Advanced Radiometric Sources for Ocean Color

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Introduction

Solid State Innovations extended to Radiometry

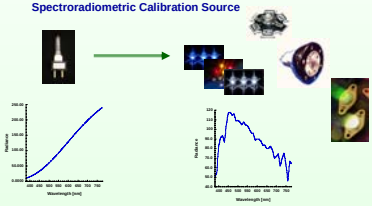
LED-based calibration sources

Solid-state LED sources have advantages over conventional tungsten lamp-illuminated sources:

- ✓ Controllable output 350 nm to >900 nm;
- ✓ Higher flux in UV and blue;
- ✓ Compact, light-weight, low power consumption;
- ✓ Good temporal stability;
- ✓ Shock resistant;
- ✓ Provides a great deal of flexibility in source design;
- ✓ Enables derivation of sources with unique spectral distributions.

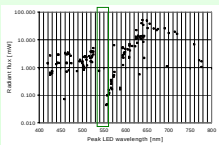
Tunable Solid-State Source Development

Spectroradiometric Calibration Source

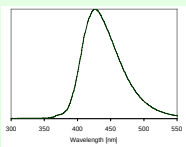


LED Characteristics

Good spectral coverage



LEDs well-matched for Ocean Color



LED Packaging Technologies

36 LEDs

Dale Wheat

50 LEDs

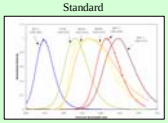
Epitex, Opto

90 LEDs

Norlux

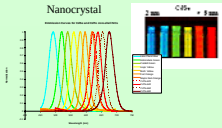
Advanced Phosphors

Standard



Poor conversion efficiency
Not well-suited for LED excitation
Each phosphor needs different color LED

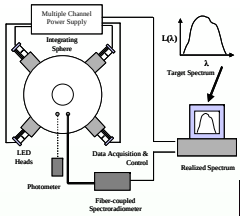
Nanocrystal



High conversion efficiency; tunable output
Common excitation LED for all colors
'Blended' phosphors for tailored spectral output

Realized Sources

NIST Tunable Solid-State Source

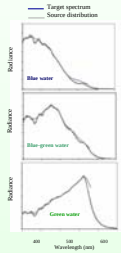


Detector-based;
Match any input spectrum within the designed operating range (spectral and radiometric)

Source radiance depends on number and type of LEDs, as well as details about the integrating sphere.

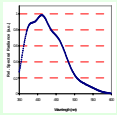
Tunable Ocean Color Source

- 40 sets of different LEDS
- Spectral coverage from 360 nm to 630 nm
- Maximum Radiance 50 to 100 W/cm³/sr



Gamma Scientific Tunable LED Source

8 Channel; 16 bit controller
Repeatability: 0.1 %
Stability: 6 months > 1 %

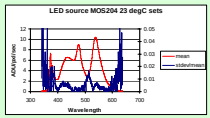


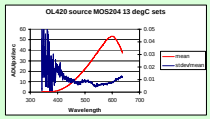
Potential Distribution

Lamp Source

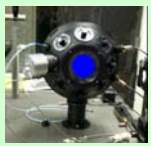
LED Source

In a proof of concept experiment, a Gamma Scientific source was measured during temperature characterizations of the MOBY sensors at the MOBY calibration site. In the region from 450 nm to below 400 nm, the measurement uncertainty was reduced about a factor of two.





NOAA Calibration Source (in development)



LEDs and Lamps in one source

- Chip-On-Board Technology
  - Up to 1440 LEDs
- Two Incandescent Lamps
- 30 cm diameter sphere
- 10 cm Exit port
- Monitors:
  - Filtered and unfiltered monitor photodiode
  - Spectrograph

Advanced Applications & On-going Research

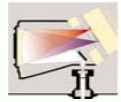
Spectrally tunable source using a dispersing element coupled with a spatial light modulator.

Basic Principle

e.g. Compact Spectrograph

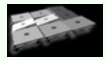
Typical design

Replace array detector with spatial light modulator



Instrument whose spectral output can be controlled

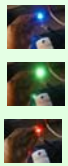
HOLOEYE'S **Spatial Light Modulator (SLM)** systems are based on Liquid Crystal Micro-displays. These devices can modulate light spatially in amplitude and phase, so they act as a dynamic optical element. The optical function or information to be displayed can be taken from the optic design directly and can be transferred by a computer interface.



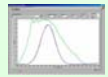
Texas Instruments Digital Micromirror Device (DMD) incorporates micromirrors mounted on tiny hinges that enable them to tilt either toward the light source in a DLP™ projection system (ON) or away from it (OFF)-creating a light or dark pixel on the projection surface.

Tidal Photonics has developed a Spectrally Programmable Light Engine (SPLE) based on DMD technology. The digital, spectrally and temporally programmable light source produces any desired spectral output, enabling advanced imaging solutions.

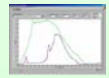
This new light source can spectrally flatten choppy sources, and produce any desired spectral distribution, and can generate high-speed, dynamic spectral color changes for multi-spectral and hyperspectral imager characterization and calibration.



Flat-Top Profile



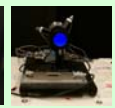
Gaussian Profile



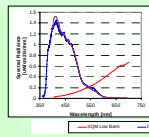
Fluorescent Lamp

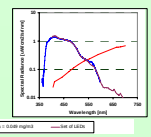
LED Field Calibrator

On-board Calibration Source



SeaWiFS Quality Monitor





Next: Development of In-water Calibrator/Illuminator

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**Commercial equipment is identified to foster understanding; it does not imply endorsement or recommendation by NIST.