Results of J1 VIIRS testing using NIST's Traveling SIRCUS

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RSR Test Lead: Joel McCorkel
Polarization Test Lead: Gene Waluschka

RSR analysis: David Moyer
Polarization analysis: Jeff McIntire

T-SIRCUS Operation: Keith Lykke, Steve Brown, Brendan McAndrew, Joel McCorkel
Raytheon Interface: TR Wang

T-SIRCUS JPSS-1 VIIRS Testing

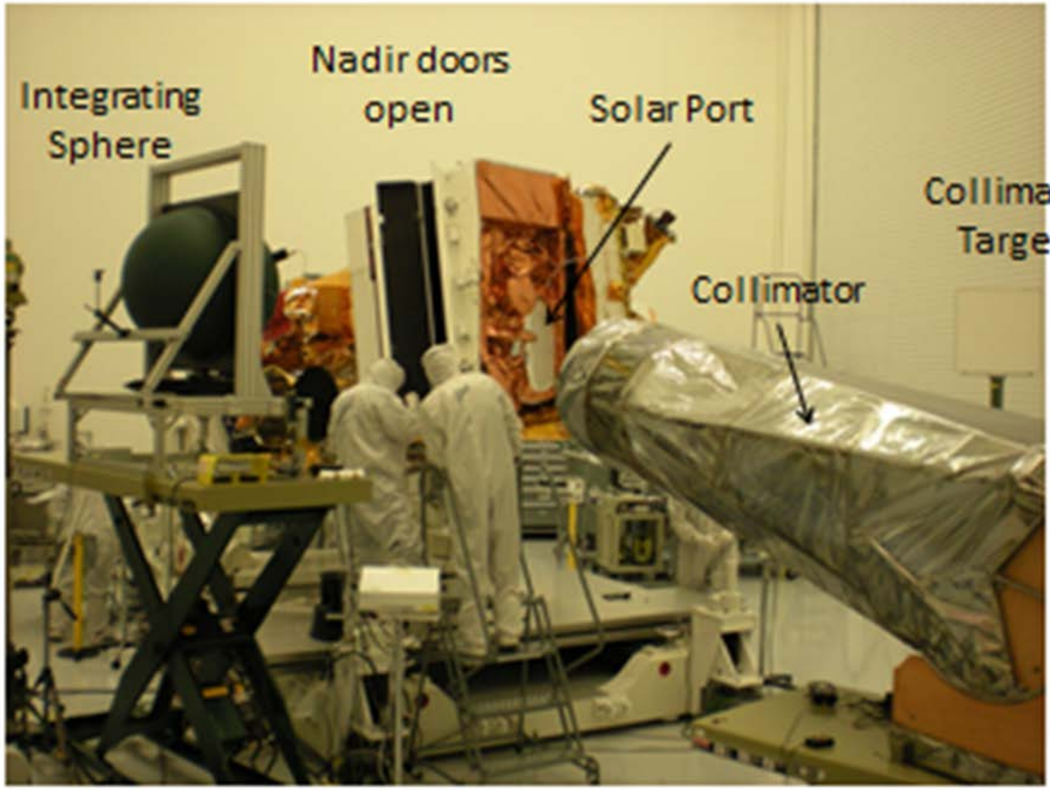
Absolute Spectral Response of VIIRS Vis/NIR Channels

Polarization Testing of Channels M1&M4

- T-SIRCUS from SNPP VIIRS to J1 VIIRS
- Responsivity Test setup
  – ASR/RSR Acquisition and Analysis
- Polarization Test Setup
  – Acquisition and Analysis

From SNPP VIIRS (2010) to J1 VIIRS (2014/15)

- SNPP VIIRS measurements at Ball Aerospace, Boulder CO
- J1 VIIRS measurements at Raytheon, El Segundo, CA

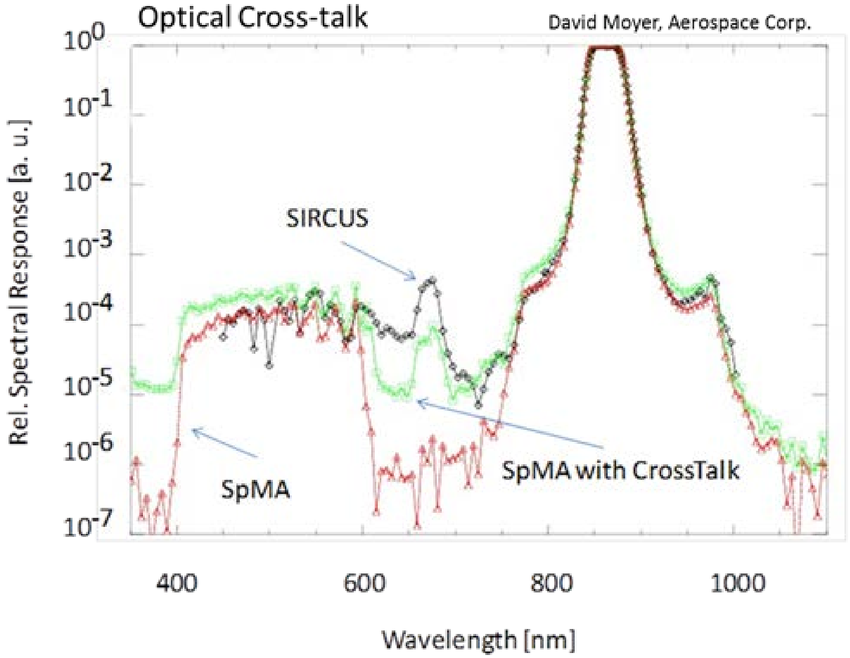


Radiance responsivity through the Earth-view (Nadir-view) port
Solar irradiance through the Solar Port

T-SIRCUS&SNPP VIIRS: The Good

Full aperture illumination v piece-parts characterization and calibration approach

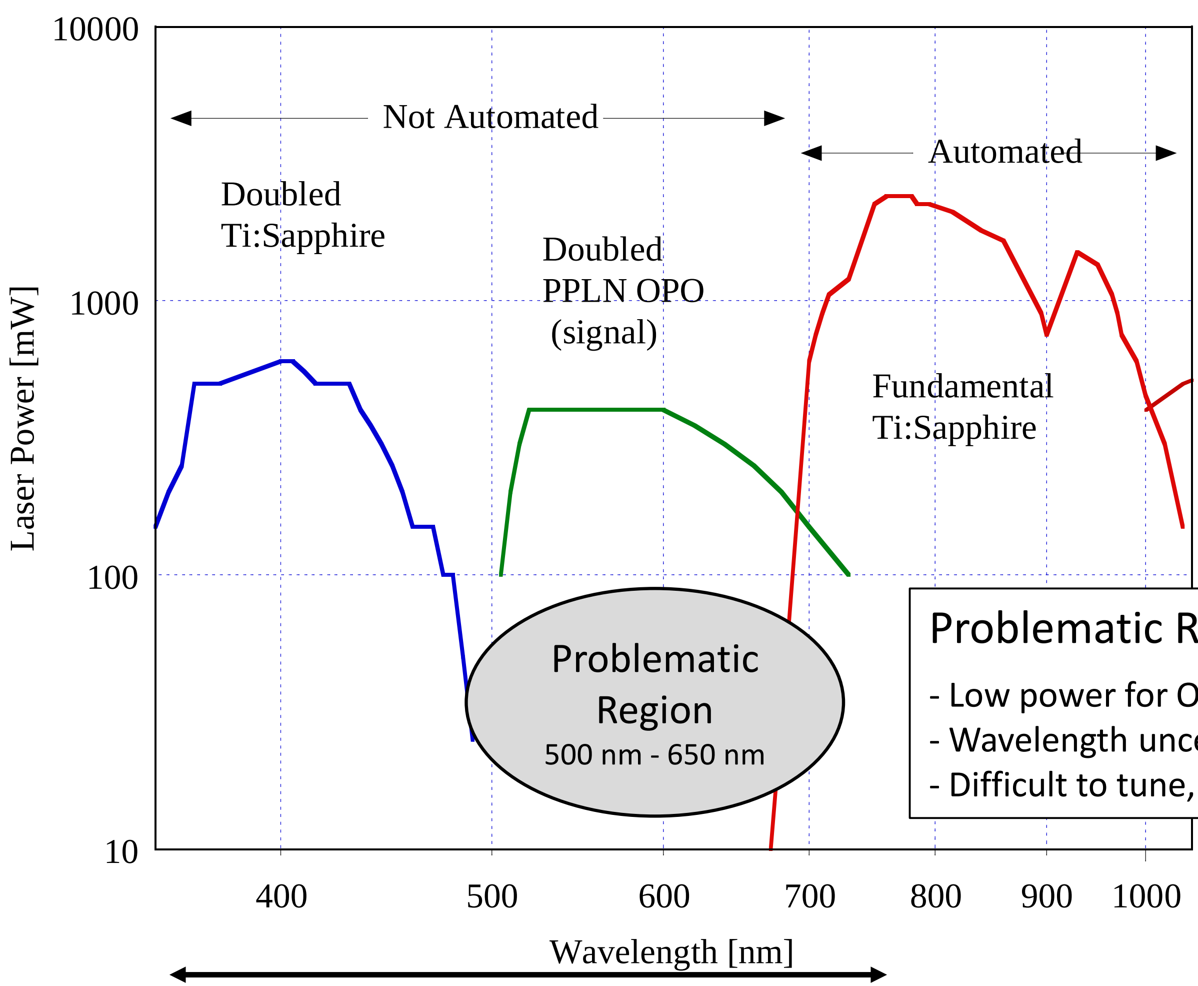
VIIRS Band M7, Detector 8



David Moyer, Aerospace Corp

- Reduced wavelength uncertainty
  - More accurate band-center wavelength determination
- Better characterization of detector-to-detector differences at the focal plane
- Absolute uncertainty ~0.5 %
  - meets the stringent ocean color calibration uncertainty requirements.

T-SIRCUS&SNPP VIIRS: The Bad
Laser issues



Problematic Region

- Low power for OOB
- Wavelength uncertainty high
- Difficult to tune, even by hand

*Most of the tuning done by hand (slow)

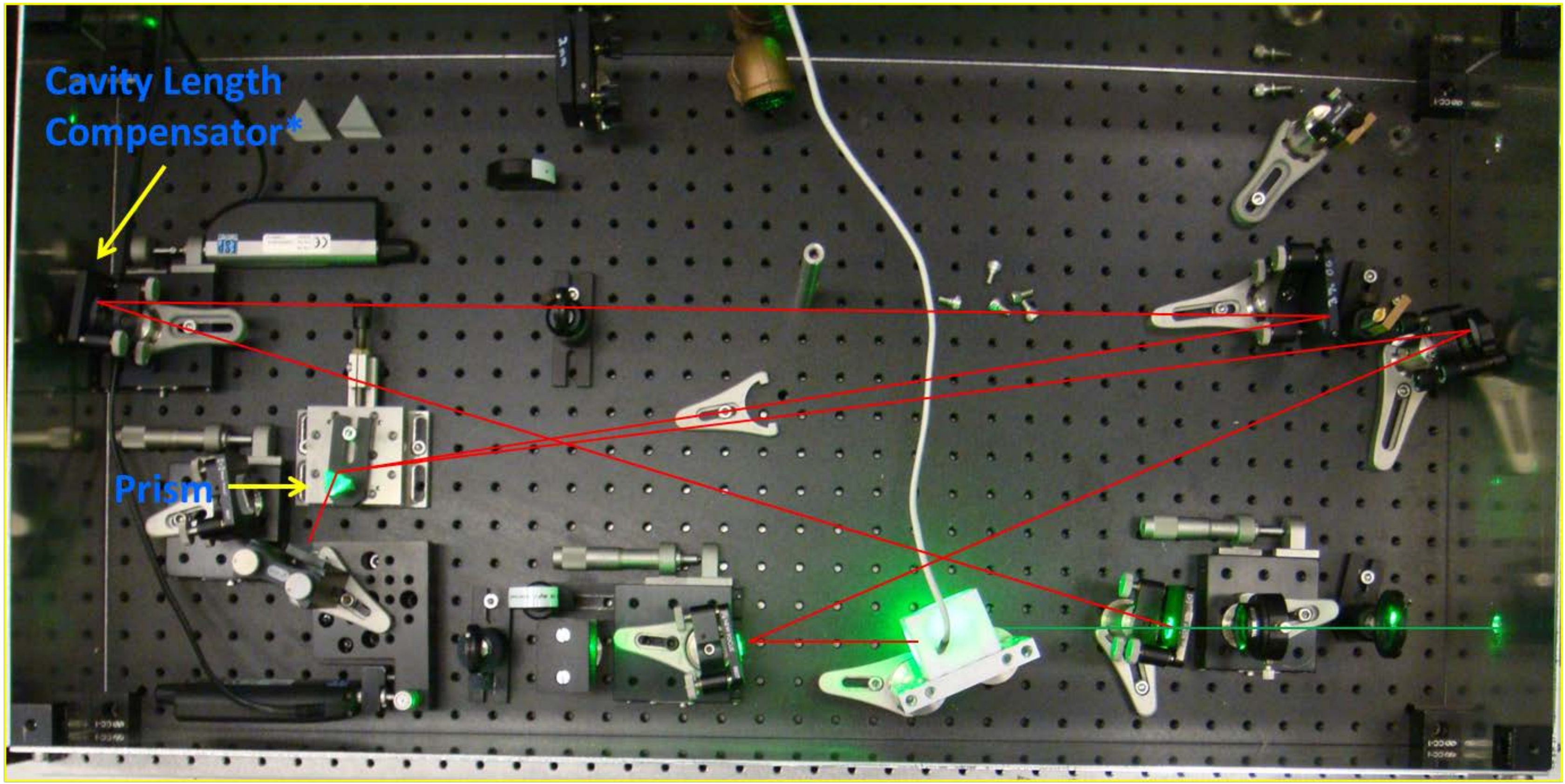
J1 VIIRS T-SIRCUS Raytheon Test Setup
Improved capabilities over SNPP measurements

1. New LBO OPO system
   - Higher Power, Automated Tuning over the full spectral range
   - Approx 10 s per step; 5 s or less for fine steps
2. Tunable Dye Lasers (DCM and R6G)
   - Higher Power, Automated Tuning
   - Approx 5 s per step
   - Fill in 560 nm to 670 nm spectral region
3. New Calibration Sources
   - 1-m Spectralon* coated integrating sphere

*Spectralon is a product of LabSphere, Inc.

1. Development of T-SIRCUS LBO OPO System

Developed by Keith Lykke, NIST



Rotation Stage*
(Prism Angle)

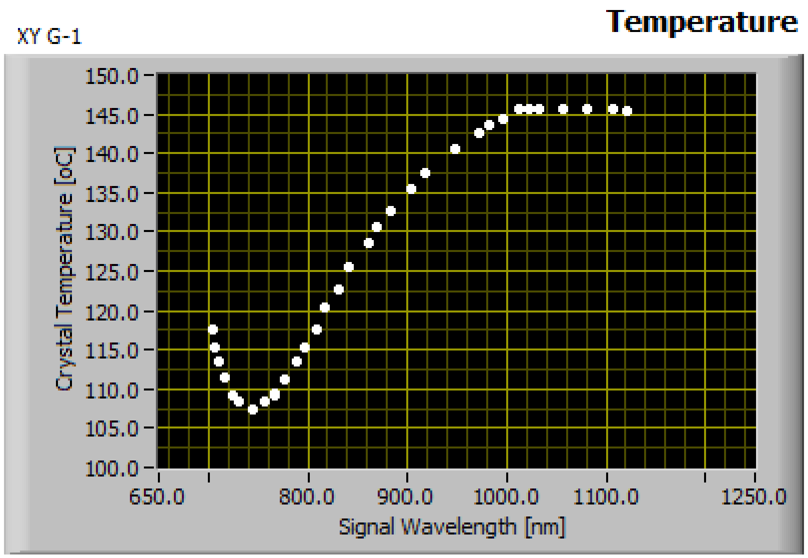
LBO Crystal Oven*

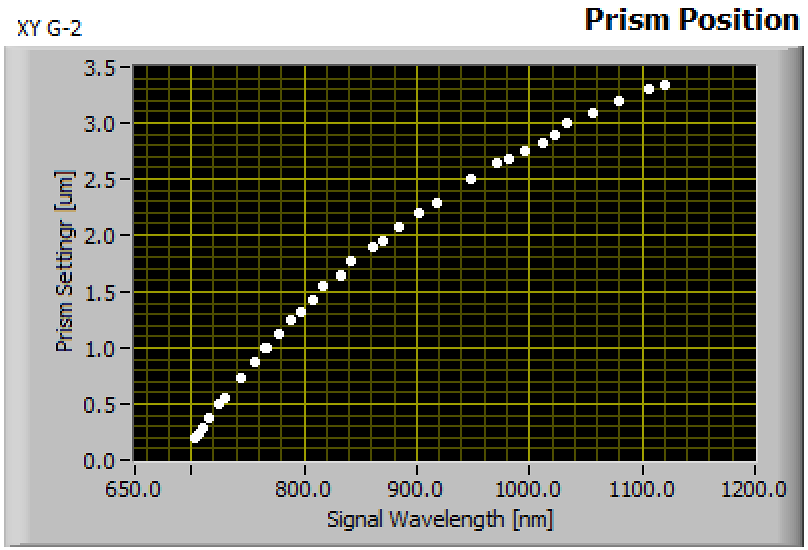
Pump Laser

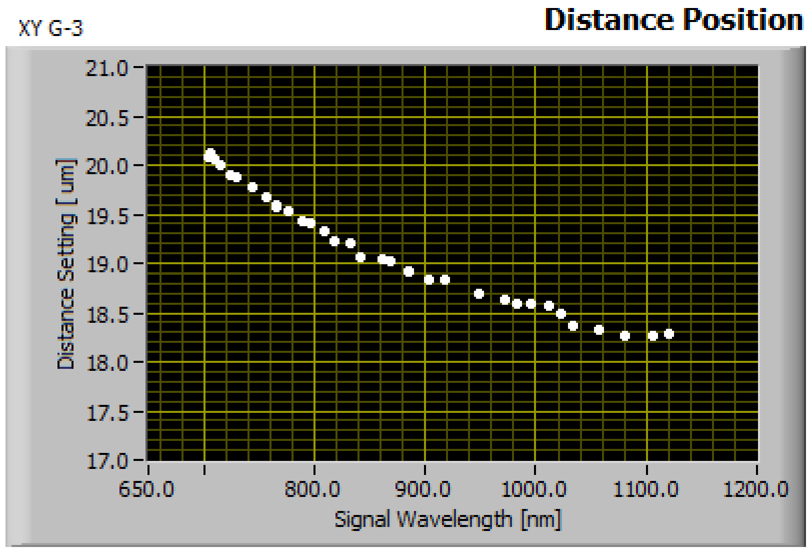
*under computer control

Benefits: Higher Power, Automated Tuning

Prism-tuned OPO Control Curves

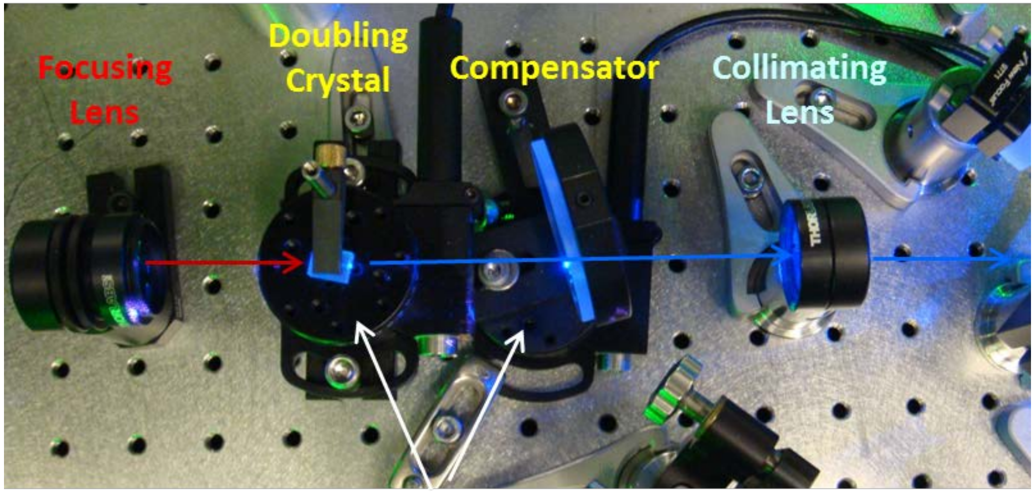






LBO OPO Doubler Path

Doubling now computer-controlled as well

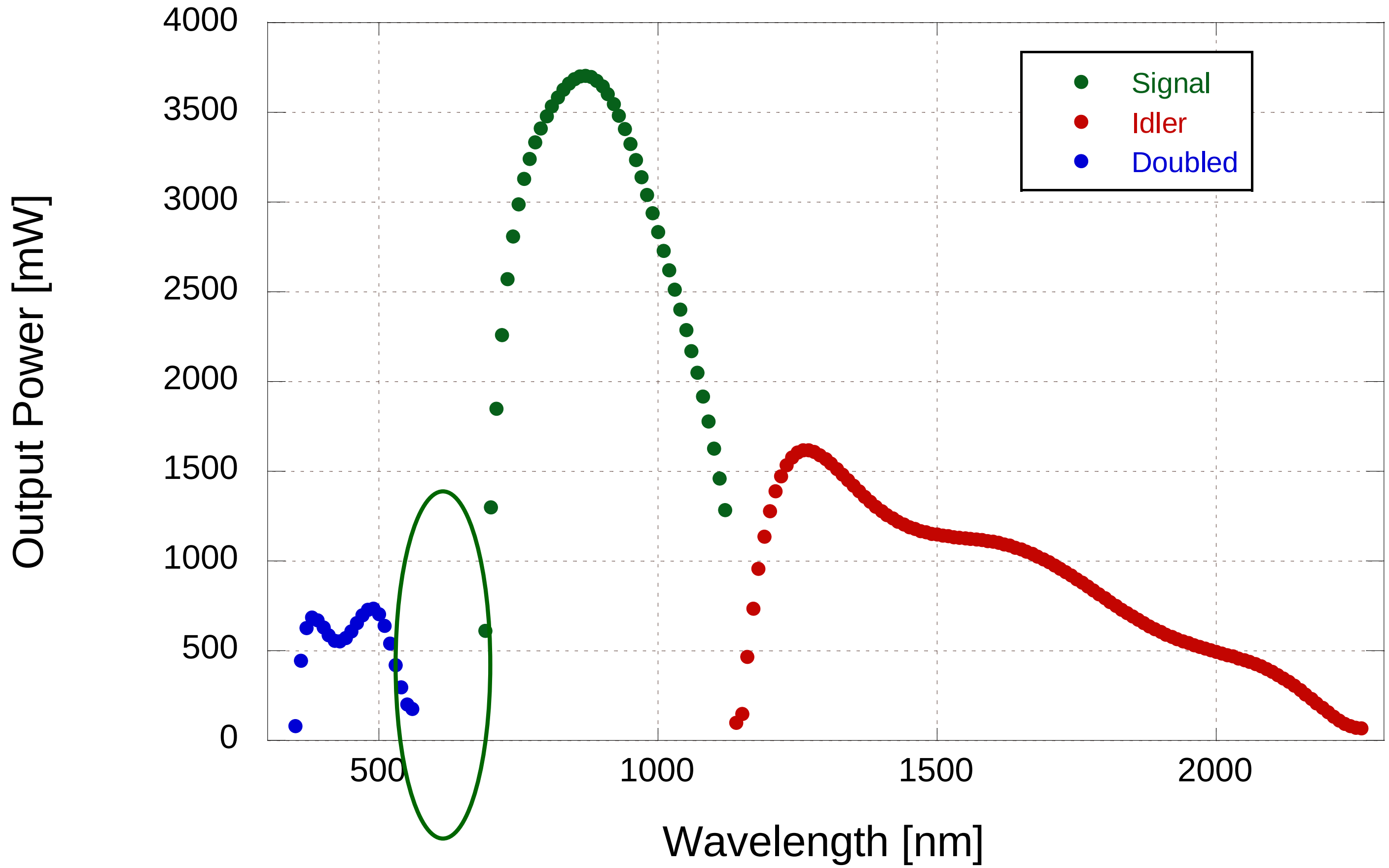


Rotary Stages
(computer controlled)

Adjust the angle of the doubling crystal
Adjust the angle of a compensator to keep the path the same

T-SIRCUS LBO OPO Tuning Curve

Gap filled in with Doubled OPO Idler Signal and/or Dye Lasers



At the time we were not doubling the Idler Signal

Used cw dye lasers to fill in the GAP

2. Include dye laser with DCM and R6G dyes

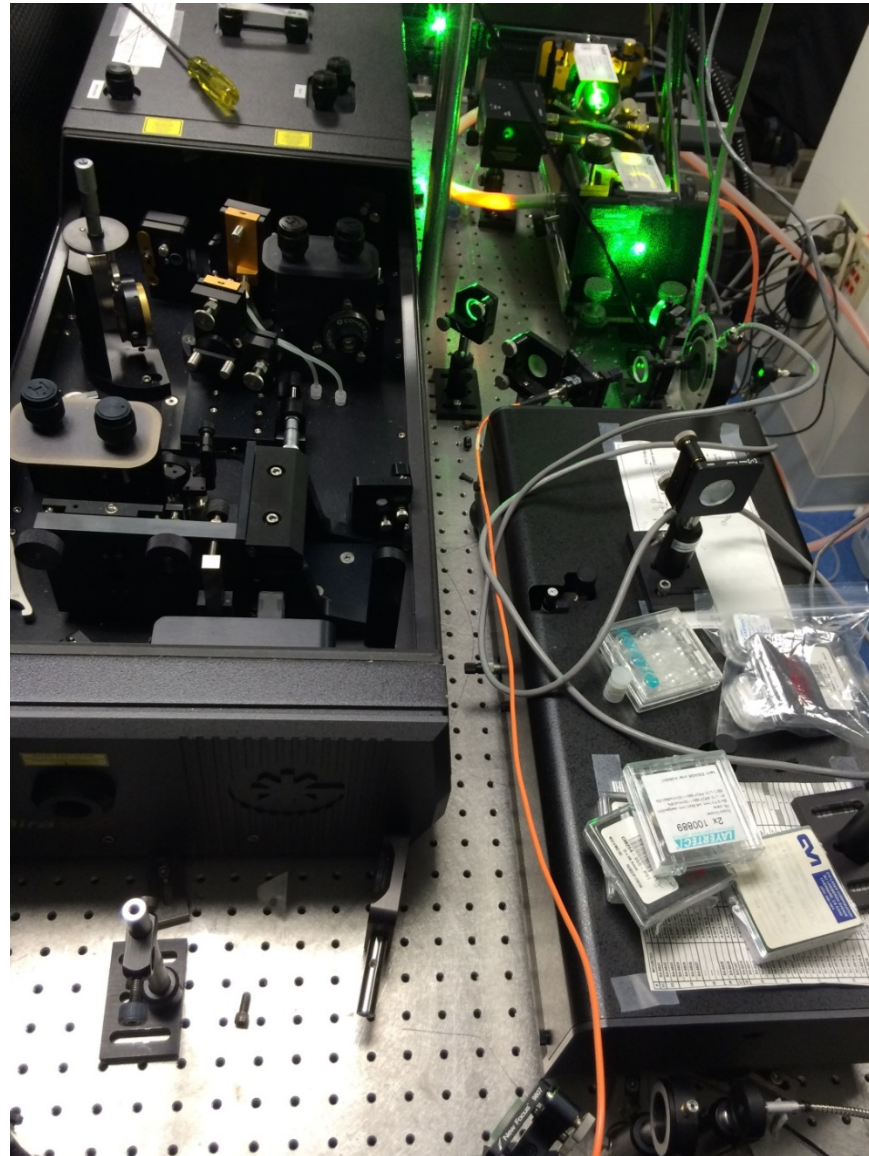
Dye laser table

2 ft x 6 ft table
- Pump laser
- Ti:S laser
- Dye Laser
- Doubling System

Dyes we used at Raytheon

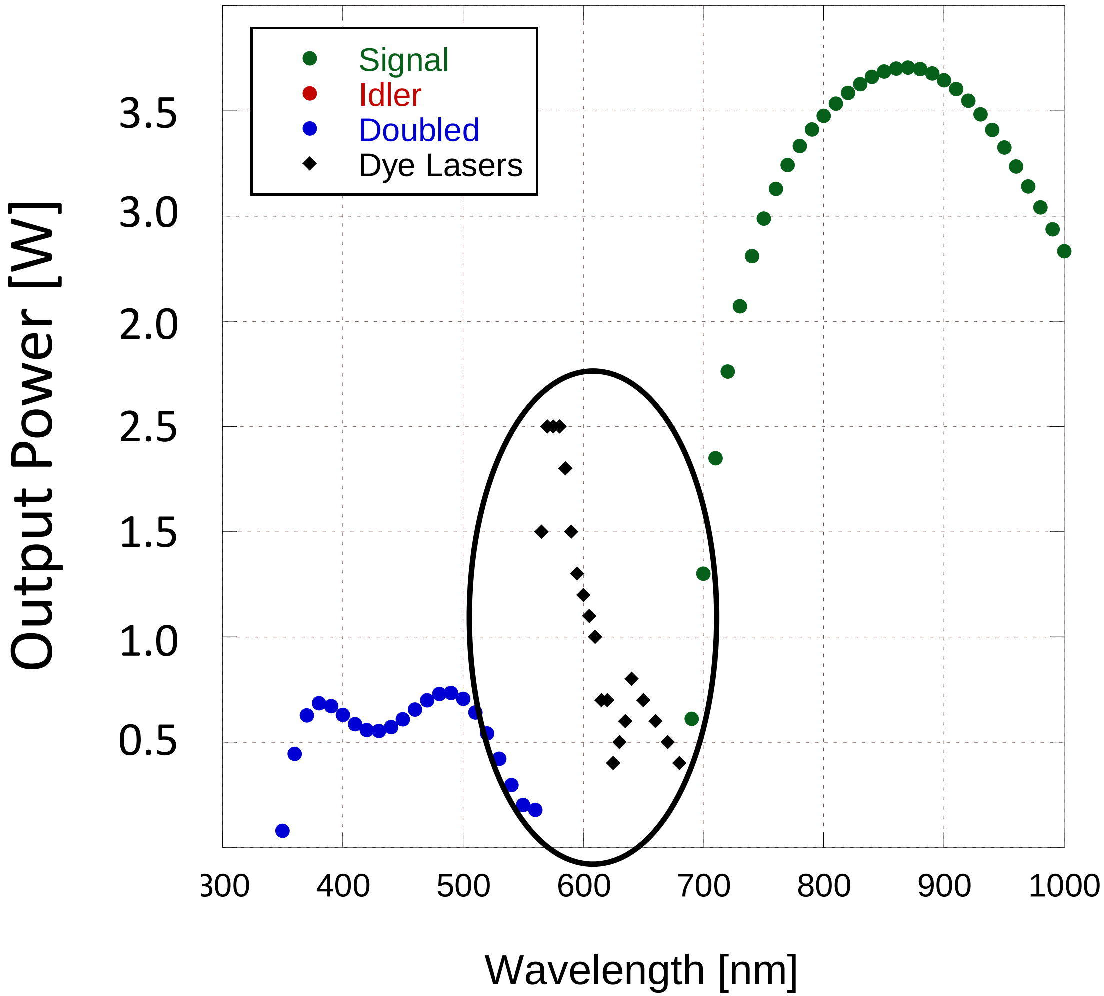
R6G: 565 nm to 615 nm

DCM: 610 nm to 680 nm



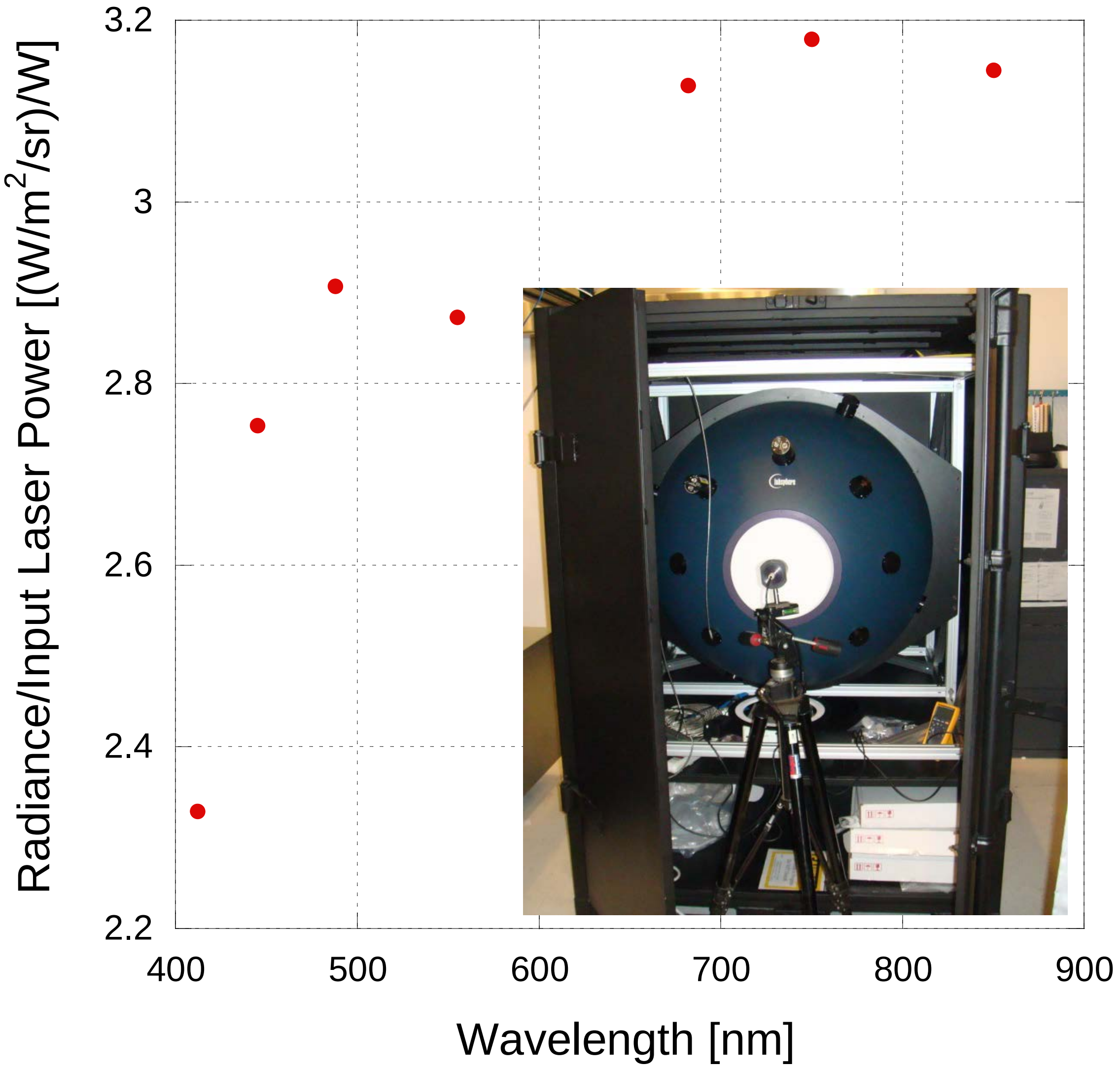
Tuning Curve LBO OPO w/ Dye Laser

Dye lasers under computer control

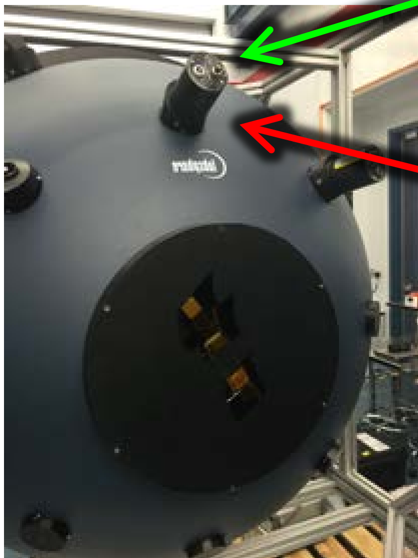


3. 1-m Spectralon SpIS Radiometric Properties

Operational Characteristics Radiance Out to Laser Power In



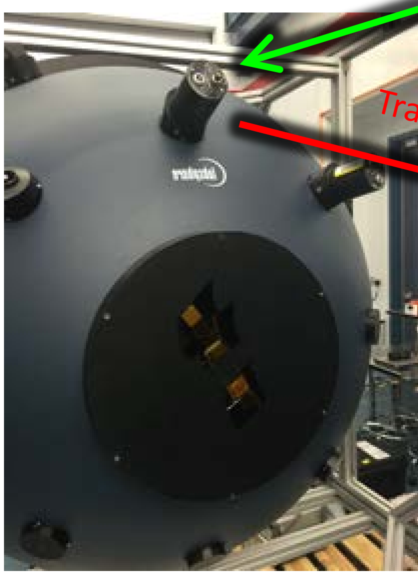
Path to radiometric traceability



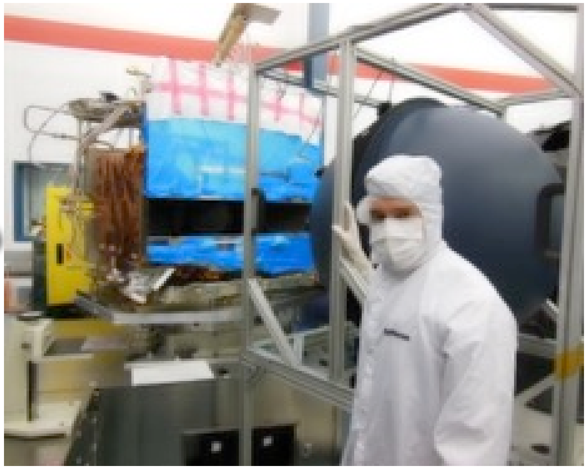
NIST Transfer Radiometer

Traceability is transferred from a NIST transfer radiometer to the Sphere Monitor prior to VIIRS calibration.

$$MonCal = L_{cal}\left(sphere\right)/MonSig_{cal}[A]$$



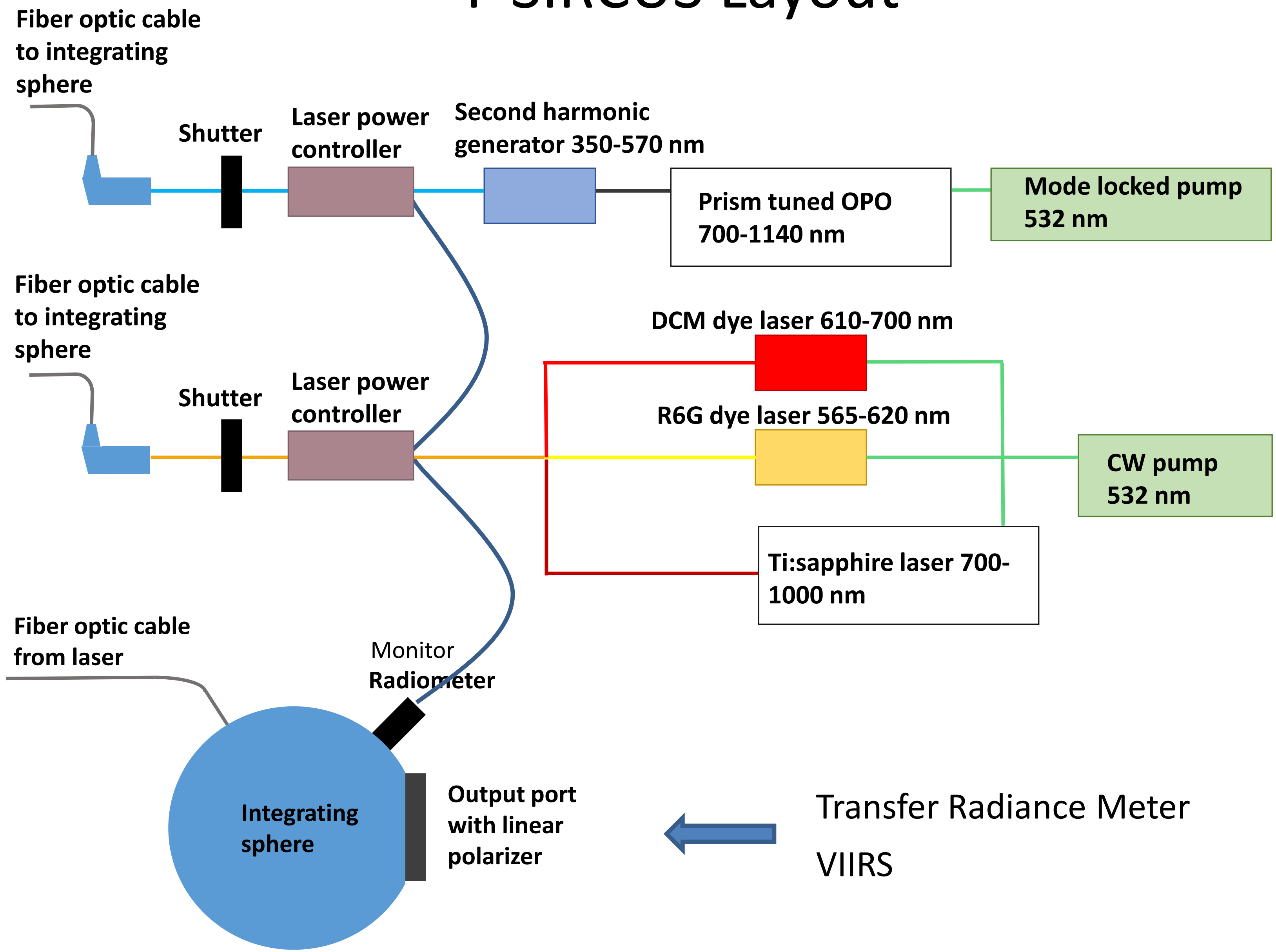
VIIRS



The monitor Signal gives the SIS radiance during VIIRS testing.

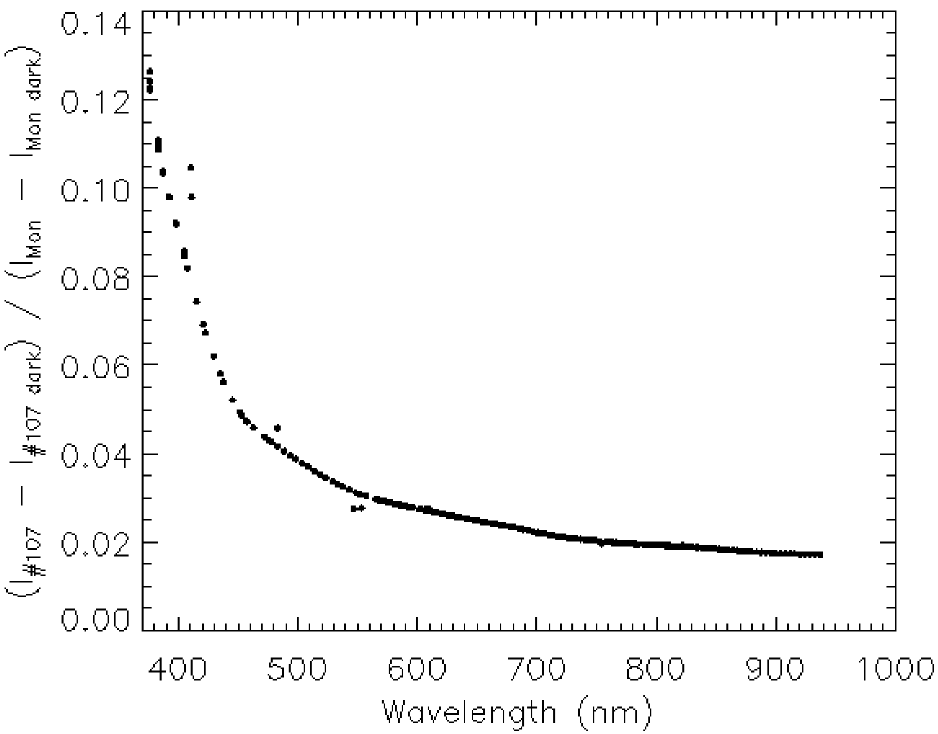
$$L_{VIIRS}\left(Sphere\right) = L_{cal}\left(sphere\right) * [MonSig_{VIIRS}[A]/MonSig_{cal}[A]]$$

T-SIRCUS Layout

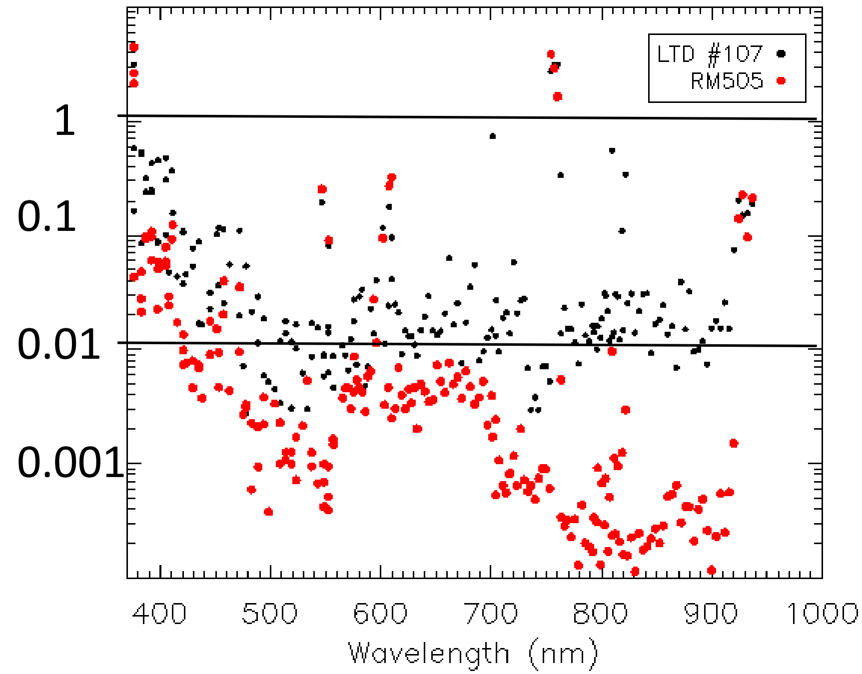


Sphere monitor calibration
16-17 Dec 2014

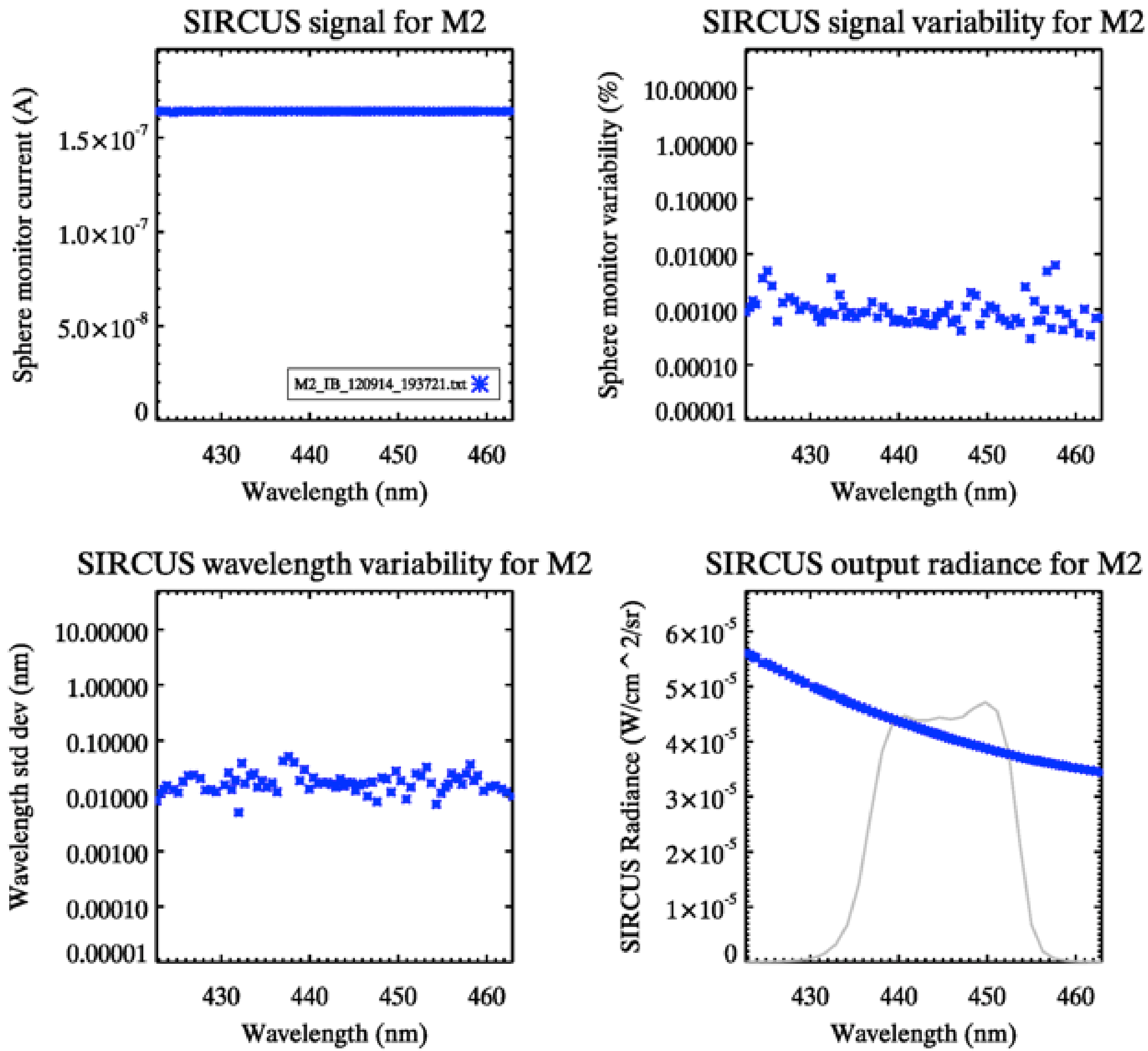
Radiometer Signal/Monitor Signal



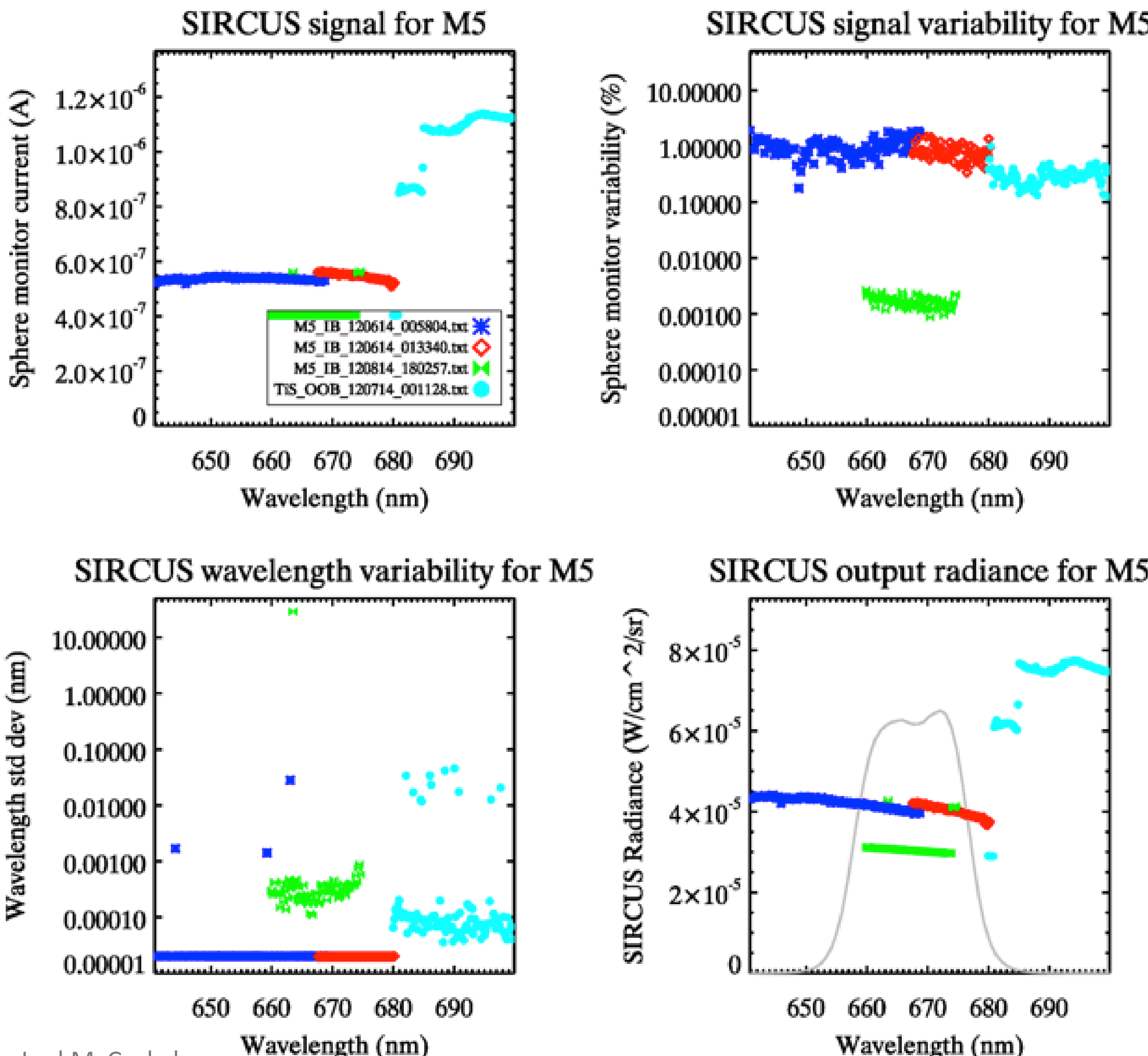
StDev [%]



M2 results


SIRCUS signal for M2
Sphere monitor current (A)
1.5×10^-7
1.0×10^-7
5.0×10^-8
0
M2_IB_120914_193721.txt
430
440
450
460
Wavelength (nm)
SIRCUS signal variability for M2
Sphere monitor variability (%)
10.00000
1.00000
0.10000
0.01000
0.00100
0.00010
0.00001
Wavelength (nm)
SIRCUS wavelength variability for M2
Wavelength std dev (nm)
Wavelength (nm)
SIRCUS output radiance for M2
SIRCUS Radiance (W/cm^2/sr)
6×10^-5
5×10^-5
4×10^-5
3×10^-5
2×10^-5
1×10^-5
0
Wavelength (nm)

M5 results



Laser power control OFF

Laser power control ON

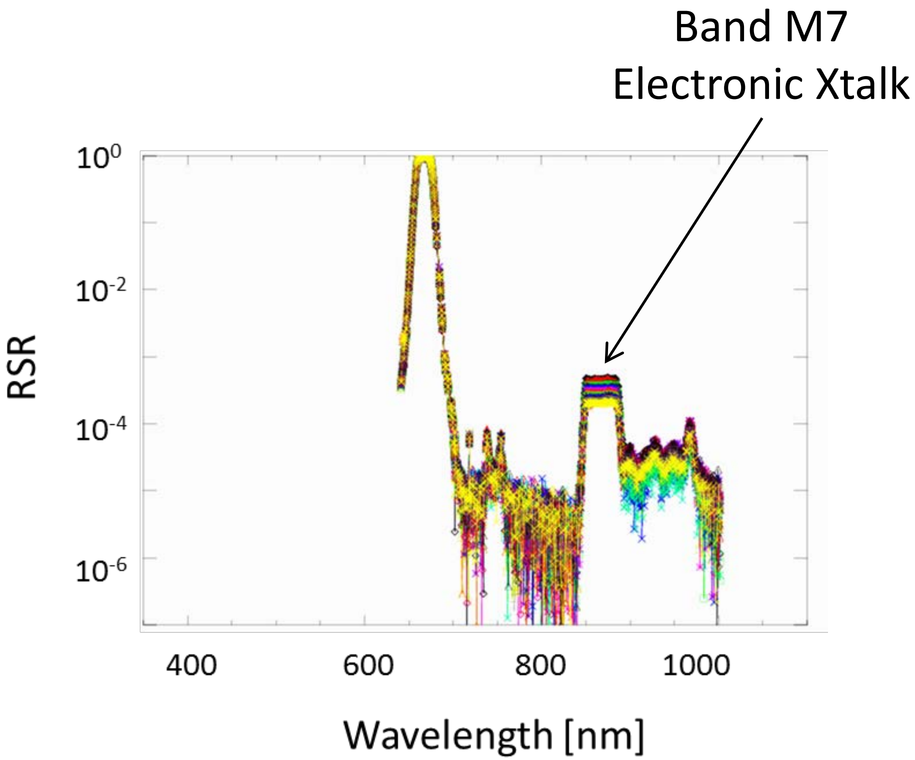
Joel McCorkel

QuickLook J1 VIIRS Test Results

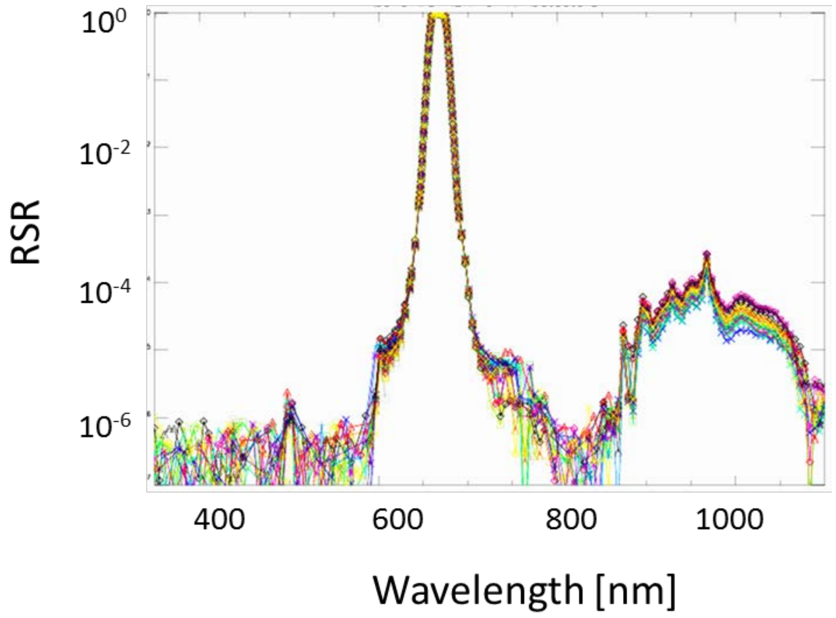
- RSR
  - David Moyer, Frank DeLuccia, and Janna Feeley
  - Manuscript in preparation, Joel McCorkel
- Polarization dependence of the sensor
  - Jeff McIntire, Gene Waluschka
  - SPIE presentations by both

Example of Cross-Talk Band 5 to Band 7

SIRCUS Measurements (Laser-Based)

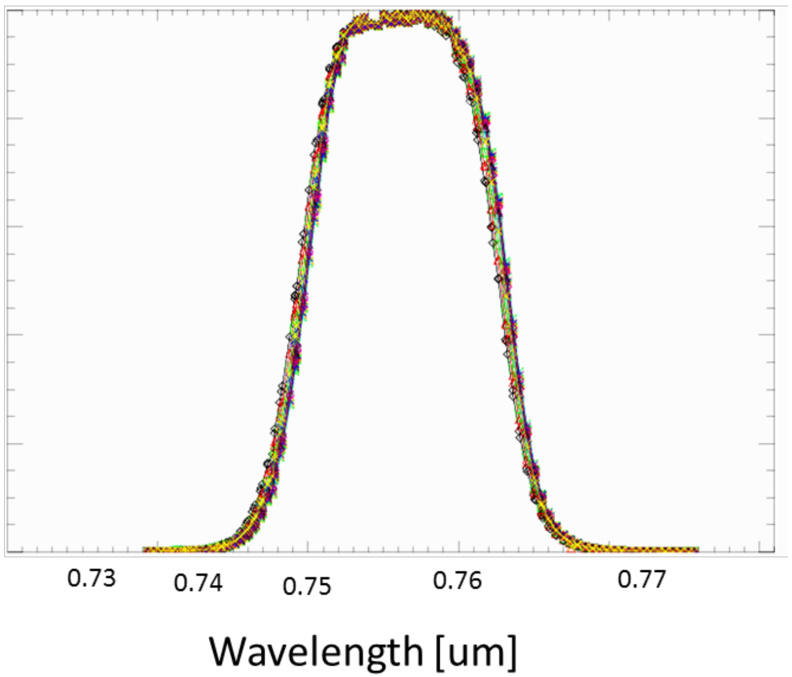


SpMA Measurements (Lamp-Monochromator)

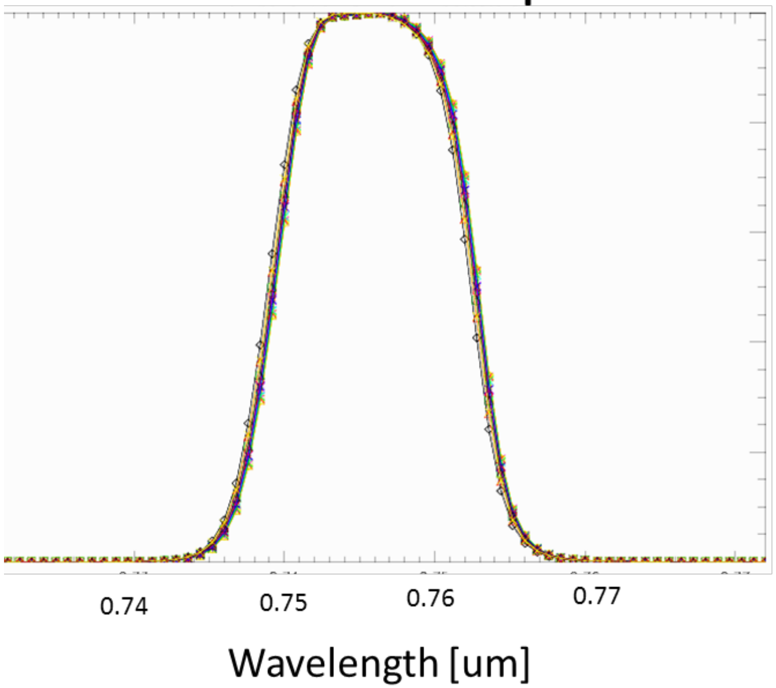


Detector-to-detector Differences

Band M6 RSR
for all Detectors SIRCUS

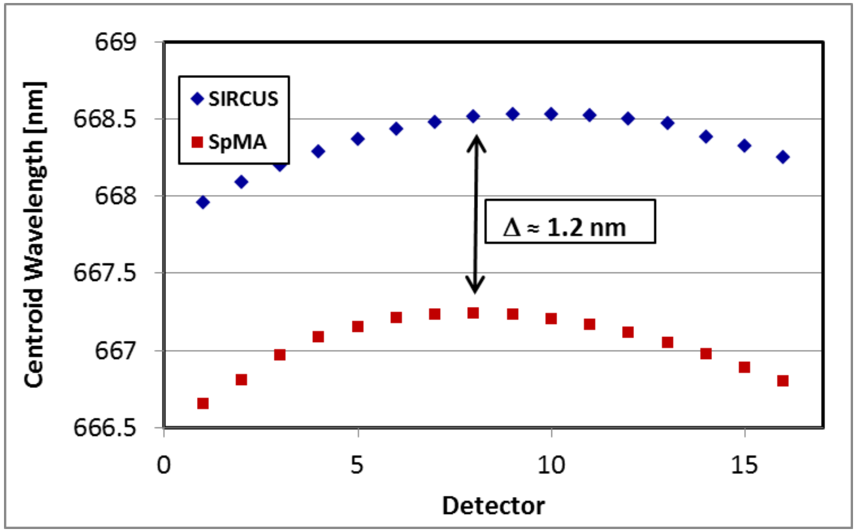


Band M6 RSR
for all Detectors SpMA

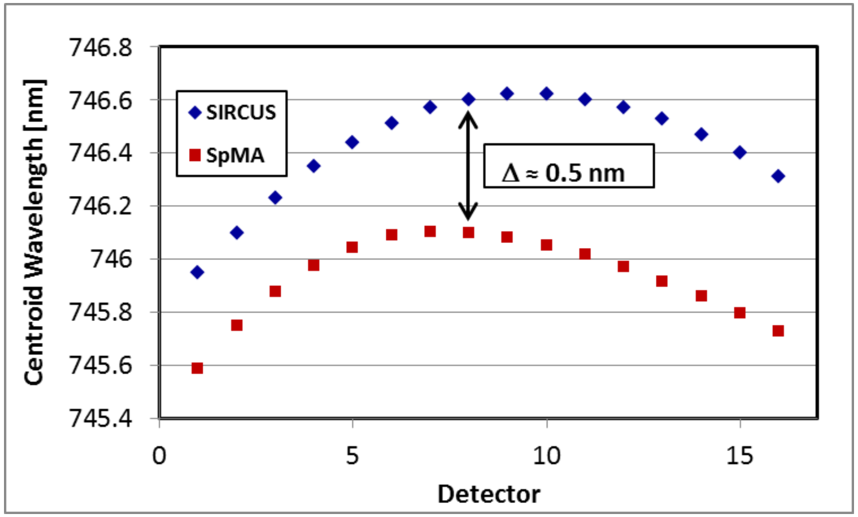


Centroid Wavelength for Bands M5 & M6
Calculated using SIRCUS and SpMA approaches

Band M5



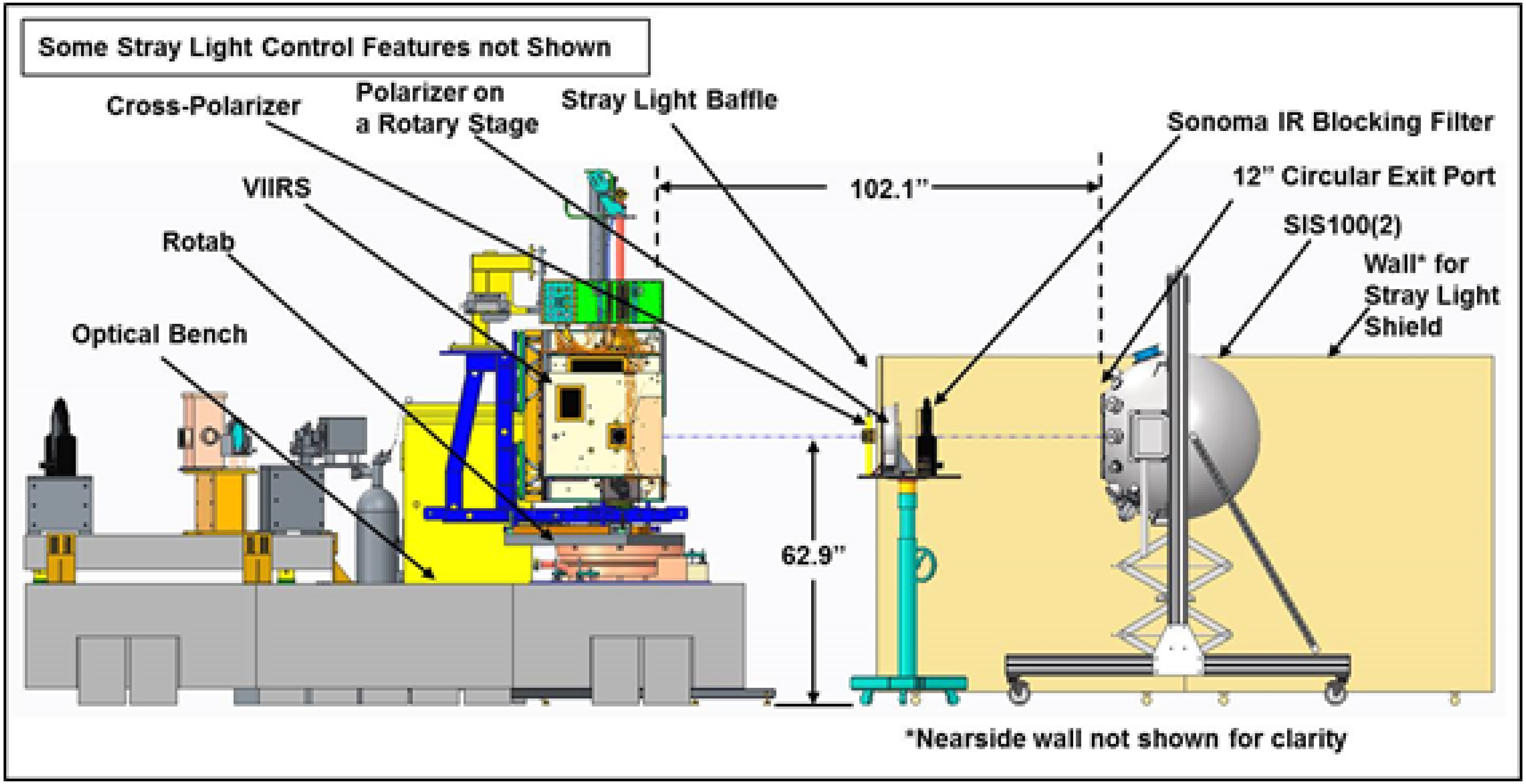
Band M6



SIRCUS – Blue symbols
SpMA – Red Symbols

Polarization Testing

Polarizer and SIS tested at NIST prior to measurements.



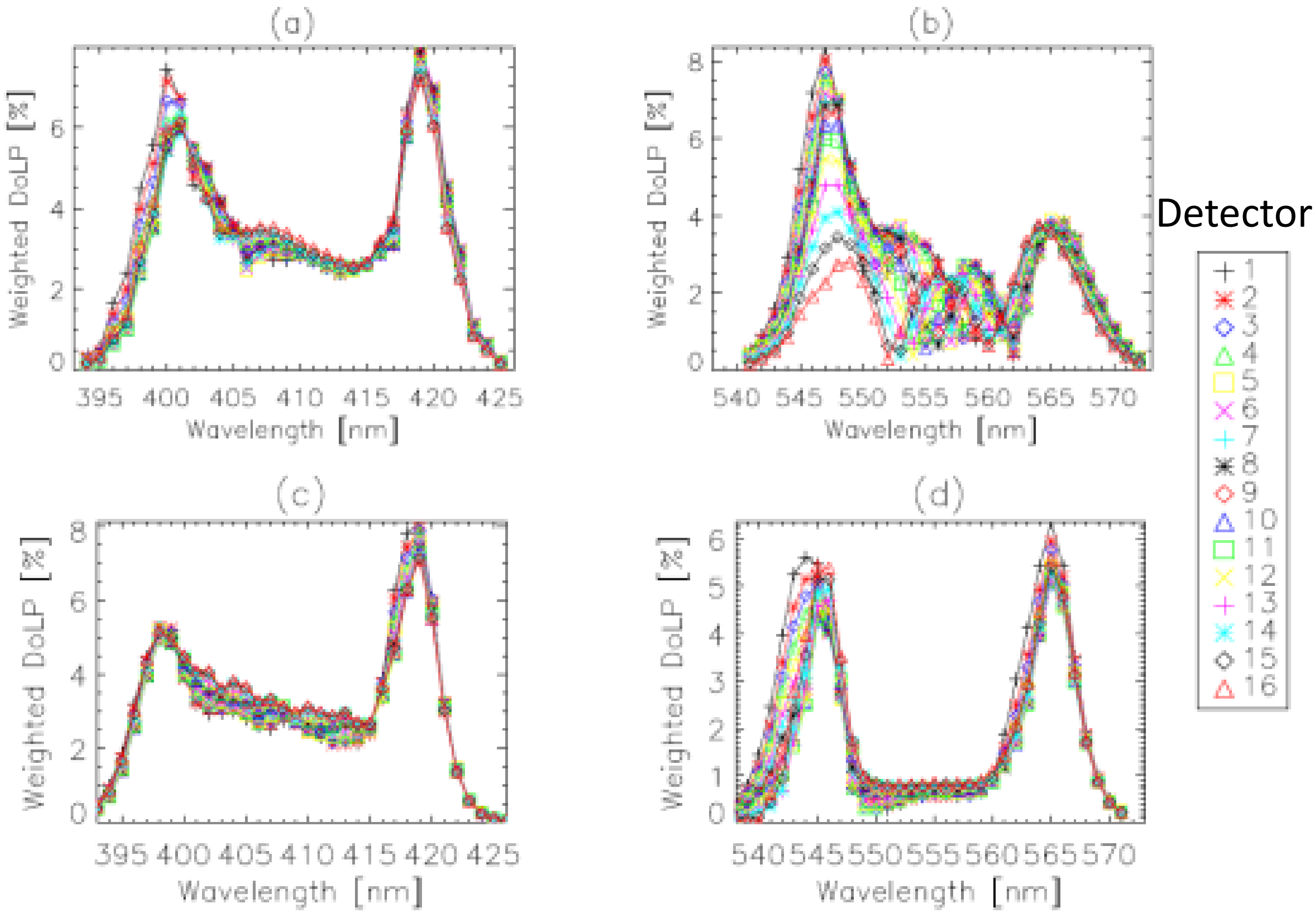
Measured DOLP at a number of scan angles, both HAM sides
Mapped out DOLP for Bands M1 and M4

Degree of Linear Polarization v Wavelength

+45 deg scan angle, HAM side 1

Band M1 | Band M4

Measured | Model



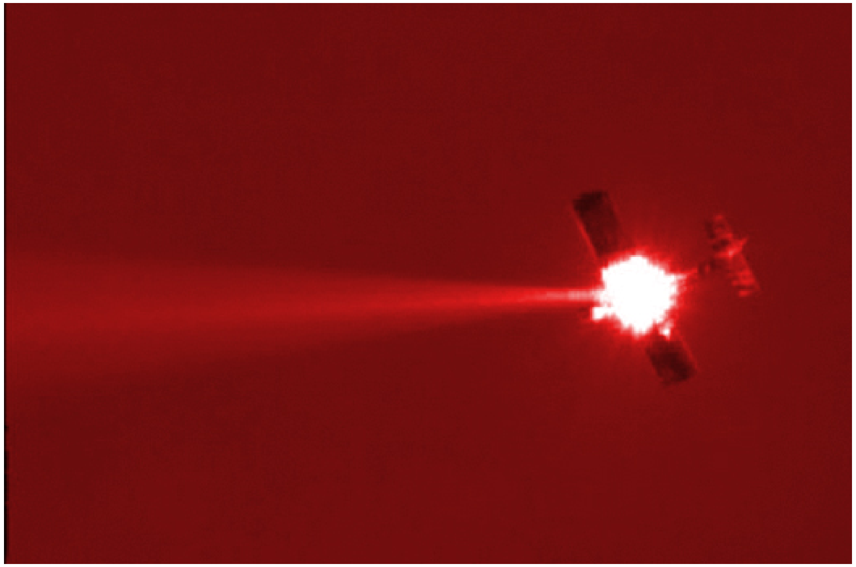
Summary

- General consensus is that the measurements went well.
  - Uncertainty in the SIS radiance 0.2 % or less (typically)
    - Good measure of band-center wavelength, detector-to-detector differences
    - Cross-talk again determined to be a small effect
  - Band ASRs (IB) uncertainty ~0.25 % or less; 5 decades OOB dynamic range
  - Observed unpredicted features in DOLP tests of Band M4
- As I understand it, T-SIRCUS measurements are planned for J2
  - Could be either the NIST T-SIRCUS or a NASA Goddard T-SIRCUS

Acknowledge Bruce Guenther, NOAA/NASA/Stellar Solutions for initiating and pushing for the T-SIRCUS measurements on SNPP VIIRS

One common response:
You want to shoot lasers at VIIRS?
You have to be kidding me!

Boeing's Matrix Laser
destroying an Air Drone

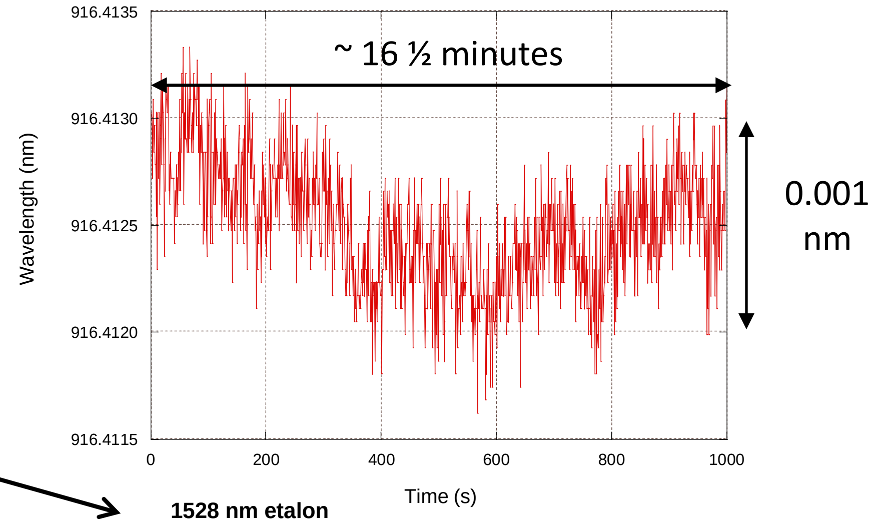


Additional Slides

LBO OPO Performance

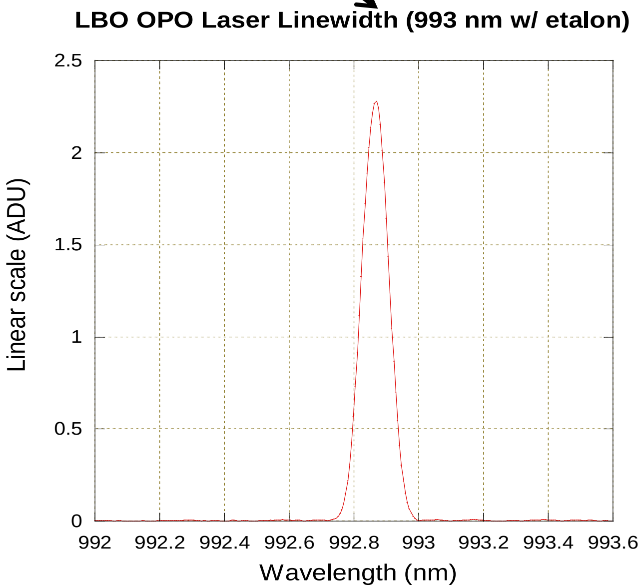
FWHM Bandpass & WL Stability

Wavelength Stability

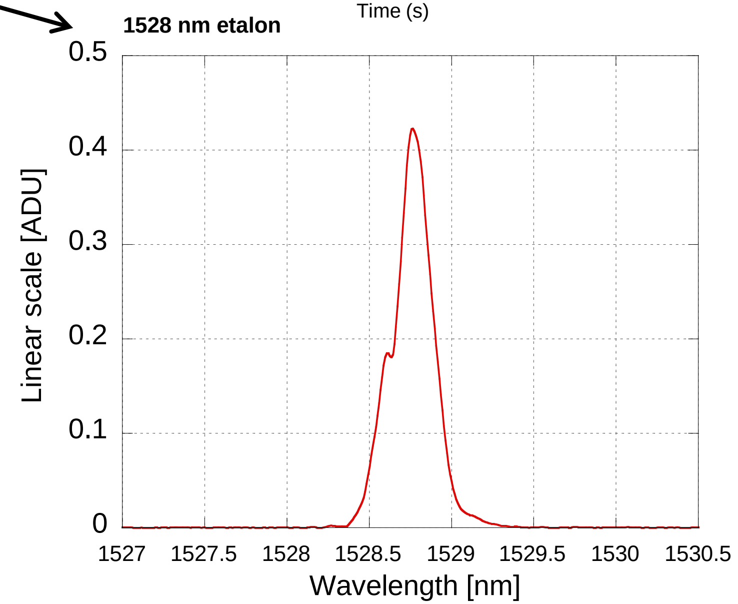


FWHM Bandpass

Signal & Idler

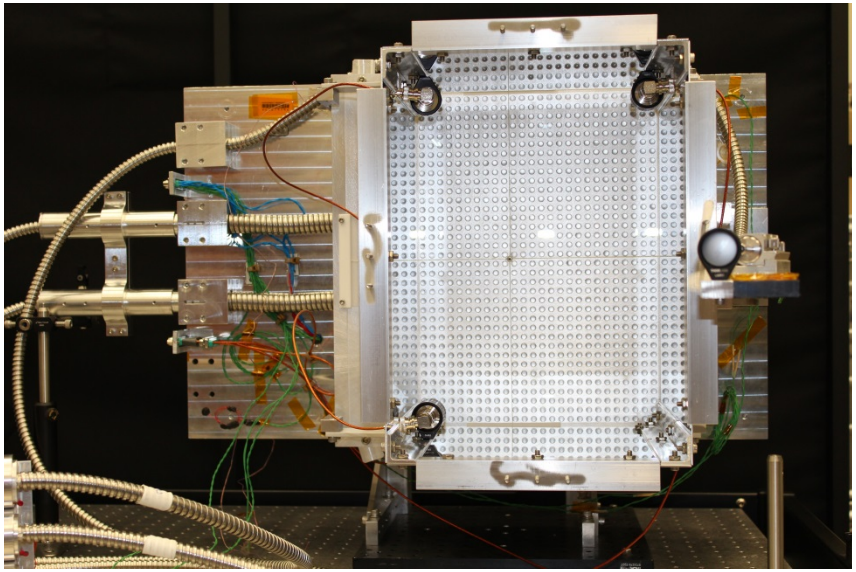


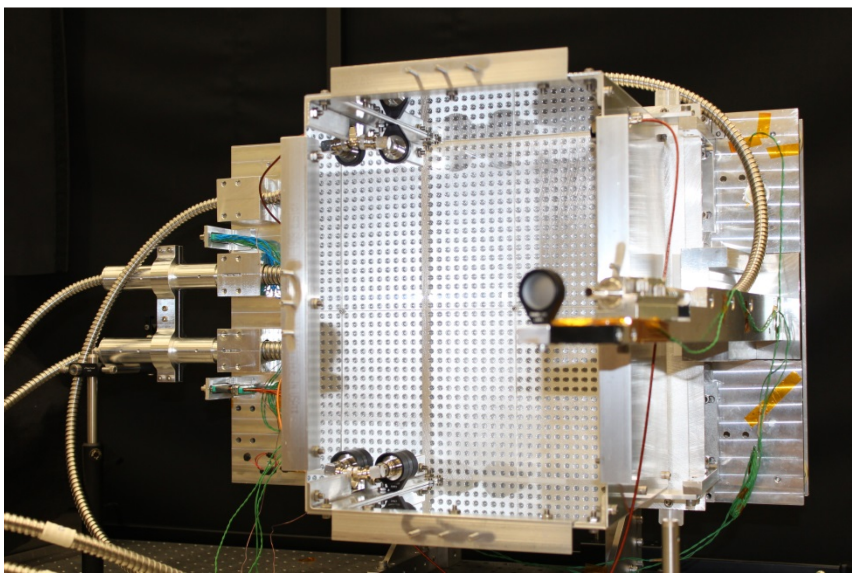
FWHM approx. 0.1 nm



FWHM approx. 0.25 nm

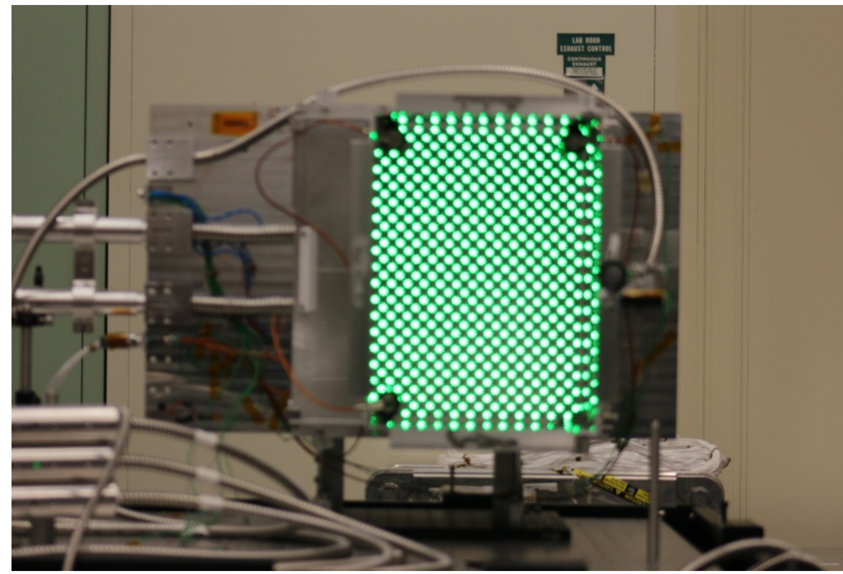
FPI Radiometric Properties





Operational Characteristics
Power In to Radiance Out

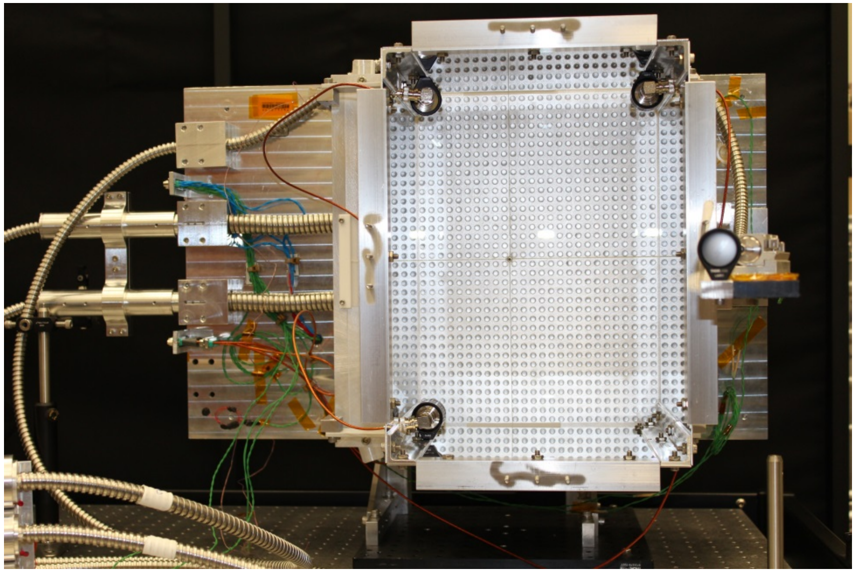
One arm illuminated@532 nm
(Camera not focused at infinity)

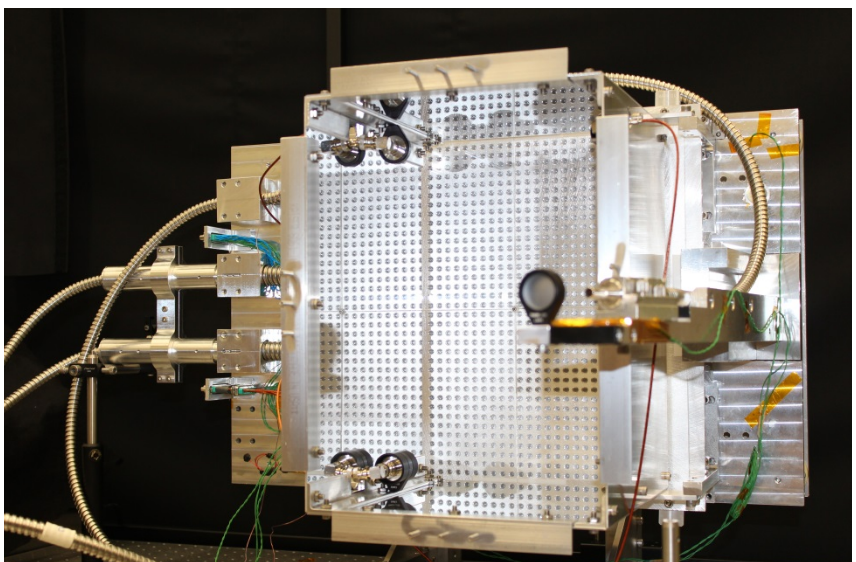


Input power to radiance conversion
L= 1.6 [W/m^2/sr]/mW @ 532 nm

Note: FPI could potentially be used in TVAC at BATC to calibrate VIIRS NIR channels

FPI Radiometric Properties





Operational Characteristics
Power In to Radiance Out

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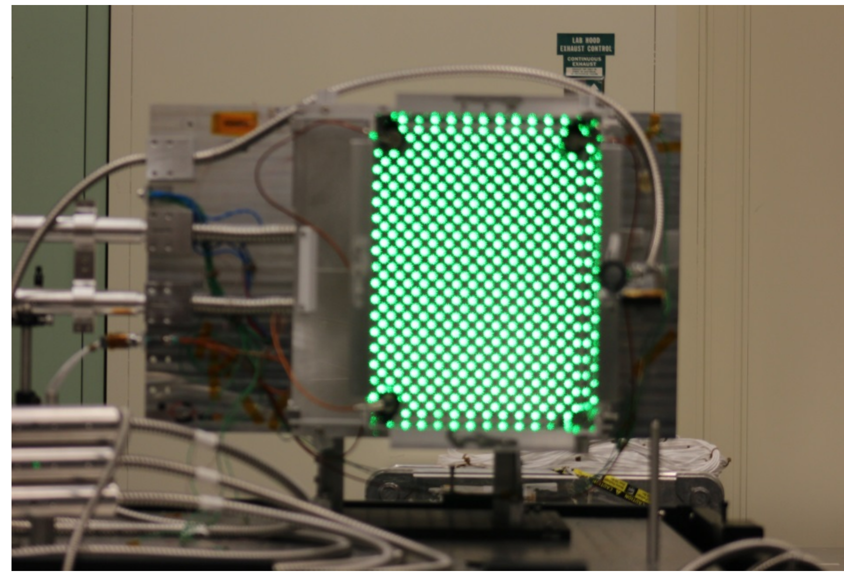
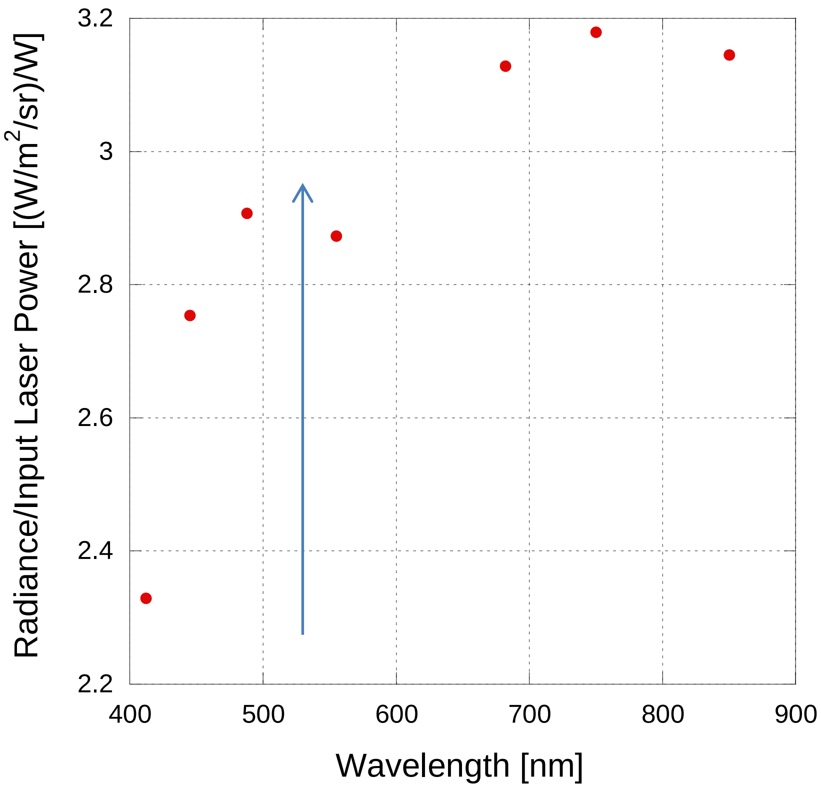


Input power to radiance conversion
L= 1.6 [$W/m^2/sr$]/mW @ 532 nm

Note: FPI could potentially be used in TVAC at BATC to calibrate VIIRS NIR channels

Compare efficiencies of SIS and FPI @ 532 nm

1-m SIS **L= 2.8 [W/m²/sr]/W** **FPI** **L= 1.6 [W/m²/sr]/mW**



- At 532 nm, FPI is approx. 500 times more efficient than the 1-m Spectralon SIS in converting Input Power to Radiance.
- For consideration: 500 mW into the SIS gives a reasonable signal for VIIRS to read. The corresponding power into the FPI is 1 mW.
- Efficient power to radiance transfer coefficient opens up other possibilities with the FPI. Lots of sources can give you 1 mW (think Supercontinuum sources or Laser-driven Arc Sources).