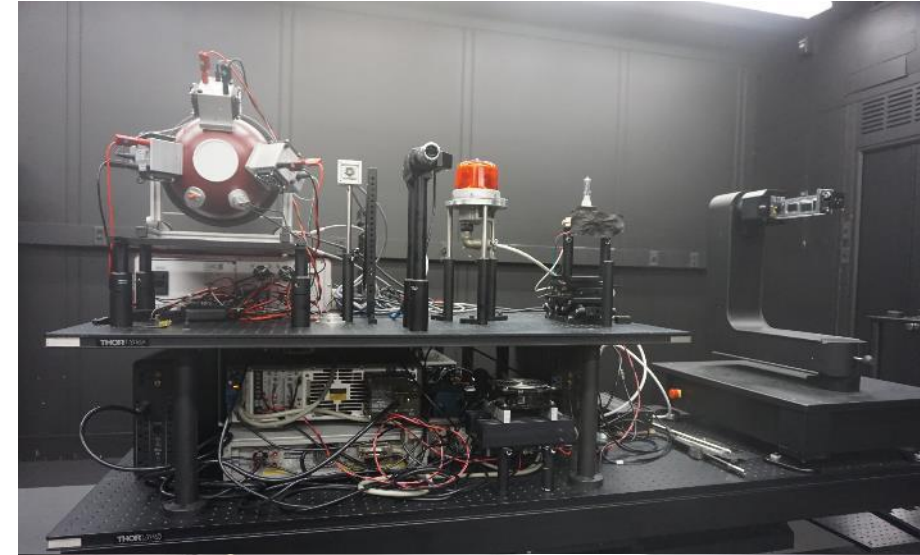


Spectroradiometer Responsivity

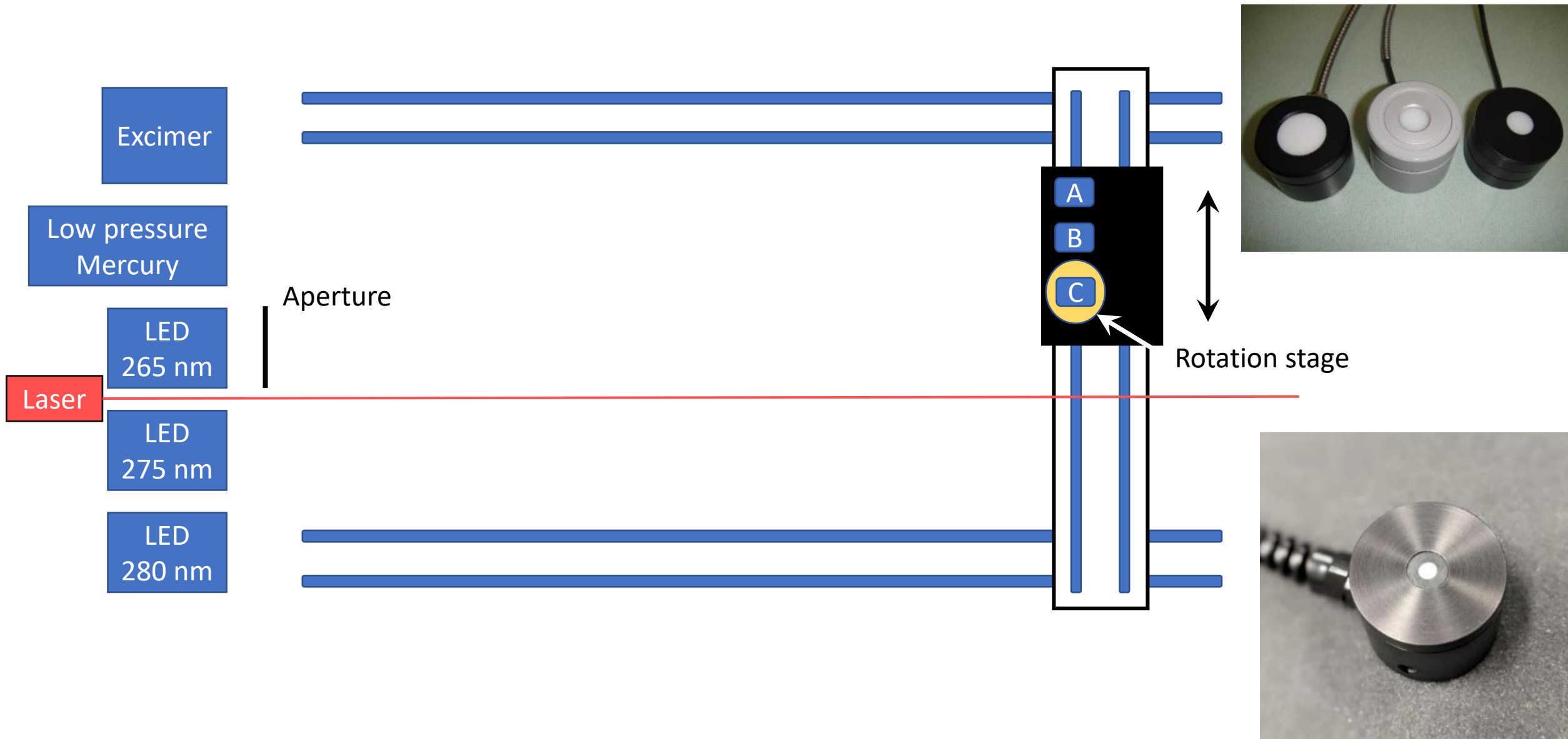


NIST Photometric Bench

NIST



Dedicated GUV Calibration Facility



Thank you,
C. Cameron Miller
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