



# Goddard Laser for Absolute Measurement of Radiance for Instrument Calibration in the Ultraviolet to Short Wave Infrared

**Brendan McAndrew[a], Joel McCorkel[a], Timothy Shuman[b], Barbara Zukowski[c], Aboubakar Traore[d], Michael Rodriguez[e], Steven Brown[f], and John Woodward[f]**

*[a]NASA Goddard Space Flight Center, Greenbelt, MD, USA 20771*

*[b]Fibertek, Herndon, VA, USA 20171*

*[c]Ball Aerospace, Lanham, MD, USA 20706*

*[d]NASA Langley Research Center, Hampton, VA, USA 23666*

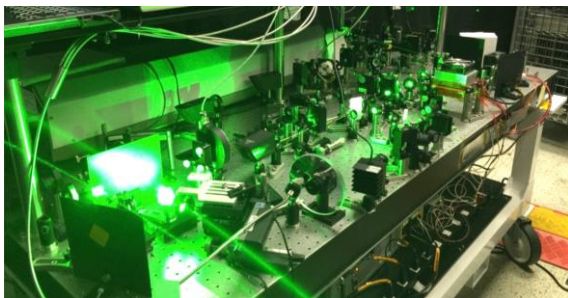
*[e]Sigma Space Corporation, Lanham, MD, USA 20706*

*[f]National Institute of Standards and Technology, Gaithersburg, MD, USA 20899*



# Introduction

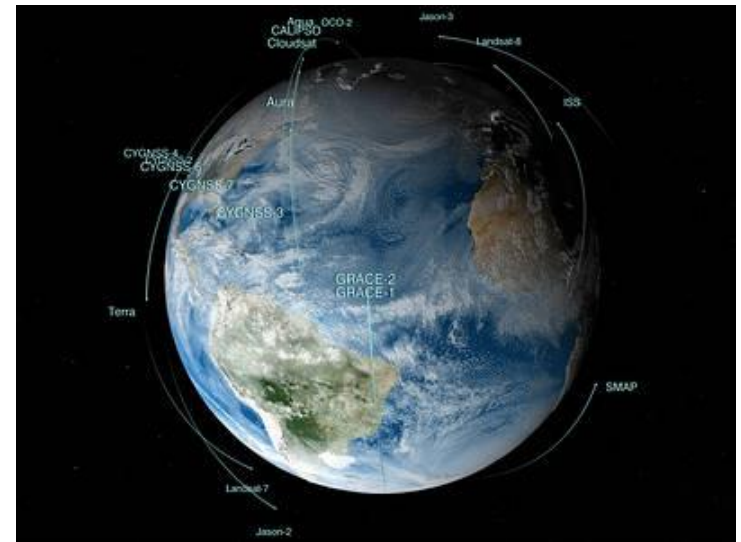
- Purpose
- Absolute radiometric scale
- Calibration scheme
- Narrow linewidth tunable sources



Light source



radiometry



prelaunch calibration for instruments



# Purpose

- Narrow linewidth, high spectral bandwidth sources provide higher signal and dynamic range, improved wavelength and radiance accuracy over broadband lamp based techniques
- More straightforward measurement and data interpretation – flat field, full signal level
- Enables more science, reduced mission lifetimes & cost



# Absolute radiometric scale

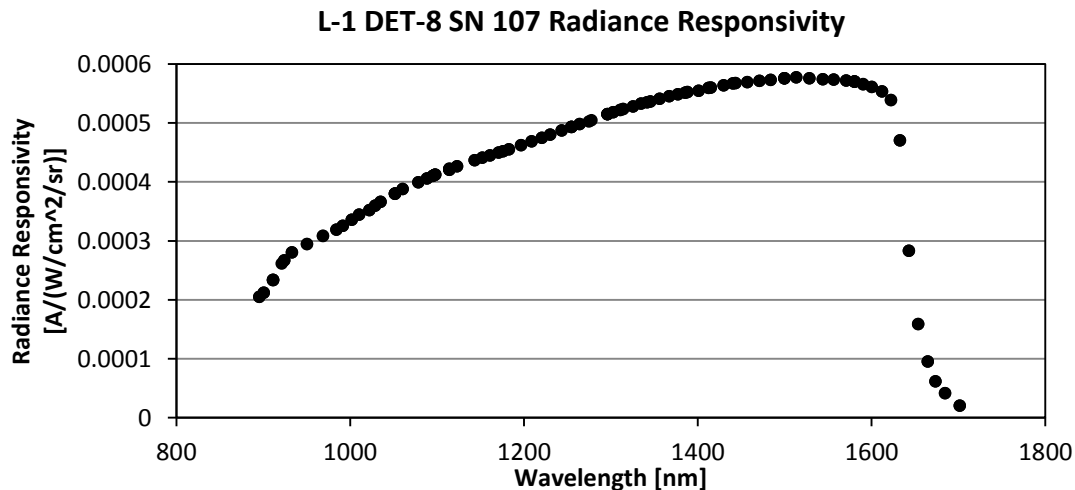
Radiance: power per unit area per unit solid angle  $L = \frac{P}{A \cdot \Omega}$

Spectral radiance: radiance per unit wavelength  $L_\lambda = L / \Delta\lambda$

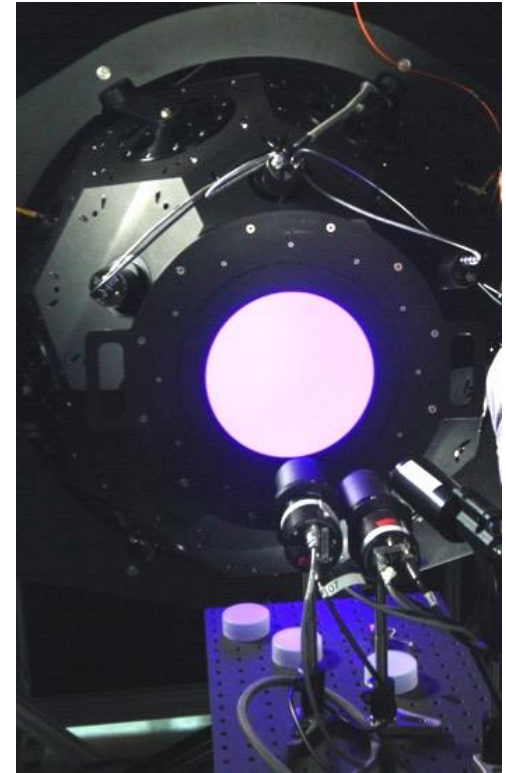
Greatest uncertainty is in optical power P

Area and solid angle are both traceable to meters

Optical power measured with electrical substitution radiometer and traceable to electrical units of measure



Narrow linewidth source eliminates error due to convolution of source spectrum with radiometer responsivity

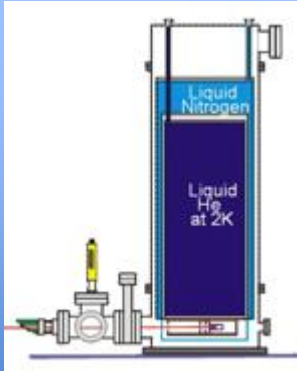


Integrating sphere with transfer radiometers

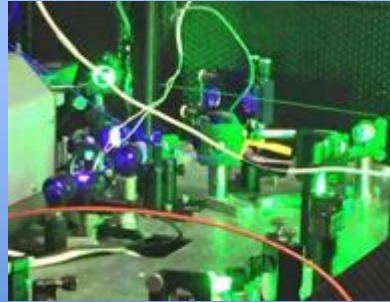


# Traceability path

**NIST Facility**



**POWR**  
Primary Optical Watt Radiometer



Stabilized laser source is used to transfer radiometric scale from POWR to portable transfer radiometer via another standard radiometer



**LTD-11 #107**  
transfer radiometer

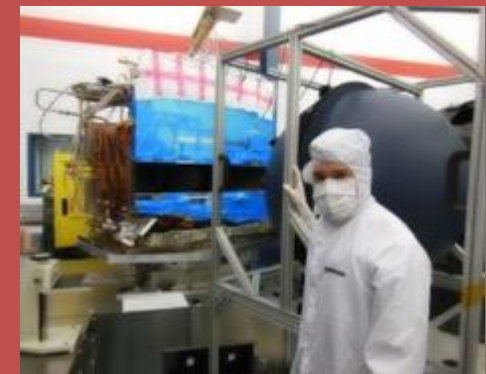
**Sensor vendor facility**



**LTD-11 #107**  
transfer radiometer



**Sphere Monitor**



**Satellite/airborne sensor**

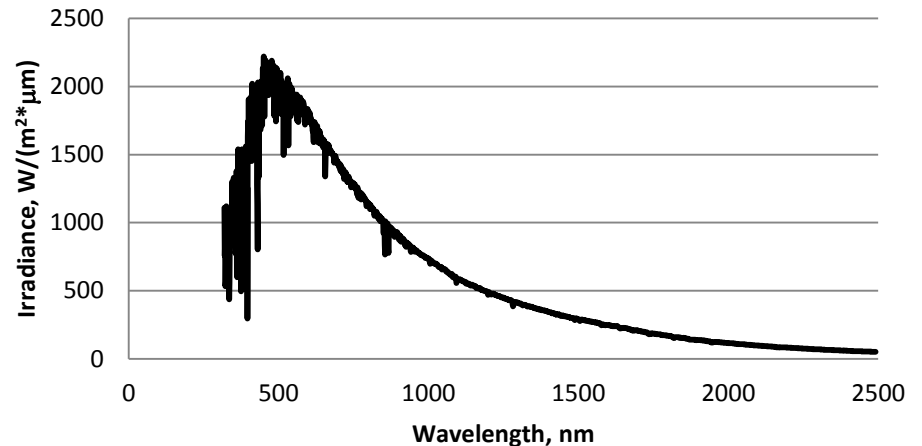


# Tunable sources

Desired properties:

- **Radiometrically stable**
- Wavelength range covering the solar spectrum, 300 to 2500 nm
- Signal level comparable to maximum reflected solar radiance (snow and cloud cover at high sun angles)
- Linewidth  $\ll$  instrument under test
- Portability, minimal setup and facility infrastructure requirements
- Time efficiency: automated wavelength tuning, synchronized tuning with shutter cycling, instrument data collects
- Reliability: critical path operations

Solar spectrum



Lamp/monochromator  
Titanium sapphire  
Dye  
Tunable diode  
Optical parametric oscillator



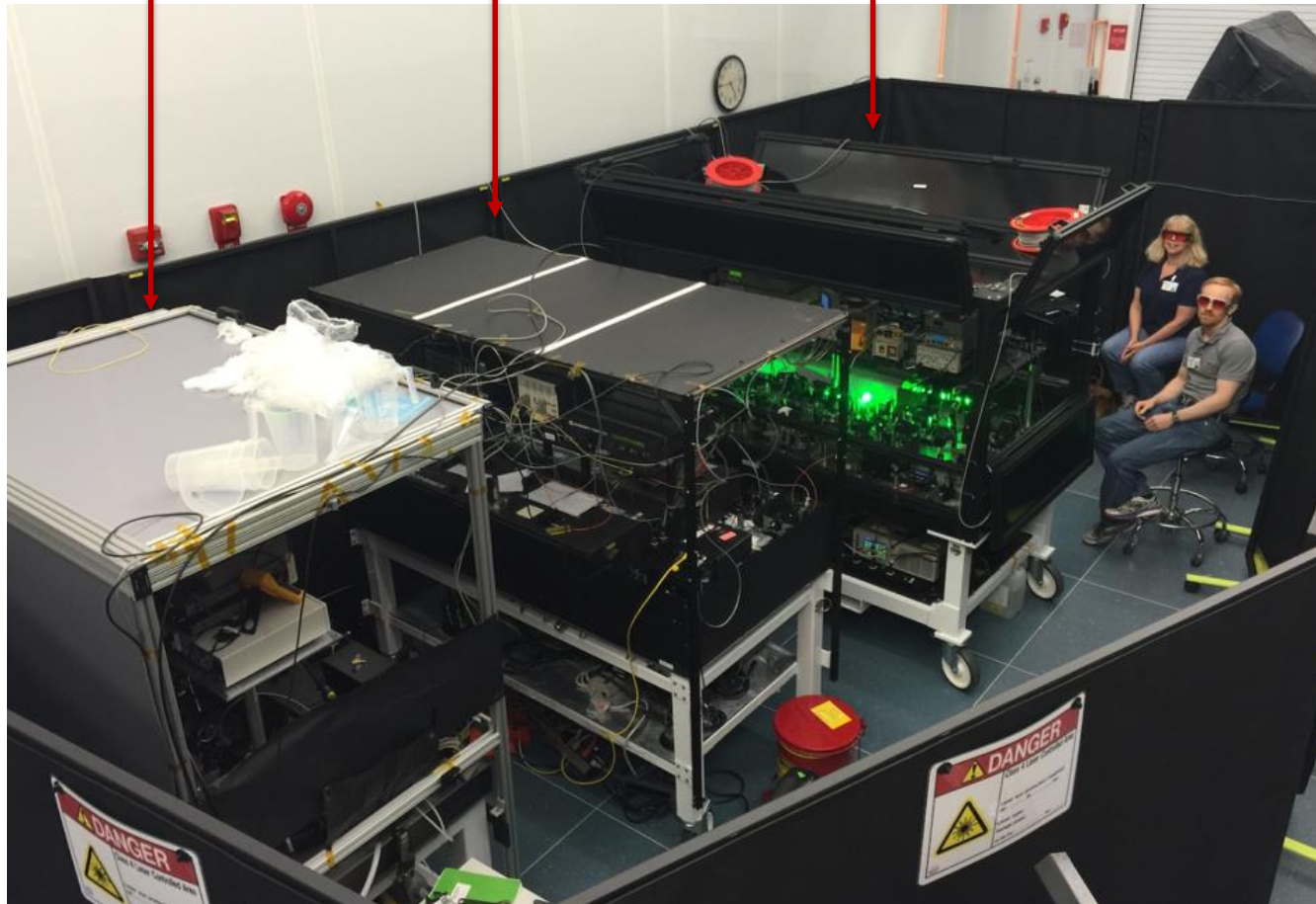
# Sources setup for JPSS-2

Dye  
570 to 680 nm

Ti:sapphire  
680 to 1000 nm

OPO  
Second harmonic: 360 to 570 nm  
Signal and idler: 720 to 2000 nm

Joint Polar Satellite System 2  
Visible and Infrared Imaging  
Radiometer Suite calibration

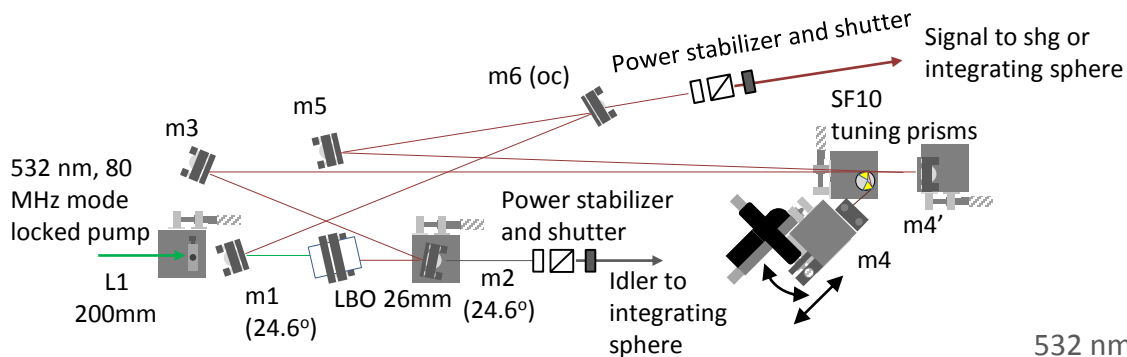


Combination of tunable  
sources covering 360 to  
2000 nm

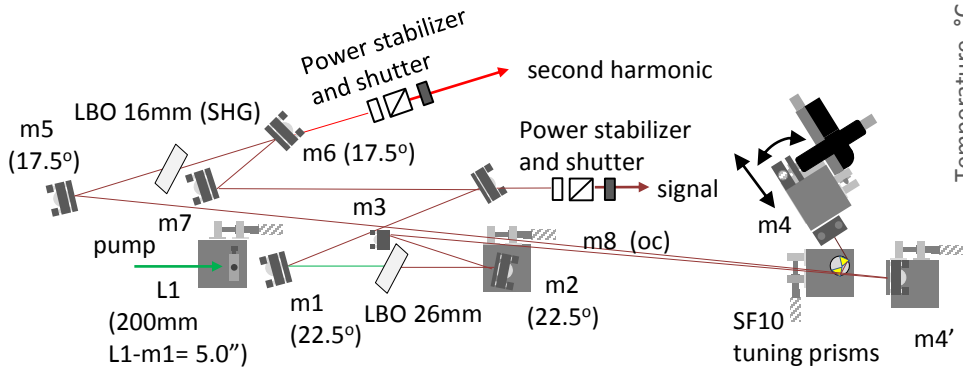


# Custom LBO OPO

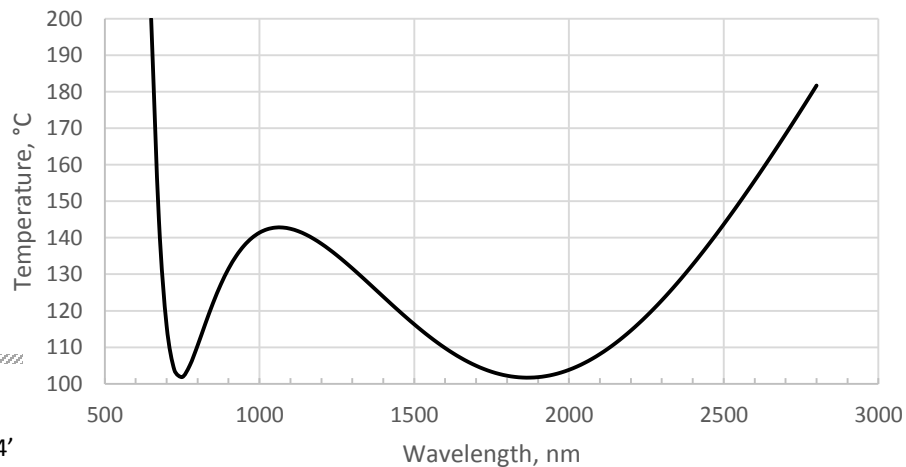
## NIR-OPO 680-1100 nm + 1200-2200 nm



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



532 nm pumped LBO OPO temperature tuning (e→o+o)





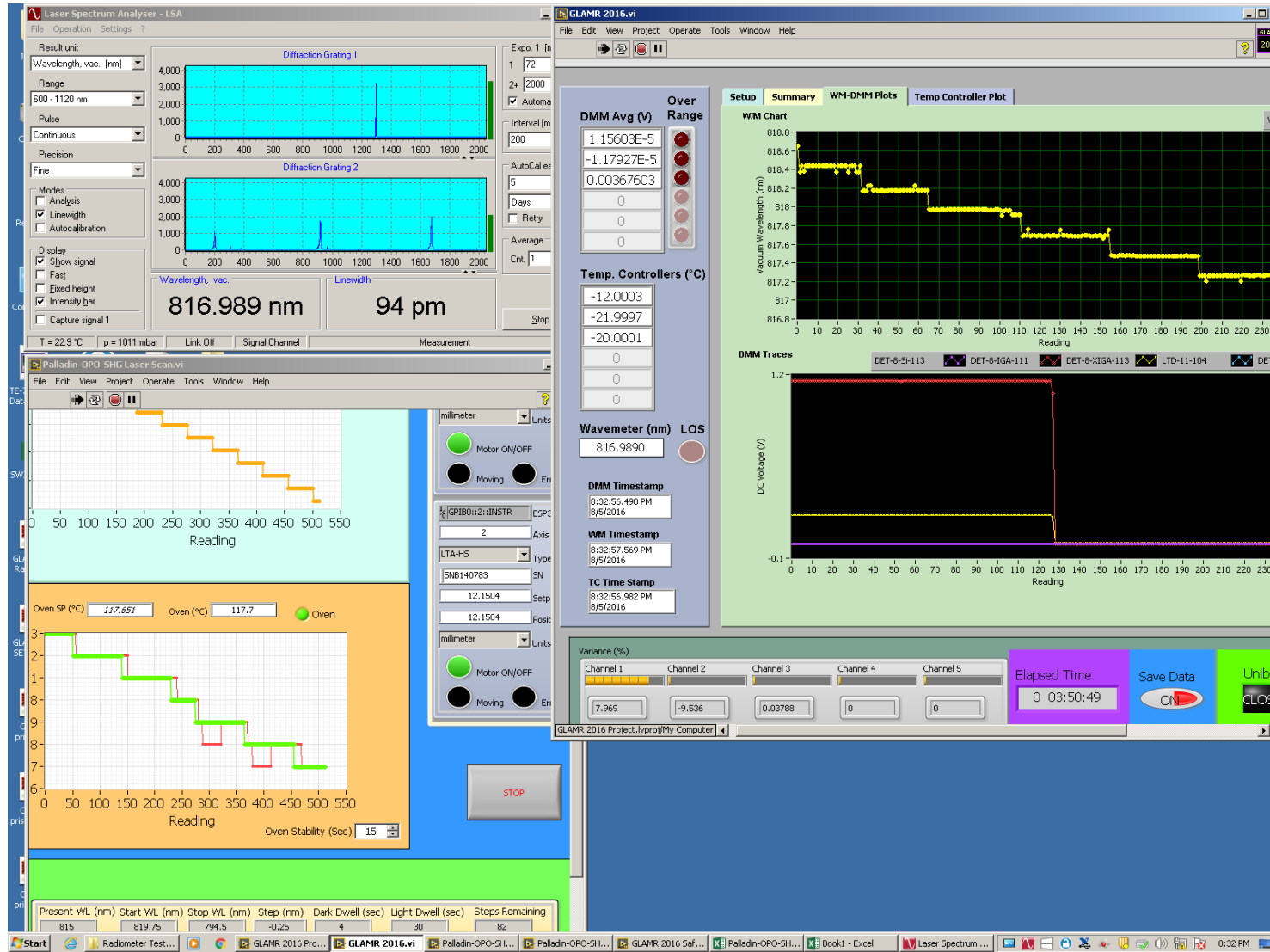
# Automation

Real time display + recording of wavelength, radiance, shutter state, and OPO parameters

Light and dark dwell time

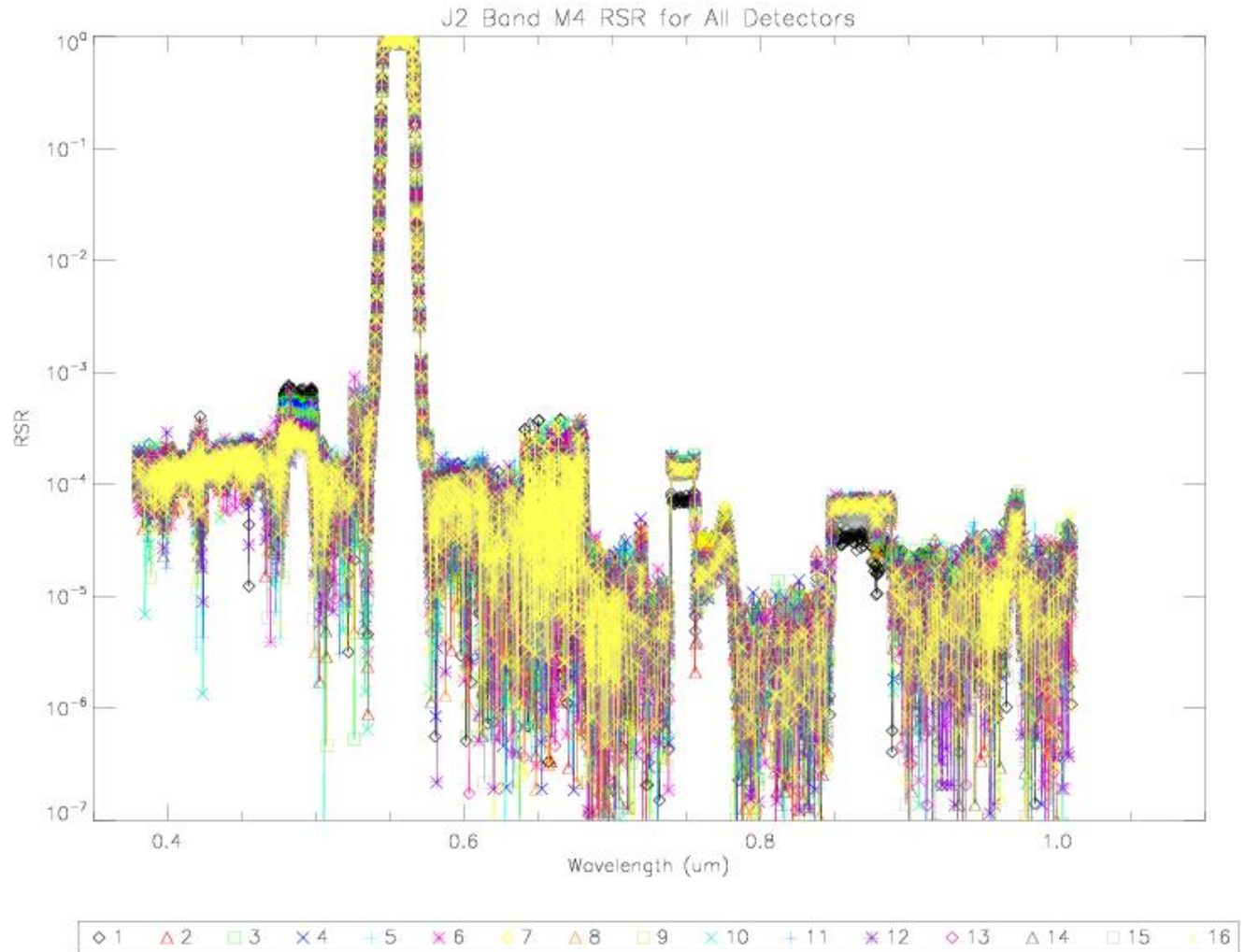
Scan wavelength interval

Automated tuning via parameter look up table





# Example calibration data

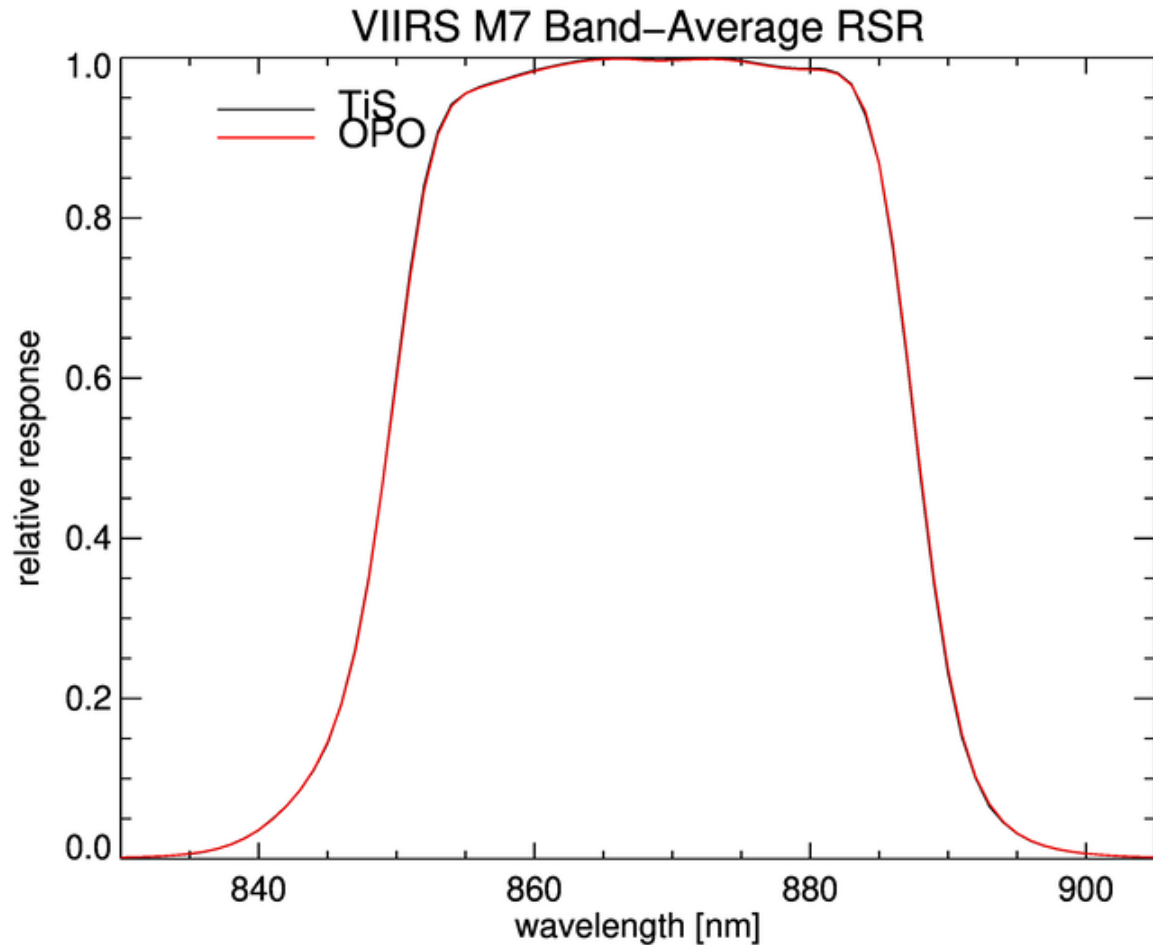


VIIRS band M2 showing electronic crosstalk with other bands



# Quasi-CW & CW sources

Integrating sphere provides temporal as well as spatial averaging with characteristic time on the order of nanoseconds



Comparison of 80 MHz prf OPO and continuous wave Ti:sapphire laser used as sources for VIIRS band M7 calibration



# Future work

- Deeper UV coverage
- Improved operation near degeneracy and water vapor absorption lines
- More repeatable wavelength steps, order of 0.1 nm
- Long term stability and decreased operator intervention during scans
- More power





# Summary, acknowledgements

Broad band optical parametric oscillator developed covering 360 to 2000 nm  
Automated scanning  
Demonstrated portability without realignment  
Ability to support critical path instrument calibration

## Technical Support

Based on design work and built with assistance from the late Keith Lykke, NIST

## Support

GOES-R

NPP

SAGE III – ISS

Landsat

PACE Ocean Color Instrument

CLARREO Pathfinder

Joint Polar Satellite System



PATHFINDER

