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 $\rightarrow$ radiometry $\rightarrow$ 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 $L = \frac{P}{A*\Omega}$

Spectral radiance: radiance per unit wavelength $L_\lambda = \frac{L}{\Delta \lambda}$

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
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 << 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**

- 532 nm, 80 MHz mode locked pump
- L1 200mm
- LBO 26mm
- 5.0"
- m1 (24.6°)
- m2 (24.6°)
- Power stabilizer and shutter
- m6 (oc)
- SF10 tuning prisms
- m4'
- Signal to shg or integrating sphere
- m3
- m5

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

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

- LBO 16mm (SHG)
- m5 (17.5°)
- m7
- pump
- L1 (200mm L1-m1= 5.0"
- m1 (22.5°)
- LBO 26mm
- m2 (22.5°)
- Power stabilizer and shutter
- m3
- m6 (17.5°)
- Power stabilizer and shutter
- m8 (oc)
- Signal
- m4'
- SF10 tuning prisms
- m4'
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

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

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