Spectroradiometric calibration using the Goddard Laser for Absolute Measurement of Radiance

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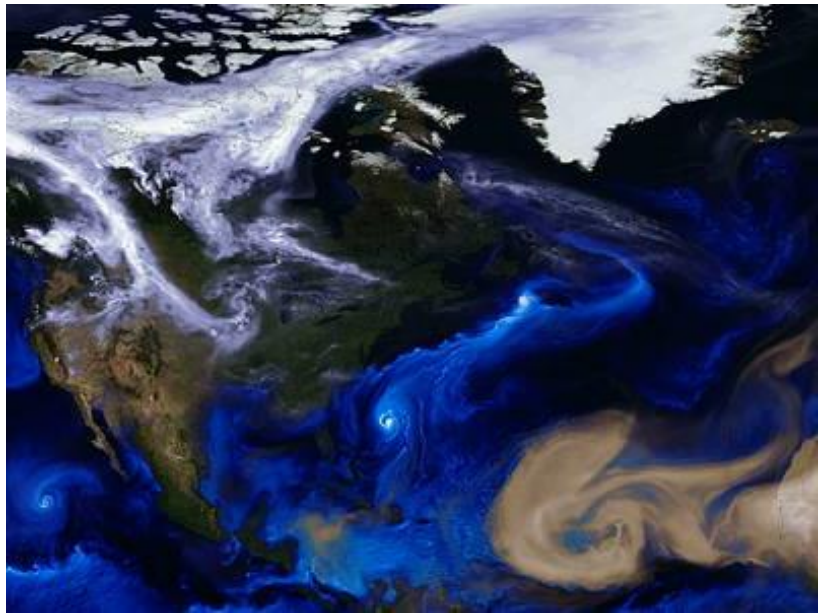
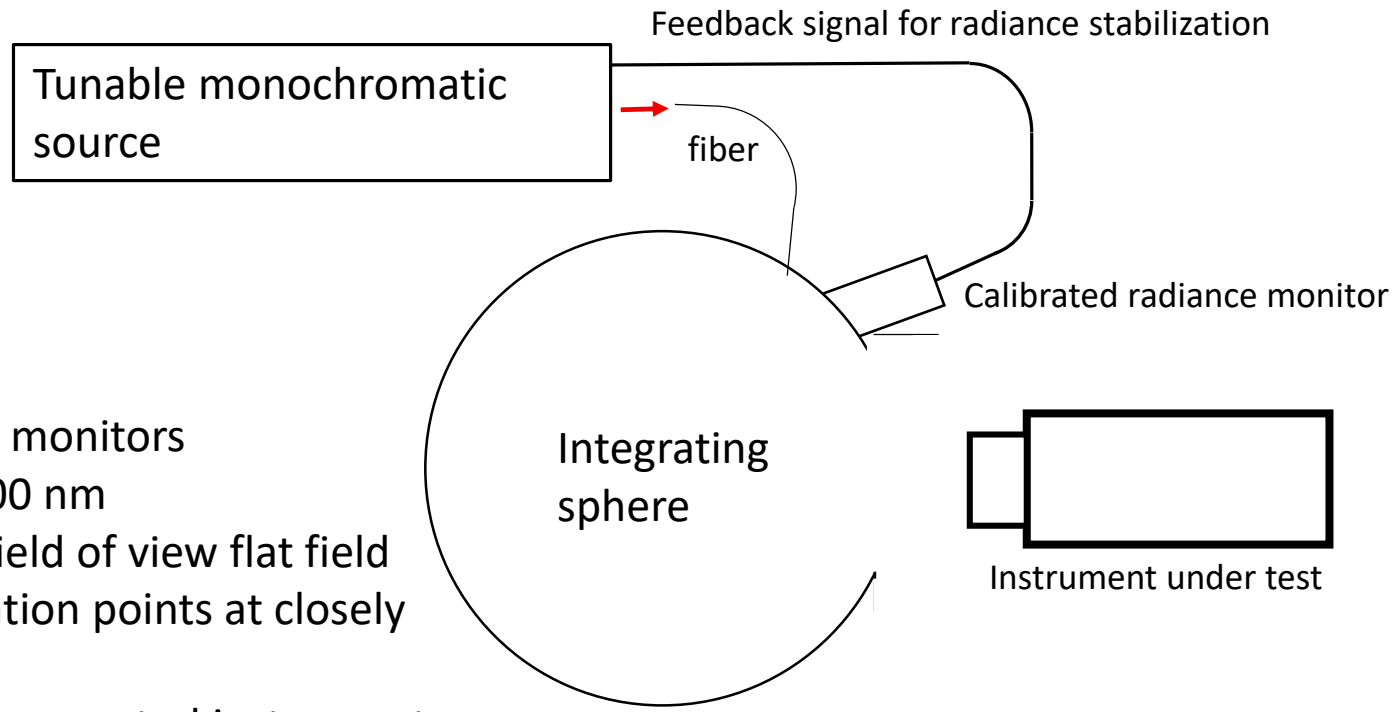
GLAMR

Goddard Laser for Absolute Measurement of Radiance



Detector based absolute radiometric calibration using tunable monochromatic light



- Temperature stabilized, unfiltered sphere radiance monitors
- Widely tunable monochromatic source, 340 to 2500 nm
- Large integrating sphere for full aperture and full field of view flat field
- Steps through spectral range and generates calibration points at closely spaced wavelength increments
- Used for calibration of earth science and other hyperspectral instruments

Calibration with monochromatic versus broadband light

Monochromatic source

$\Delta\lambda$ small compared to variations in radiometer responsivity R(λ) and spectral resolution of instrument under test

At every λ, radiance *L* is found from the signal *S* and responsivity *R(λ)* as

$$L = {}^{S}/_{R(\lambda)}$$

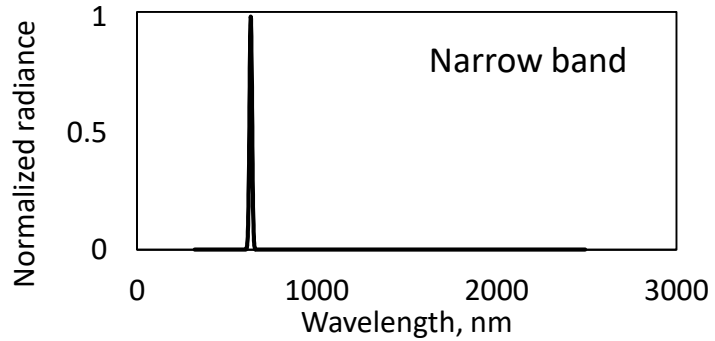
Broadband source

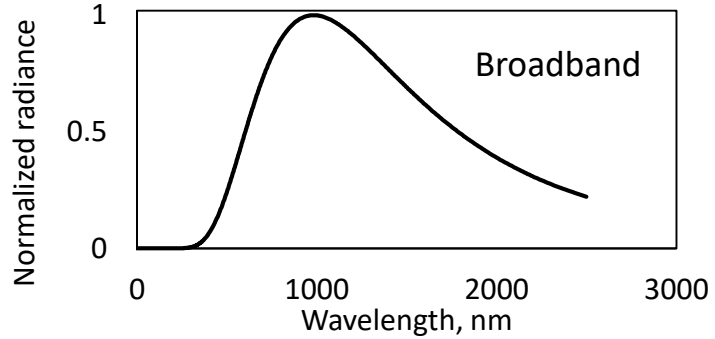
Requires knowledge of the spectrum over the response range of the radiometer and instrument under test, where the normalized spectral radiance ℓ_λ can be defined such that

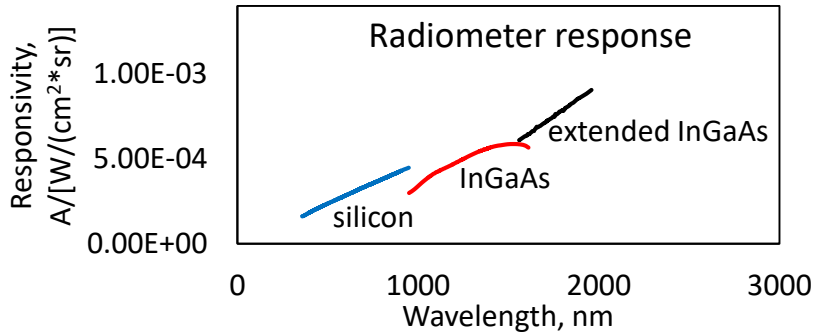
$$\int_{\lambda_1}^{\lambda_2} \ell_\lambda d\lambda = 1.$$

Radiance is then found as

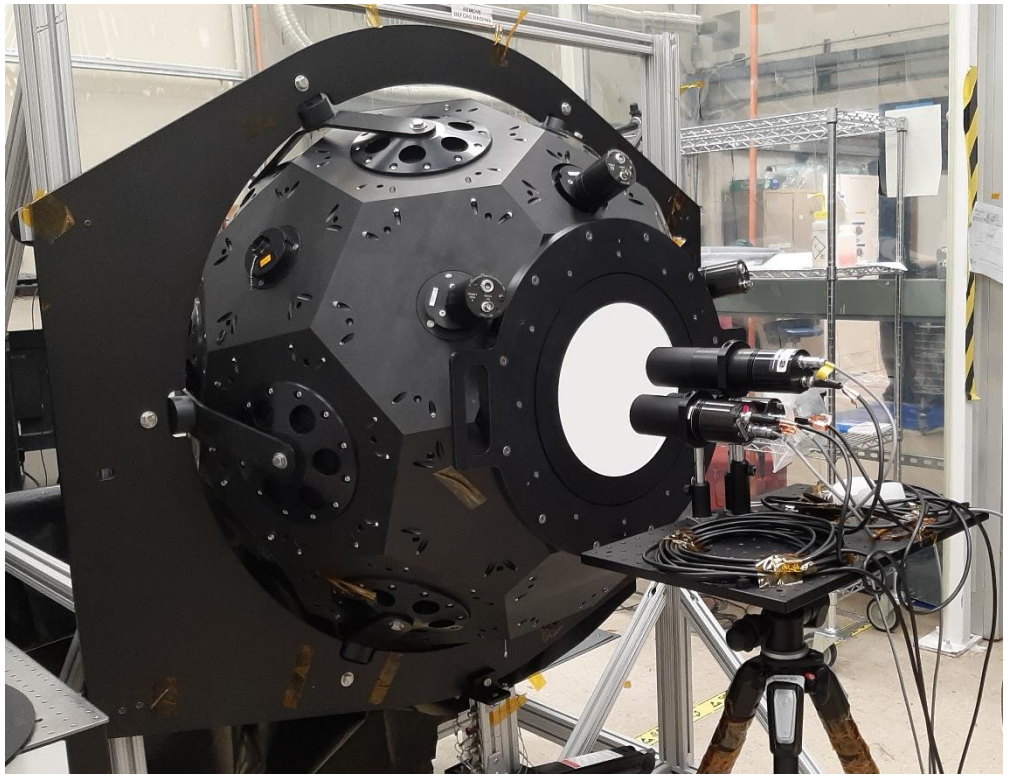
$$\mathrm{L} = {}^{S}/_{\int_{\lambda_1}^{\lambda_2} R(\lambda)*\ell_\lambda d\lambda}$$







Design considerations

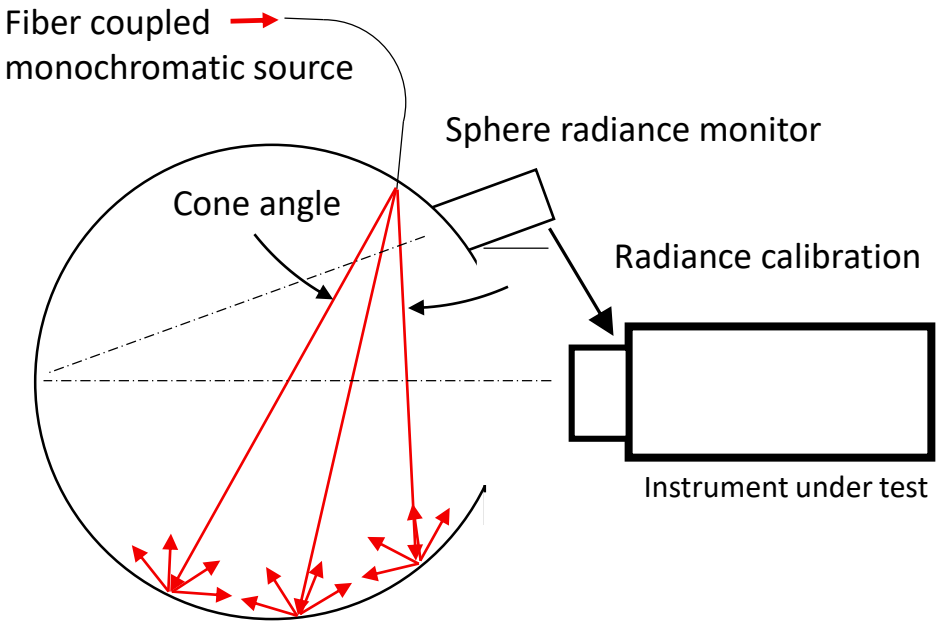


Calibrating sphere monitors with transfer radiometers

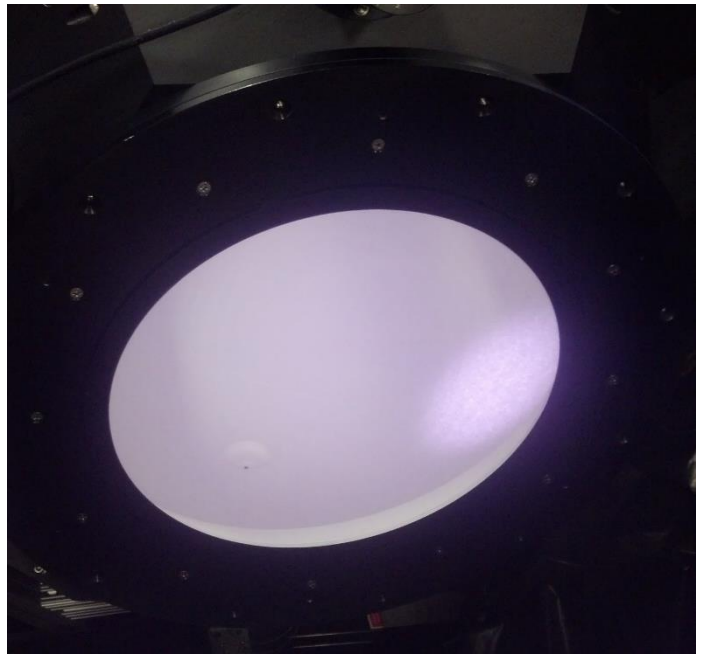
Field of view for source, radiometer, and instrument

Baffling

Sphere loading

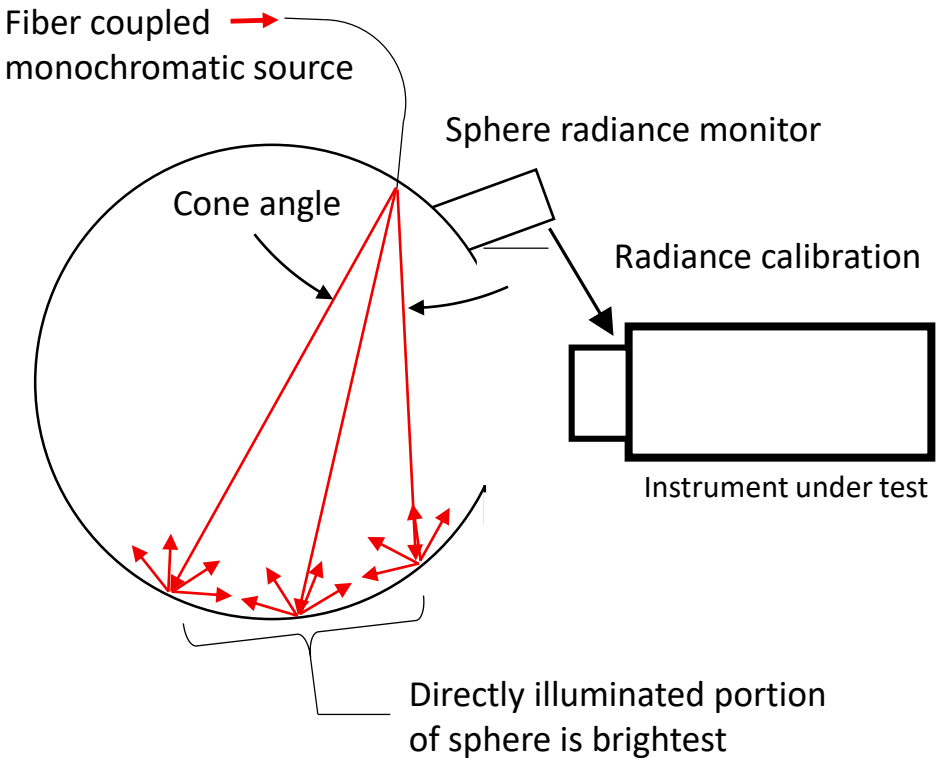


Fiber coupling



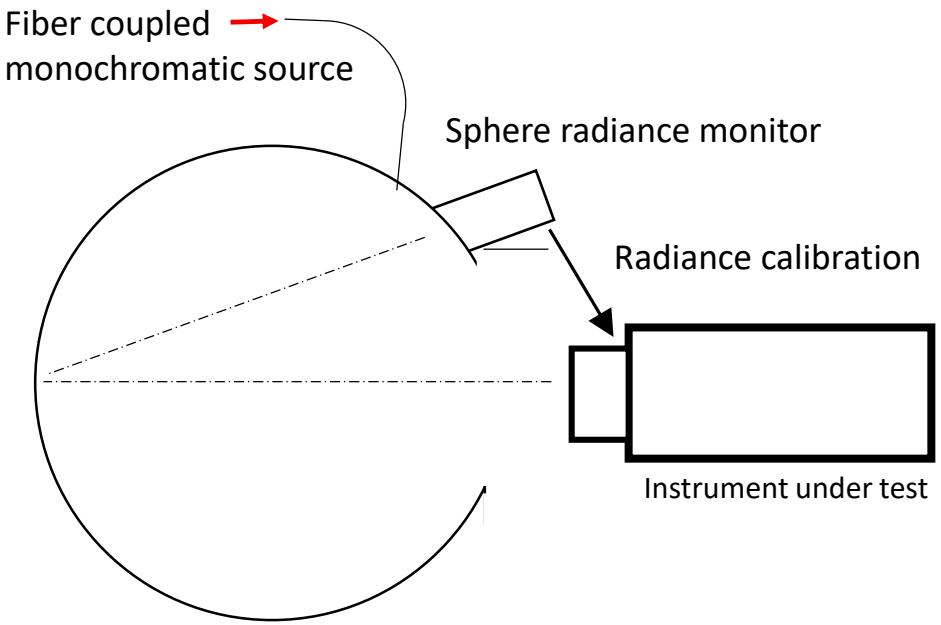
View showing direct illumination from fiber source

- Minimizes input port size
- Produces narrow divergence of light in well defined cone
- Can be angled to keep direct illumination out of instrument FOV
- Eliminates need for extra baffling around source



Field of view for instrument and radiance monitor

- Arranged to view same portion of sphere, not in region of direct source illumination
- For our work, instruments are generally focused at infinity; this can be advantageous as working out of focus provides additional spatial averaging
- Active feedback from radiance monitor compensates for sphere loading; works best with monochromatic light



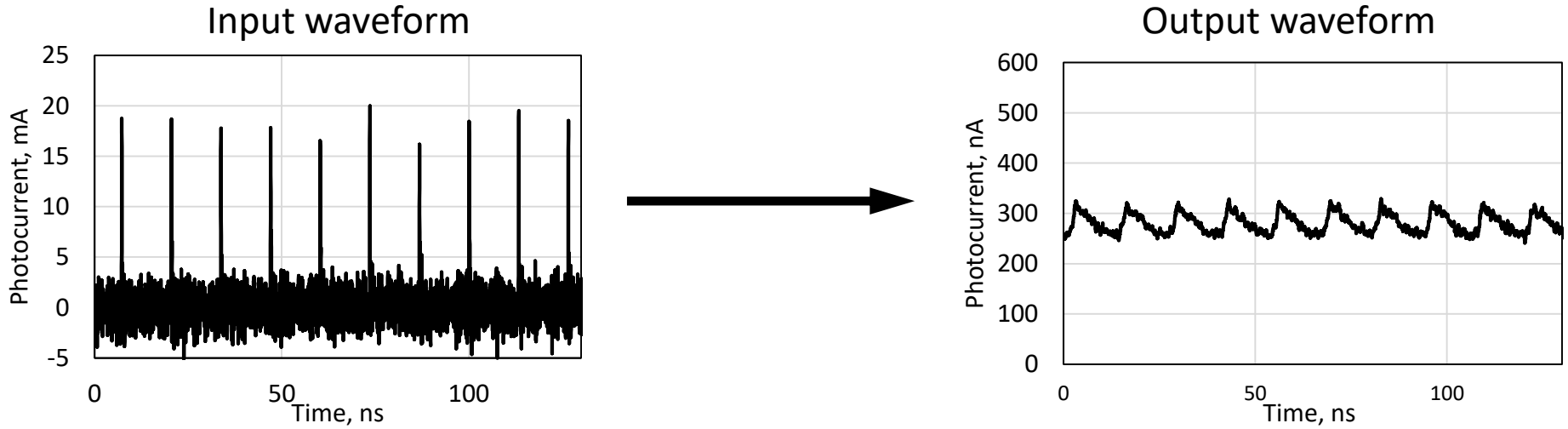
A note about temporal averaging

The integrating sphere provides temporal as well as spatial averaging due to the finite speed of light.

For a sphere of inner diameter D_S, average reflectivity of $\bar{\rho}$, and speed of light c, the characteristic time constant is

$$\tau = -\frac{2D_s}{\pi c \ln \bar{\rho}}$$

For example, the GLAMR sphere D_S = 76 cm, $\bar{\rho}$ = 0.95, and τ = 33 ns. This effect typically becomes important for signals in the MHz range.

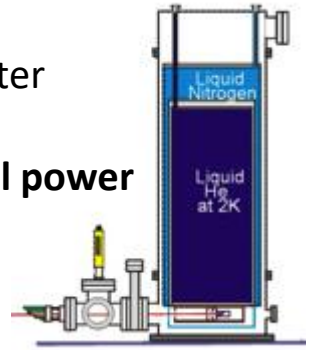


Calibration path
relating radiance to fundamental units

NIST Facility

POWR – electrical substitution radiometer

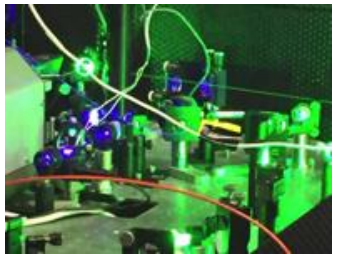
SI traceable Electrical power → Optical power



NIST reference radiometer

Optical power → Radiance

($Watts \rightarrow \frac{Watts}{m^2 * steradian}$**)**



GLAMR transfer radiometers (set of three)

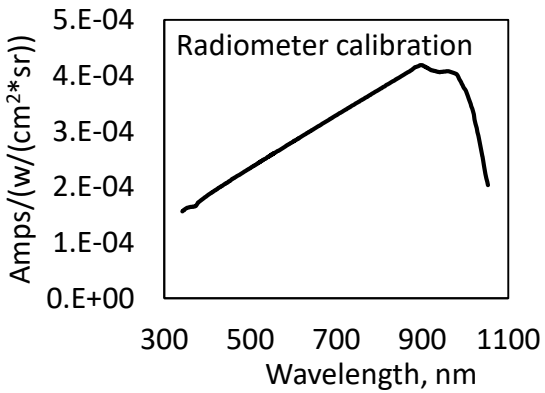
Radiance → Photocurrent

Monochromatic light used throughout calibration path

Instrument facility

NIST calibrated GLAMR transfer radiometers

Photocurrent → Radiance

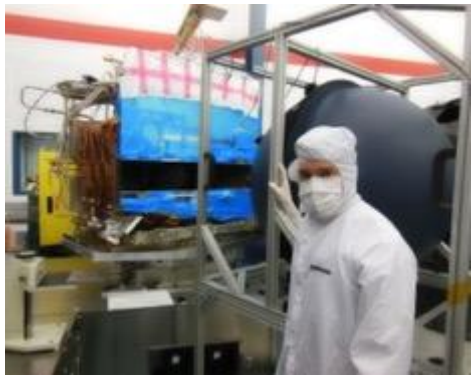


Sphere calibration

Sphere monitor/Transfer radiometer signal ratio

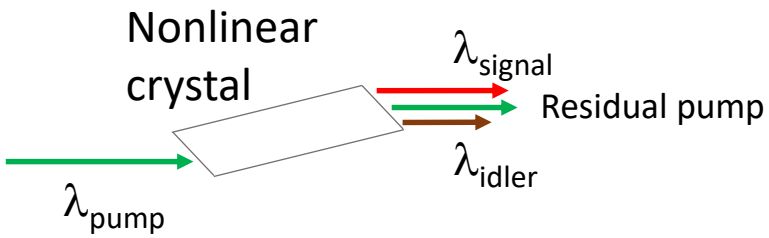
Instrument calibration

Sphere radiance → Instrument response (counts)



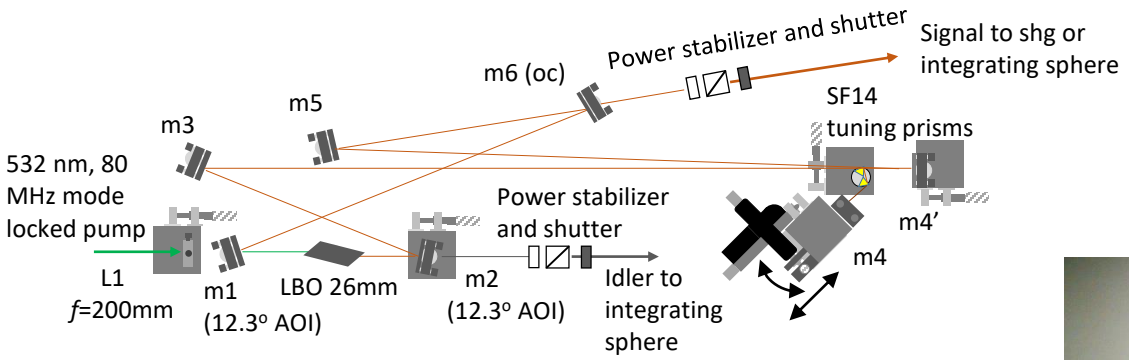
Source

Tunable monochromatic source:
Two optical parametric oscillators with signal, idler, and second harmonic output

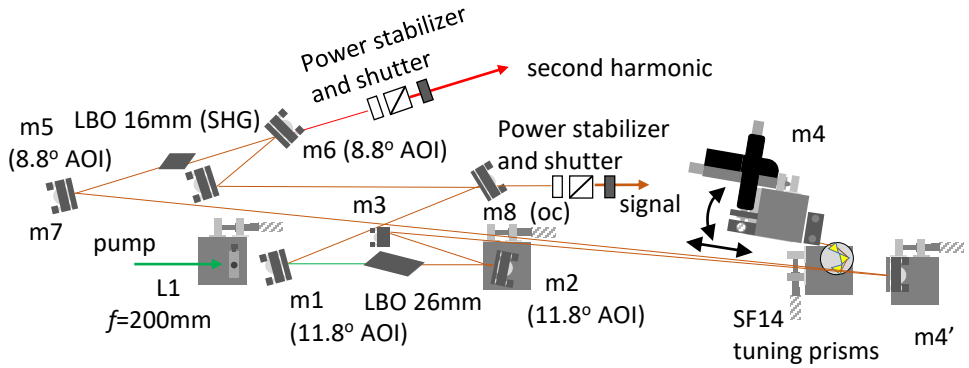


$$\frac{1}{\lambda_{pump}} = \frac{1}{\lambda_{signal}} + \frac{1}{\lambda_{idler}}$$

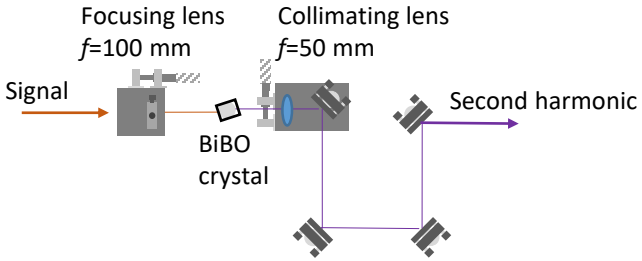
NIR-OPO 680-1120 nm + 1200-2400 nm

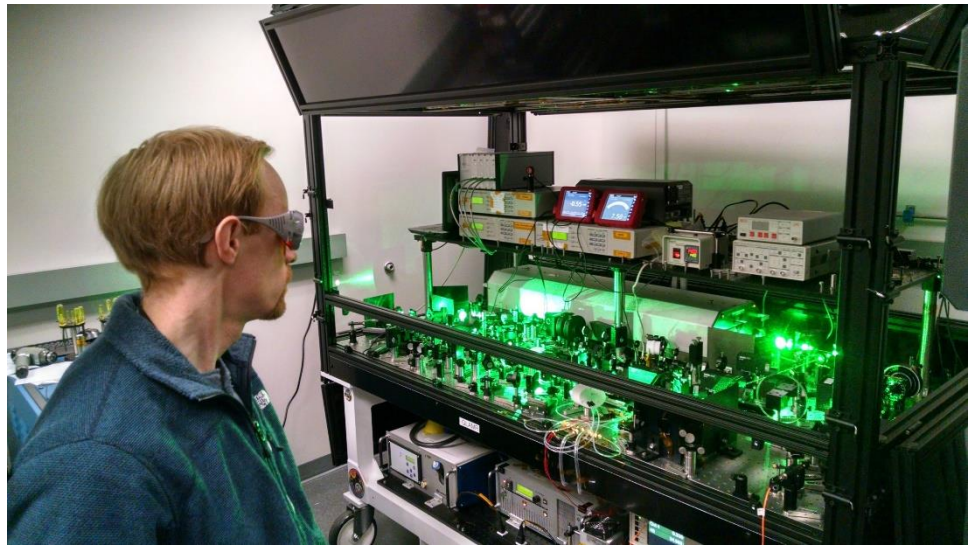


SWIR-OPO 1080-1400 nm + 540-700 nm

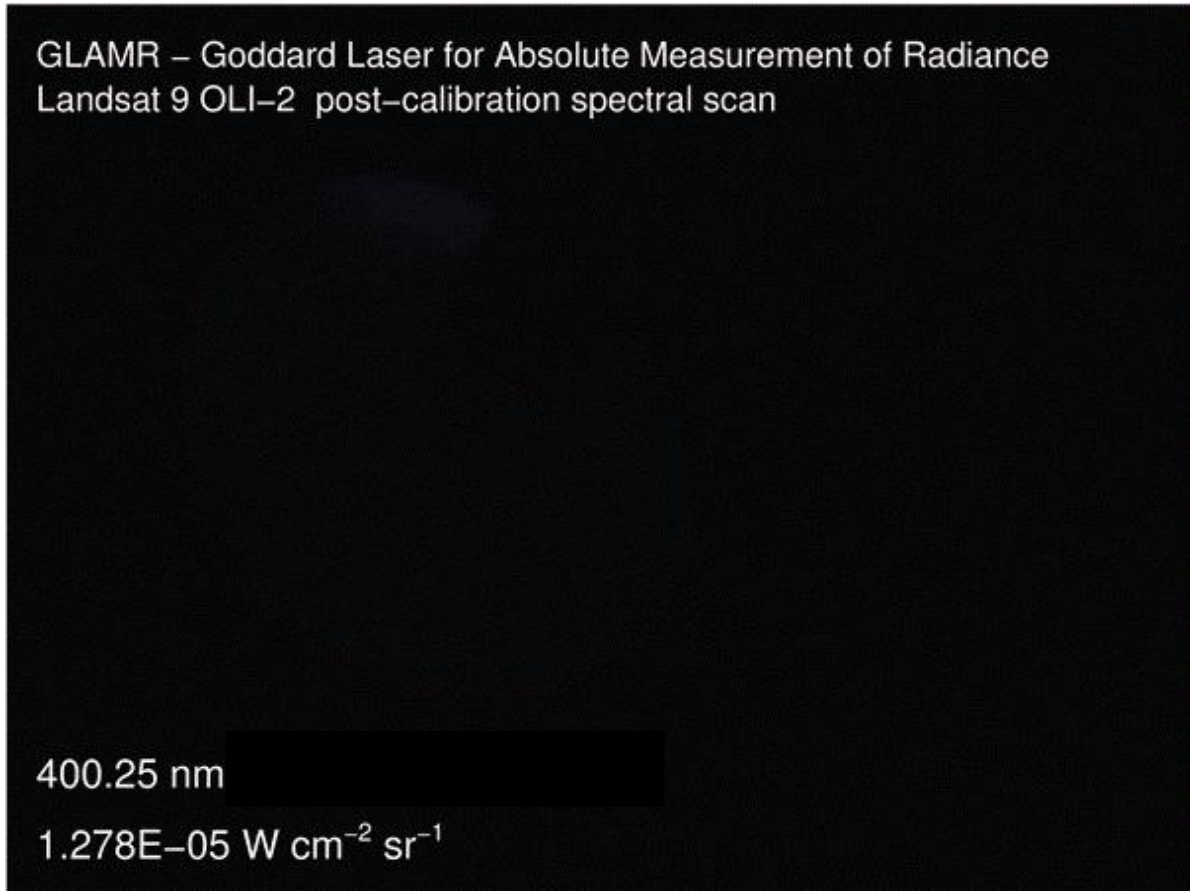


NIR second harmonic generator



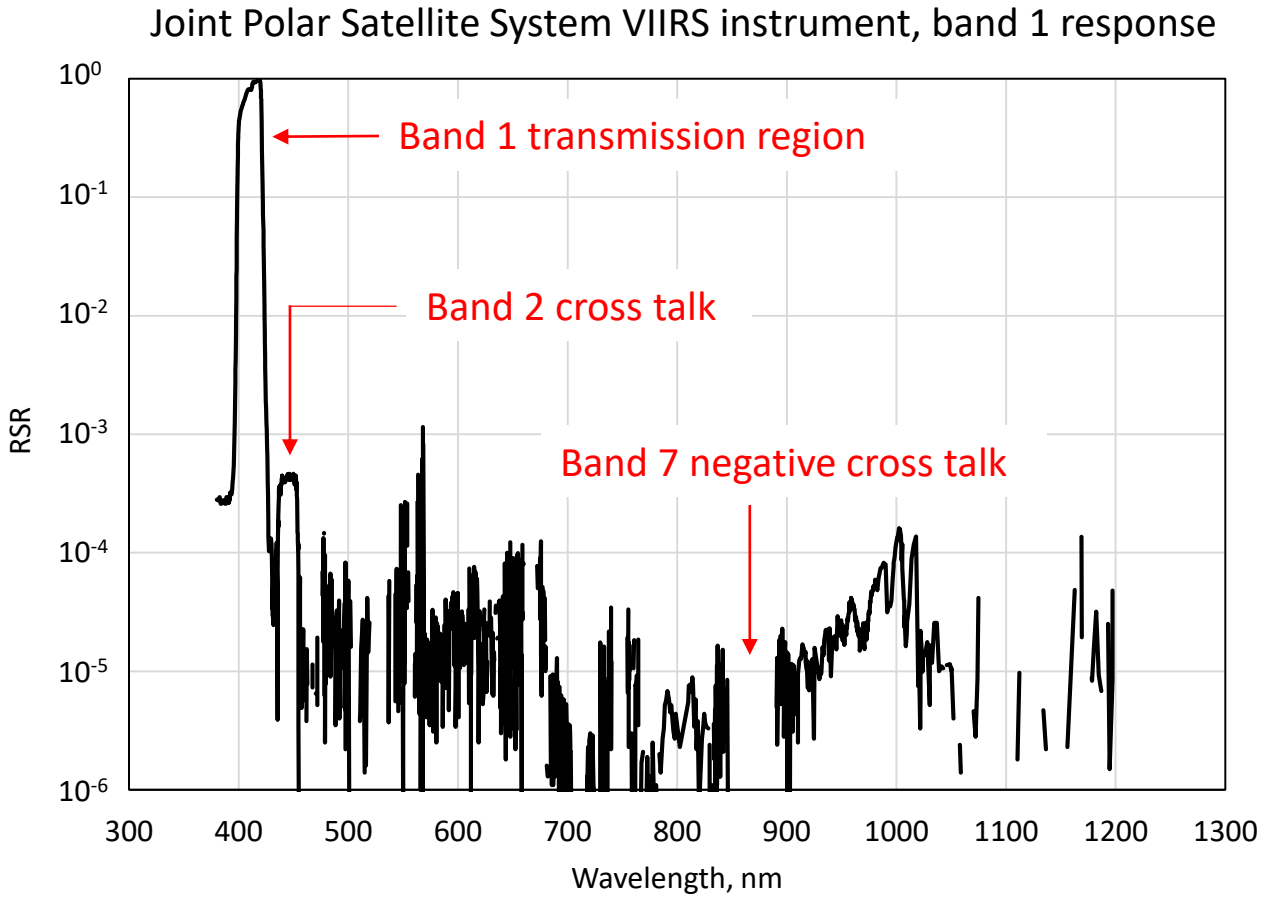


Tuning time lapse



Integrating sphere time lapse with commercial RGB camera
Note infrared filter leaks

Calibration example



Filter based instrument, each band characterized for both in band and out of band response

Acknowledgements

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GOES-R

NPP

SAGE III – ISS

Landsat

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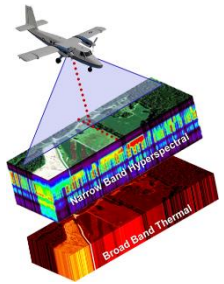
CLARREO Pathfinder

Joint Polar Satellite System

Lucy L'Ralph

G-LiHT



GLAMR team

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Questions?

Still images from calibration of integrating sphere monitors