Radiometric Calibration History of MOBY/NIST Single Channel Dual Mode Radiometers

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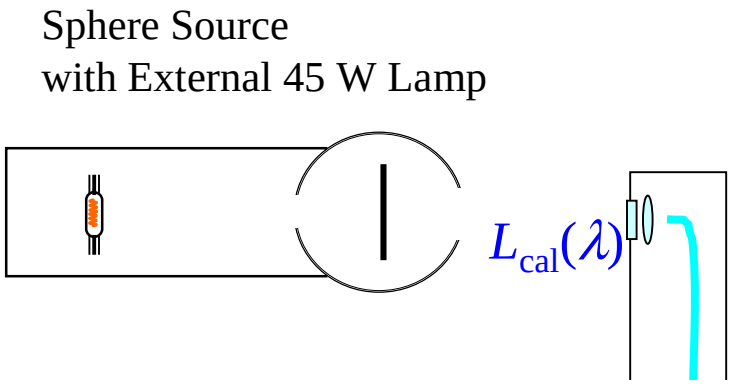
Marine Optical Buoy (MOBY) Project

- NOAA/NESDIS Program
- Methods
  - MOBY deployed off coast of Lanai, Hawaii: 1994—present
  - MOCE cruises
- Goals
  - daily values for L_w in SeaWiFS and MODIS bands—5% (k=1)
  - bio-optical algorithm development
- Field Radiometers
  - MOBY & MOS (Marine Optical Spectrograph)
  - Various commercial radiometers for in-water and at surface measurements (filter radiometers and grating instruments)

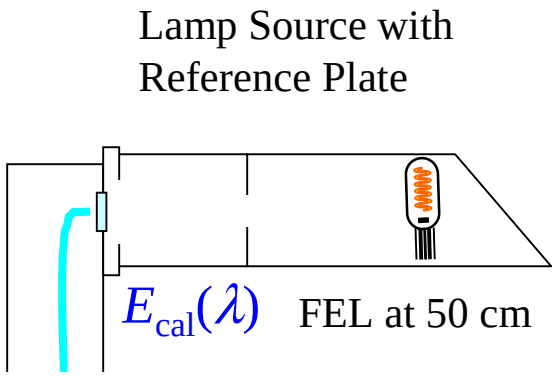
L_u Calibrations of MOBY and MOS

- Measurement Protocol
  - Integrating sphere source(s)
  - Calibrated by commercial standards laboratory (~2.5% at $k = 1$)
  - Re-lamped every 50 h
  - Calibrated twice—at the beginning and end of the 50 h
  - Lamp current and voltage recorded
  - Used before and after field deployments



Schematic of Radiance Input on buoy arm (window, lens, and fiber optic)

E_s & E_d Calibrations of MOBY and MOS



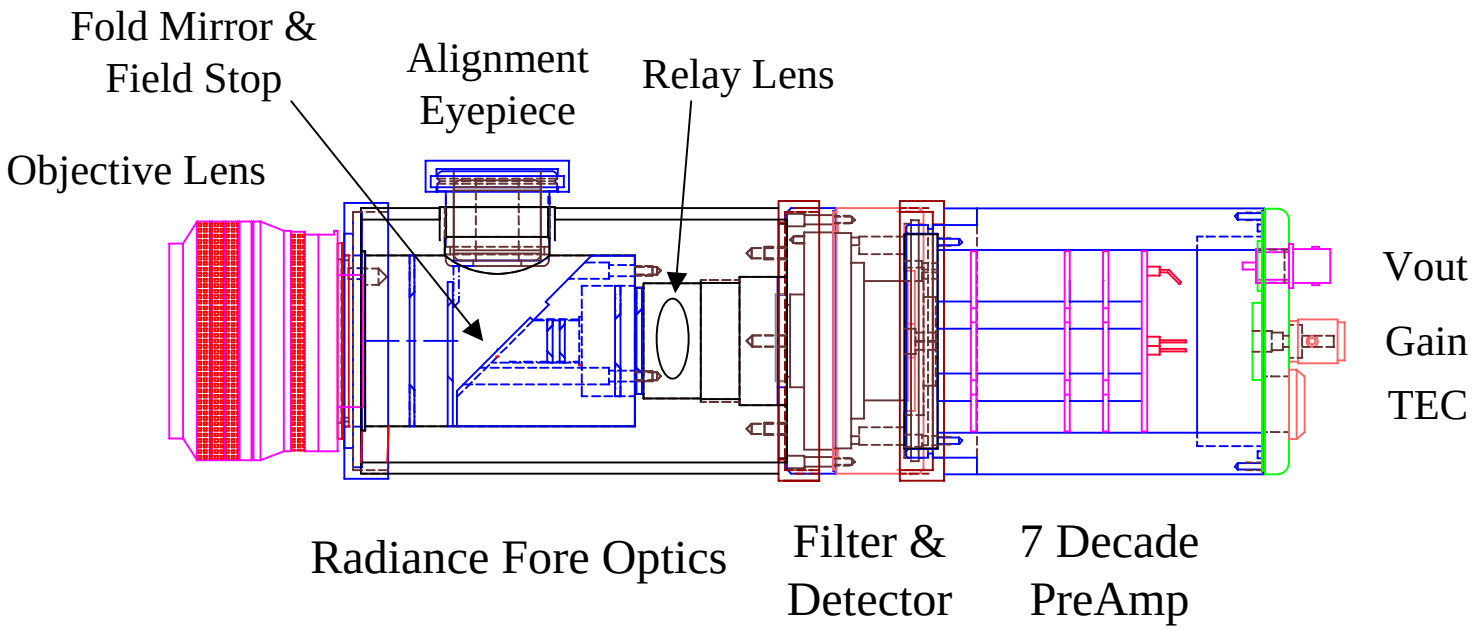
Schematic of
Irradiance Input
on buoy arm
(diffuser and fiber optic)

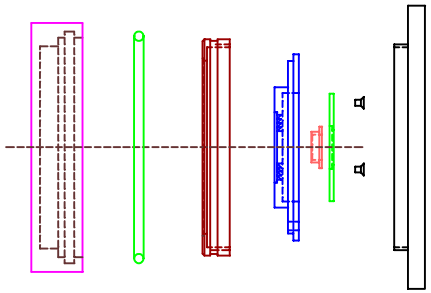
- Measurement Protocol
  - 1000 W lamp standards of spectral irradiance (M/N FEL)
  - Calibrated by NIST (~ 0.3% at $k = 1$)
  - Recalibrated every 50 h
  - Lamp current and voltage recorded during radiometer calibrations
  - Used before and after field deployments

Verification of $L_{cal}(\lambda)$ and $E_{cal}(\lambda)$

- NIST response—Transfer Radiometers
  - Standard Lamp Monitors (SLMs)
    - Dual Mode (Irradiance and Radiance)
    - Interchange Fore Optics for *E* and *L* modes
    - Single Channel using Interference Filters (412 nm & 870 nm)
    - Temperature-controlled filter and detector
    - 7 decade custom preamp
    - Rugged design
- Recalibrated at NIST to ensure accuracy & verify stability of SLMs
- Used in Comparisons at Snug Harbor with SXR and VXR (six channel filter radiometers from NIST for SeaWiFS and EOS)

SLM Design

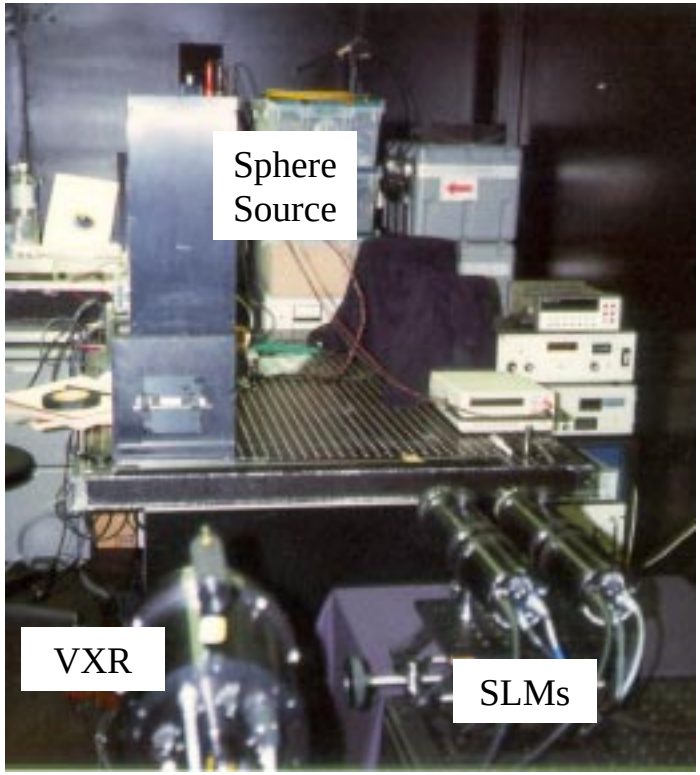




Irradiance Fore Optics
(Exploded View)

SLM Specifications

Calibration Hut, Honolulu

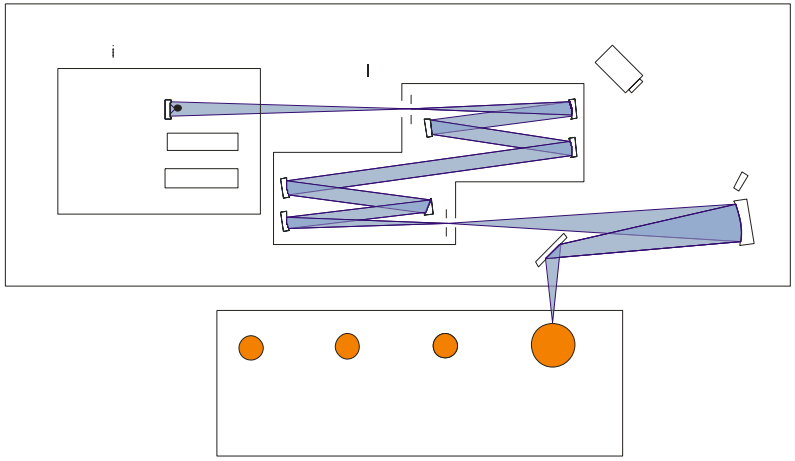


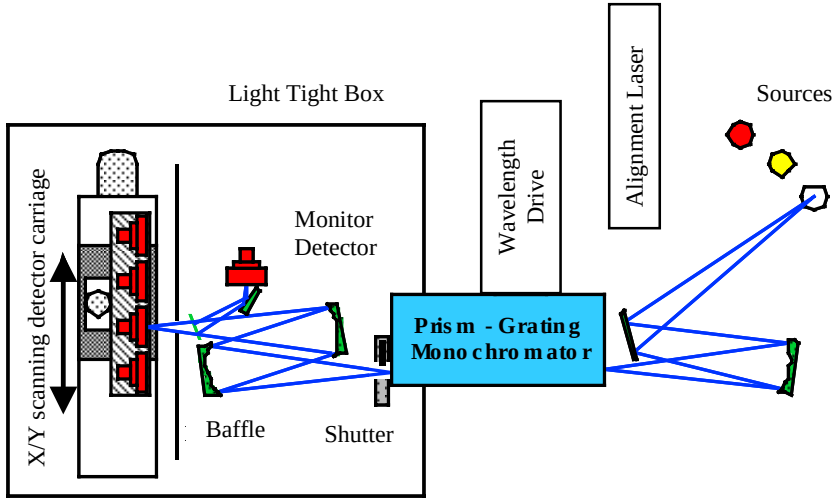
- Wavelength
  - 412 nm and 870 nm
  - 10 nm bandpass
- Field-of-View
  - 5° (radiance)
  - hemisphere (irradiance)
- Temperature-stabilized
  - 28 °C
- Uncertainty & Stability
  - 1.5% or better (k = 1)

Characterization and Calibration at NIST

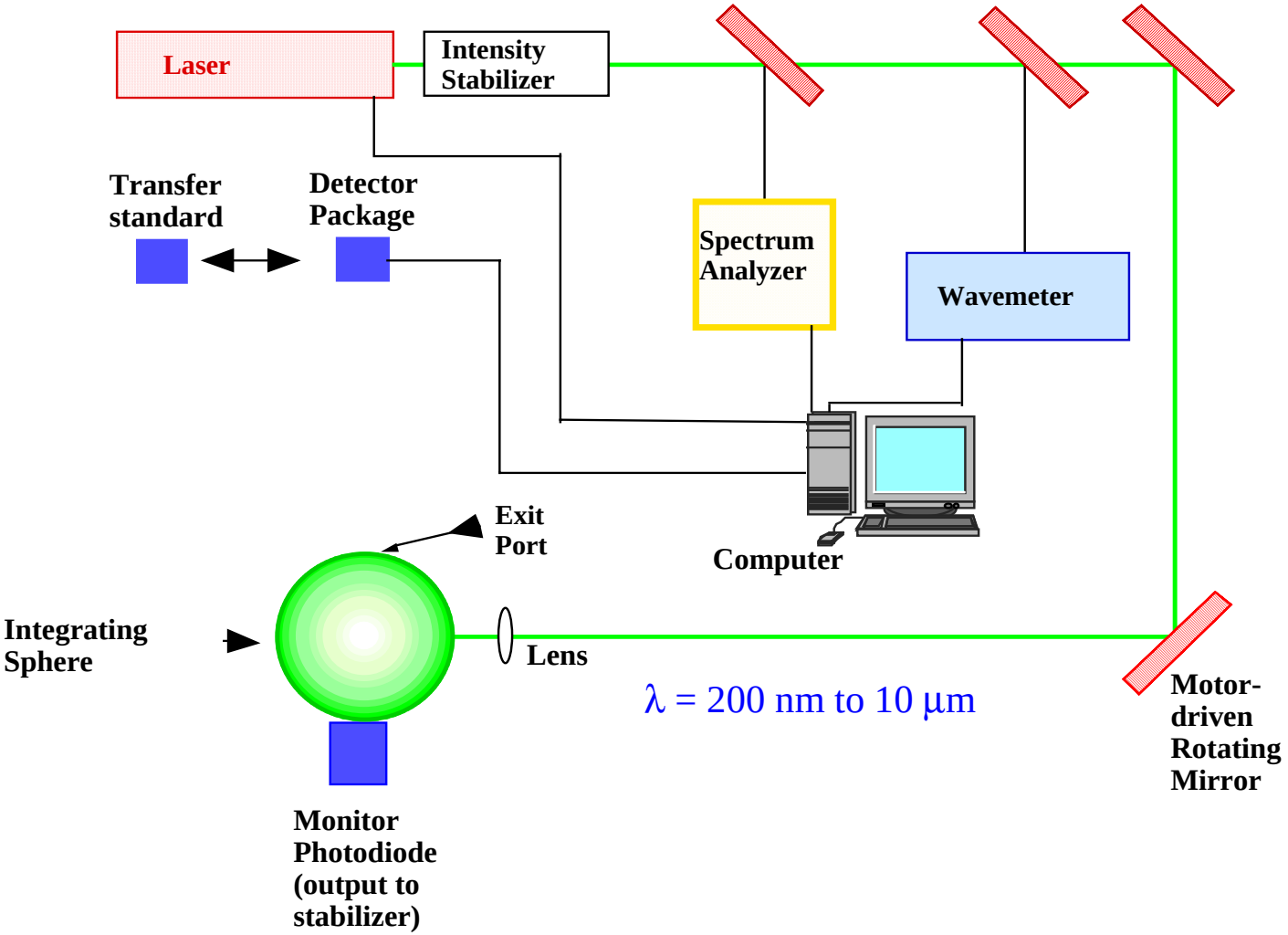
- Characterizations Performed:
  - Electronics
    - Gain factors
  - Spatial
    - Cosine response
    - Point spread
  - Stability
    - Interchange foreoptics
    - Repeat absolute calibrations
  - Spectral
    - Relative (Vis/SCF)
    - Absolute (SIRCUS)
- Calibrations Performed:
  - Radiance Mode
    - NIST-calibrated sphere sources (1996 to 2000)
    - SIRCUS Facility (2000)
  - Irradiance Mode
    - NIST FELs (1996 to 2000)
    - SIRCUS Facility (2000)

Calibration with Broadband Sources





Calibration with Tunable Laser Sources



Contrast Methods

- Broadband Source
  - Requires multiple steps
  - Difficult to fill optics
  - Poor S/N ratios
  - 0.1 nm wavelength accuracy

Calibration Coefficient

$$D_b = \frac{S}{\frac{\int r(\lambda) L_{\mathrm{NIST}}(\lambda)\, d\lambda}{\int r(\lambda)\, d\lambda}}$$

$r(\lambda)$ = relative spectral responsivity

S = net signal

$L_{\mathrm{NIST}}(\lambda)$ = source radiance (or irradiance)

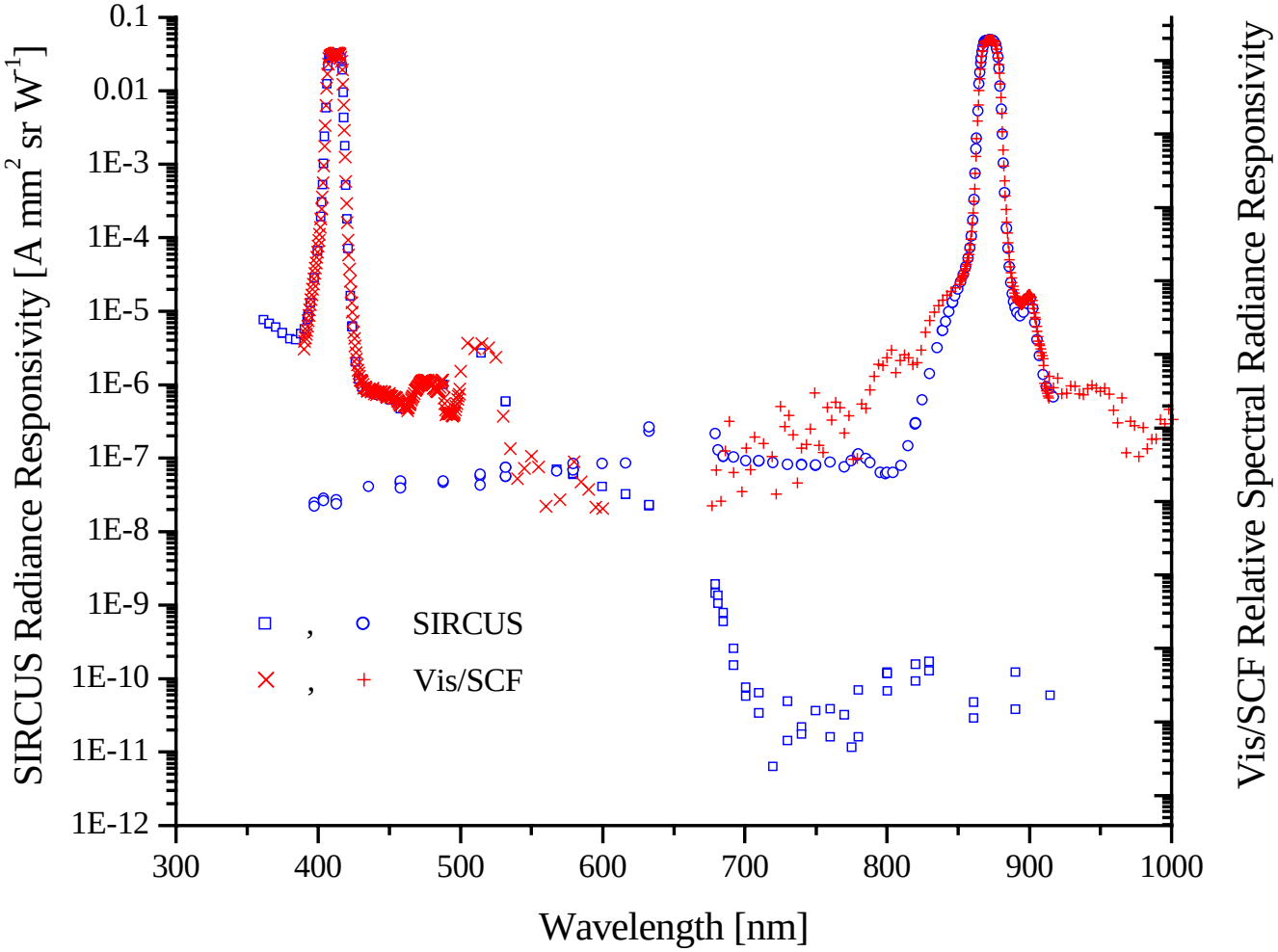
- Narrowband Source
  - Single step
  - Extended or point source
  - Good S/N ratios
  - Superb wavelength accuracy
  - Residual coherence and fluorescence issues

Calibration Coefficient

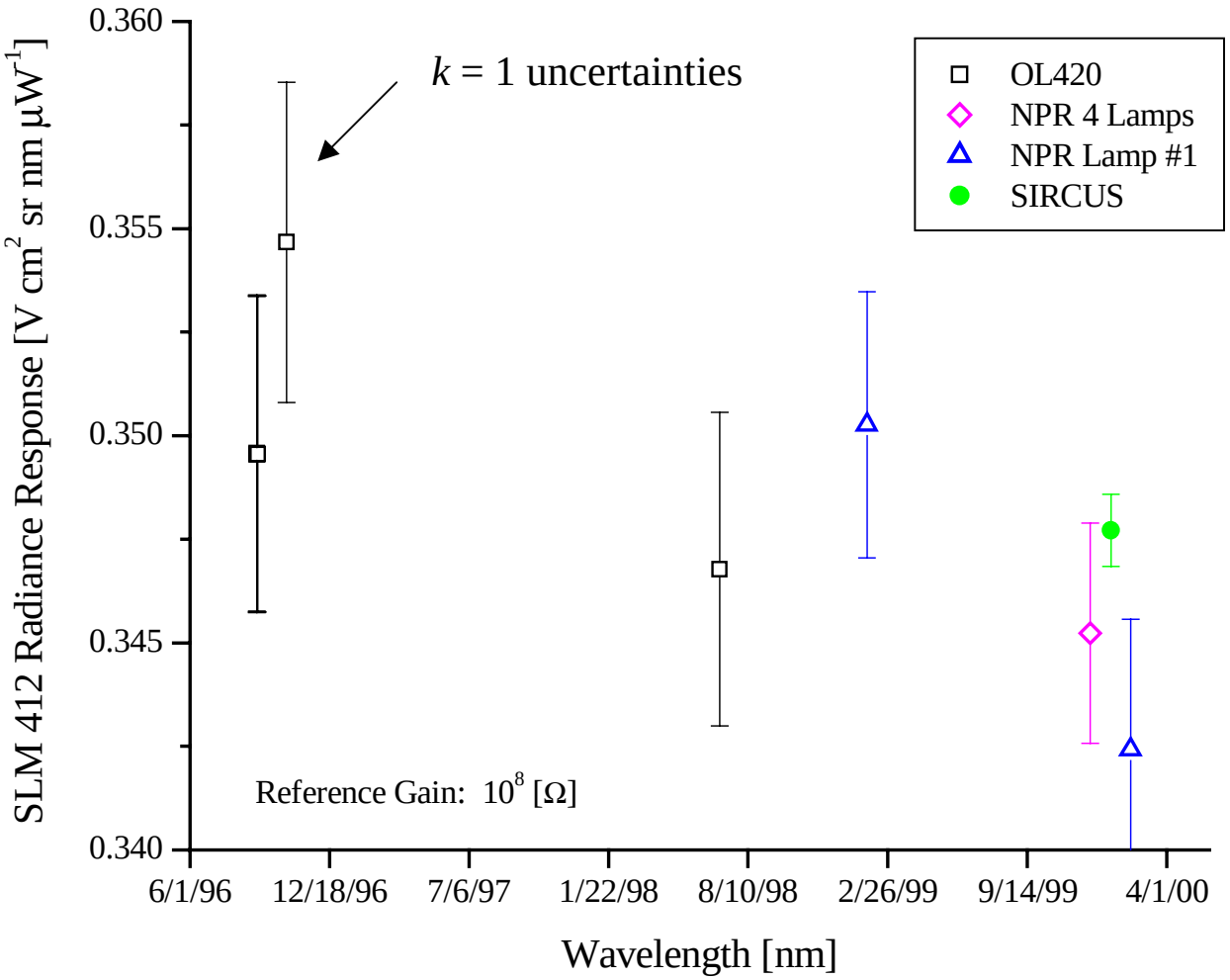
$$D_d = \int R(\lambda)\, d\lambda$$

$R(\lambda)$ = absolute spectral responsivity

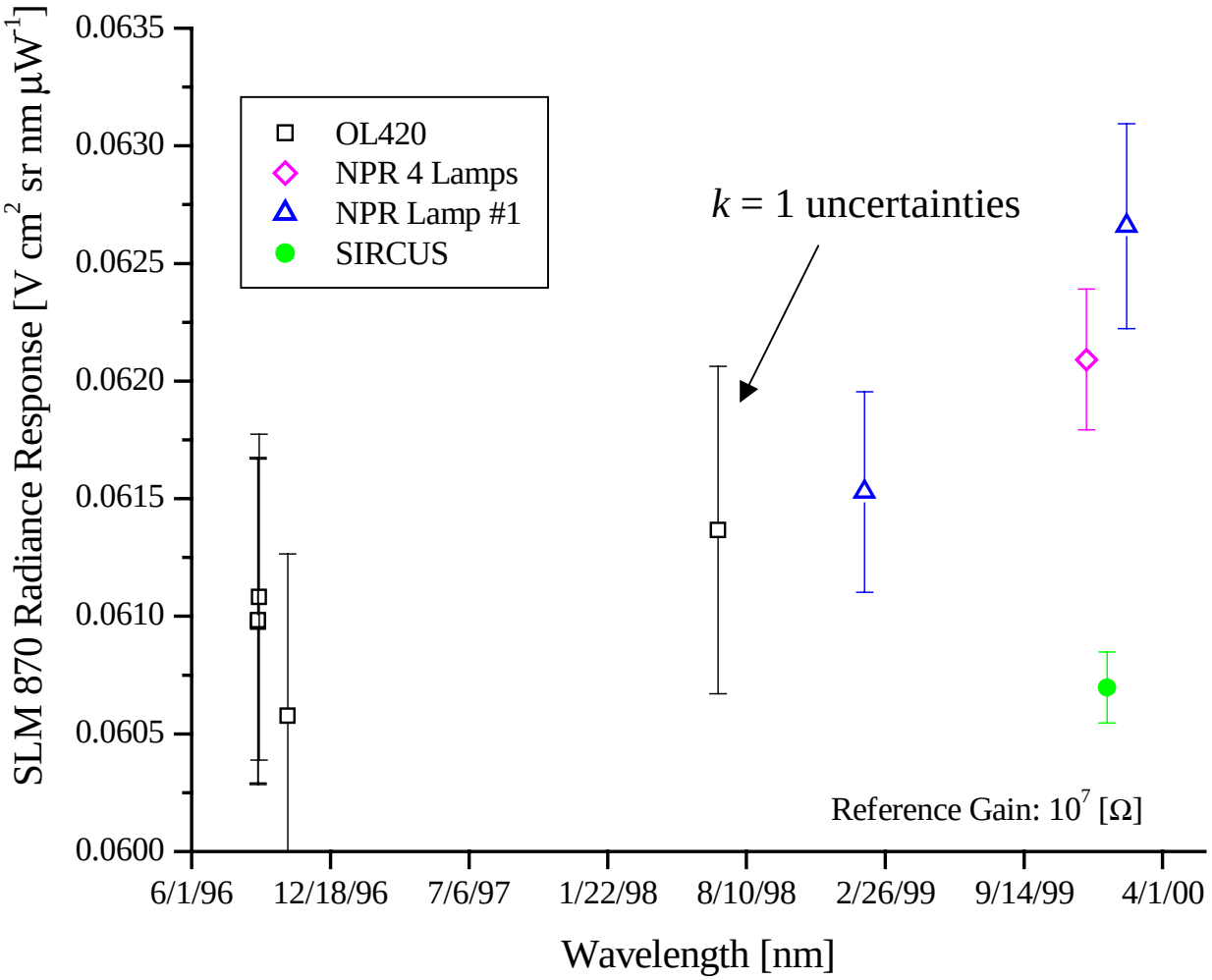
Spectral Response—Radiance Mode



History of SLM 412, Radiance Mode



History of SLM 870, Radiance Mode



Conclusions—SLMs for MOBY/MOS

- Traceability to NIST
- Continuous Monitoring of Standard Sources
- Verification of FEL-derived radiance scales from commercial standards laboratories
- Estimated uncertainties, broadband source calibration method—1.2% (k = 1)
- Estimated uncertainties, SIRCUS—0.25% (k = 1)
- Methods agree within the standard uncertainties
  - 0.4% at 412 nm
  - 0.9% at 870 nm