a-Sphere Calibration and Quality Assurance Certificate

Date:	2011-9-25	**Lead Technician**:	DRD
Model:	SP1	**Serial Number**:	SP110411
Calibration Type:	Comprehensive	**Previous Cal:**	none, new instrument
Wavelength Range:	354 to 766 nm	**Wavelength Res.:**	≈0.35 nm/pixel

Calibration and Quality Assurance Statement

HOBI Labs certifies that this instrument has been carefully calibrated, and its functions and operating condition thoroughly tested, in strict compliance with rigorous methods in our calibration facility. Absorption values are calibrated with reference to independent spectrophotometer measurements, and to baseline values of UV-sterilized, ultra-purified water with resistivity of at least 18.2 MΩ-cm.

Test and calibration results are shown in plots on the following pages, briefly described below. Further details are available from HOBI Labs upon request.

BRIEF DESCRIPTION OF DATA AND METHODS

1. Wavelengths

The spectrometer input is illuminated with a Mercury-Argon light source, which emits narrow peaks at precisely known wavelengths. The peaks in the measured spectrum are correlated with the known wavelengths and a second-order polynomial fit is calculated to translate pixel number (from 1 to 2048) into wavelength (in nm).

2. Dark Signal Rate

Photodetector elements in the spectrometer's CCD have small leakage currents that cause signals to appear even in the absence of light. Just as with the currents caused by light exposure, these leakages cause signals that are proportional to integration time, and are expressed in digital counts per millisecond. This dark signal rate is measured for each pixel, allowing it to be subtracted from later data processing. Pixels that have unusually high dark signals are identified and excluded from processing.

3. Pixel Noise

This plot shows the standard deviation in repeated readings from each pixel, for both short and long integration times. This allows us to identify any unusually noisy pixels and exclude them from processing. It is typical for a CCD to have a few noisy pixels, and excluding them has no significant effect on routine results.

4. Integration Time Intercept and Nonlinearity Correction

With stable illumination provided by the a-Sphere's light source, the integration time is varied over a wide range, with spectra recorded at each time. In principle the measured signals should vary in direct proportion to integration time, but CCDs exhibit slight nonlinearity. The plot on the left shows output versus integration time. When extrapolated, these lines should intercept zero signal at zero integration time. Any significant offset would indicate a timing problem. The plot on the right shows deviation from a linear relationship between signal and integrated illumination over the entire signal range. Deviations are measured and fit with an additive correction function (ACF). The ACF is added to future raw signals to compensate for this nonlinearity.

5. Individual LED Spectra

The a-Sphere's light source is an array of LEDs, each with a characteristic spectrum. This plot shows the spectra of all LEDs in the arry, normalized to a uniform peak value. In practice, the LEDs are adjusted to produce a smooth composite spectrum as shown in the next plot.

6. Pure-water and Air Reference Spectra

The outputs of the individual LEDs are adjusted so as to produce a spectrum optimized for in-situ measurements. The spectrum is adjusted higher at shorter wavelengths to complement natural absorption spectra that attenuate those wavelengths more. Wavelengths above 700 nm are also set to higher power to overcome water's high inherent absorption at those wavelengths. This produces a high peak in the near-IR spectrum in air, but flattens the spectrum in water.

7. Absorption Spectrum of Calibration Dye

Absorbing dye is used as the reference material for calibrating the a-Sphere's response to absorption. The absolute absorption spectrum of each batch of dye is measured with a benchtop spectrophotometer. This plot shows the specific absorption of the dye in units of inverse meters per concentration in grams per liter.

8. Response to Absorption

Water is circulated through the a-Sphere while precisely measured quantities of the dye shown in figure 7 are added. This produces a characteristic curve of output versus absorption for each pixel (wavelength). In this figure, each curve represents a 10 nm bandwidth, with the color corresponding to the measurement wavelength (black represents UV; near-IR wavelengths are shown as deep red).

9. Absorption Calibration Functions

From the data shown in Figure 8, a best-fit polynomial function is calculated that maps measured signal to calibrated absorption. A separate fit is calculated for each pixel. This plot shows selected pixels at 10 nm intervals, with color corresponding to wavelength.

10. Residual Fitting Error

This plot shows the difference between the polynomial fits and the actual measurements. The residual error is typically well below 1%, as shown.

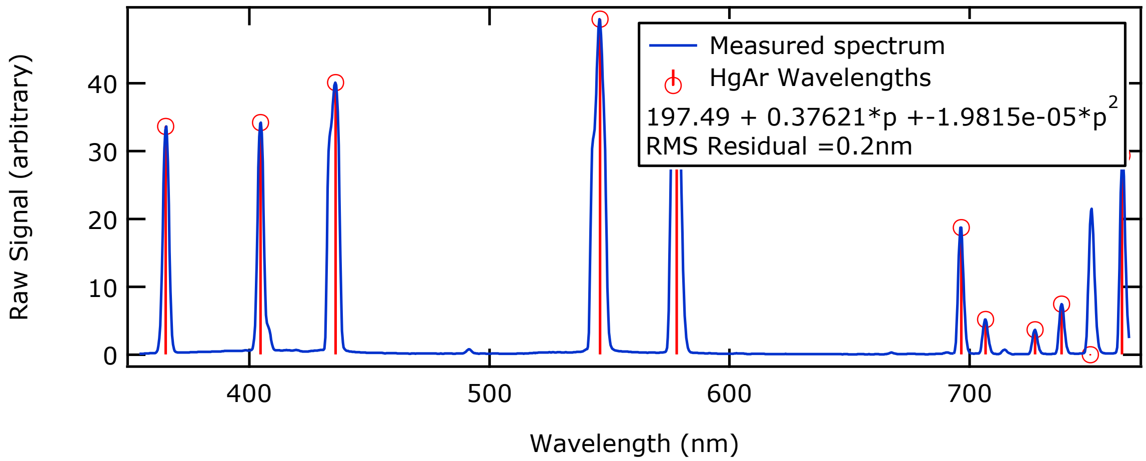
11. Incremental Path in Pure Water

This plot shows the effective path length for an infinitesimal change in absorption. Because of multiple reflections within the spherical cavity, the effective path length is much larger than the diameter of the cavity. The magnitude of the multiplying effect at a particular wavelength is a function of the absorption, so this curve is lower when absorption is higher. For the same reason, the shape of this curve is closely related to the absorption spectrum of water itself.

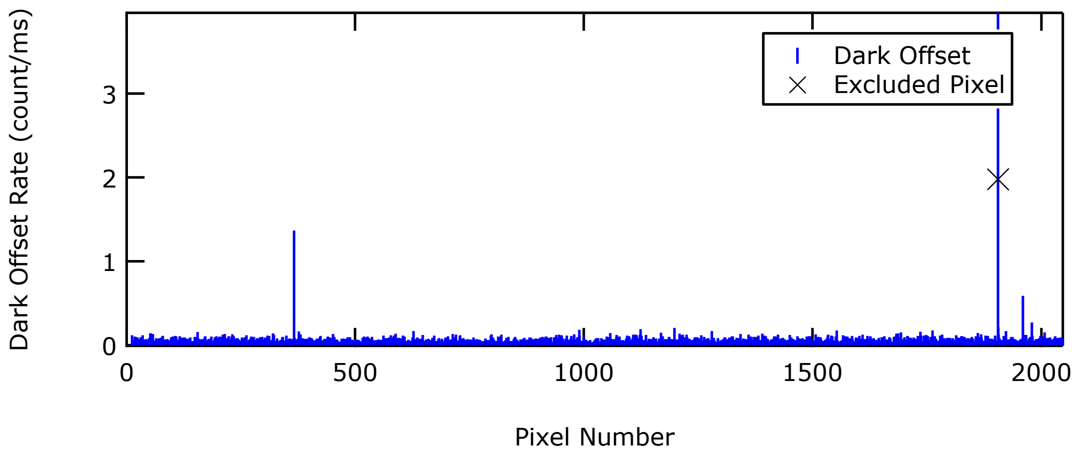
12. Pressure Transducer Calibration

The entire instrument is immersed and pressurized up to the limit of its internal pressure transducer, while the pressure is simultaneously measured by a separate calibrated transducer. A linear fit produces a coefficient for converting raw digital counts to meters of salt water .

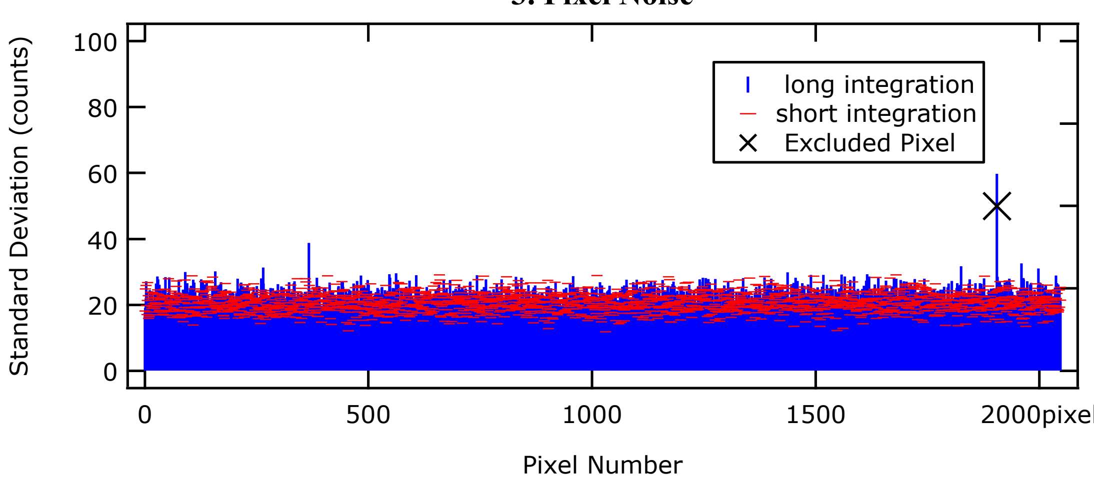
1. Wavelength Calibration



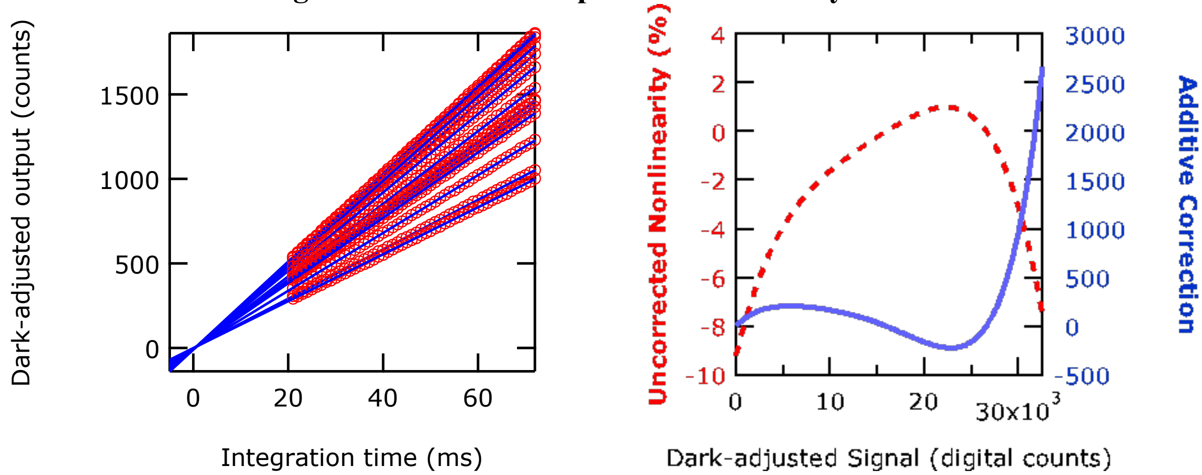
2. Dark Signal Rate



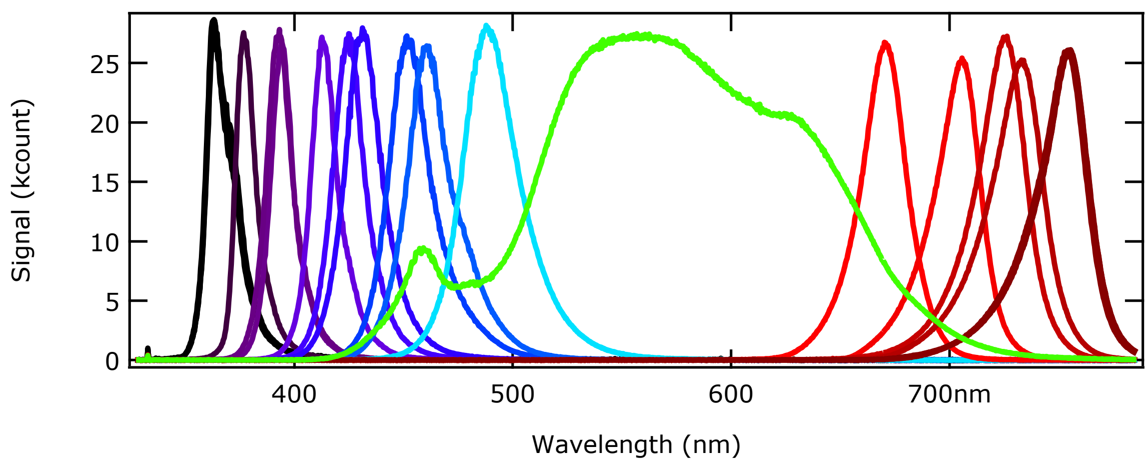
3. Pixel Noise



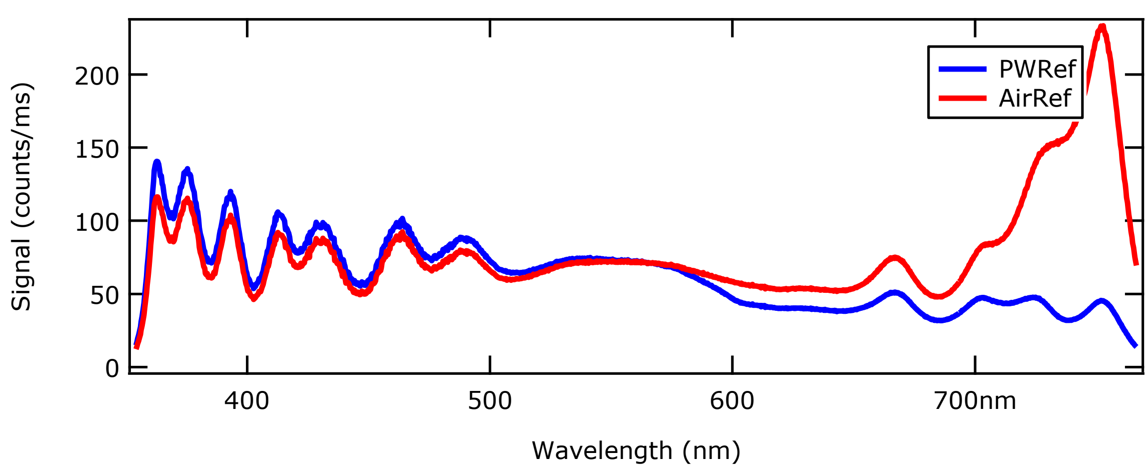
4. Integration Time Intercept and Nonlinearity Correction



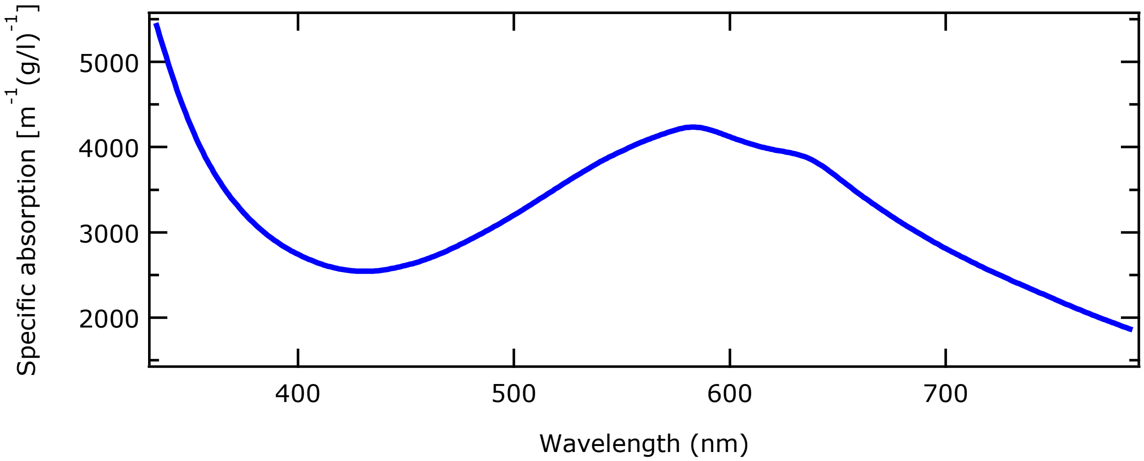
5. Individual LED Spectra



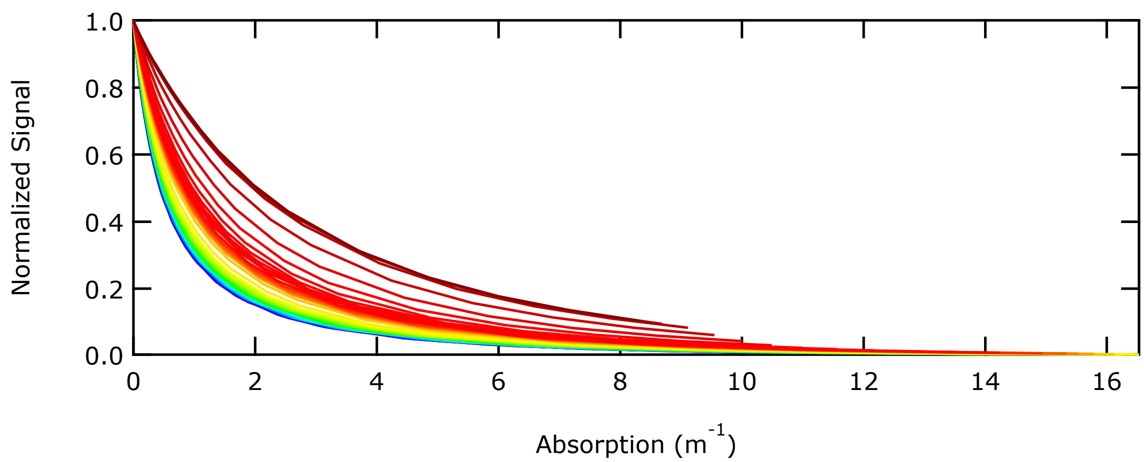
6. Pure-water and Air Reference Spectra



7. Absorption Spectrum of Calibration Dye



8. Response to Absorption



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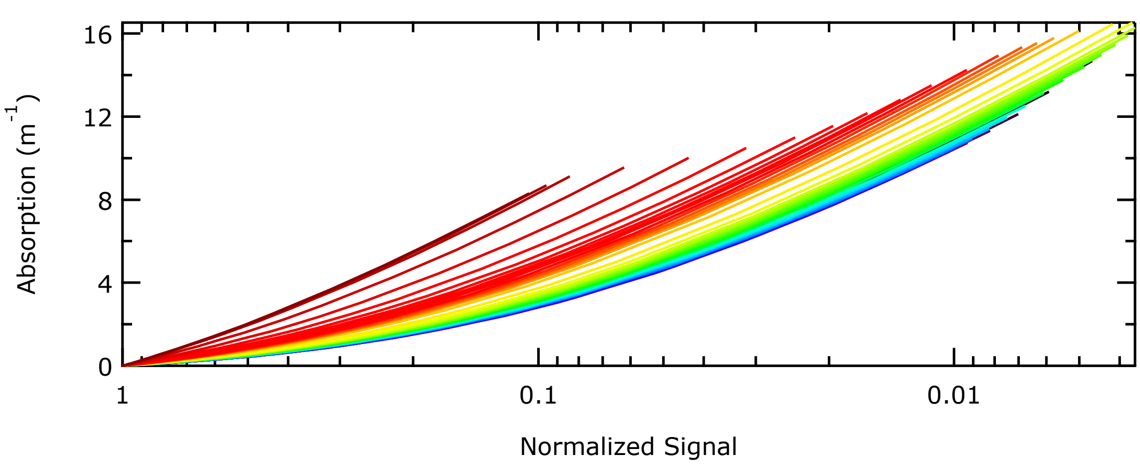
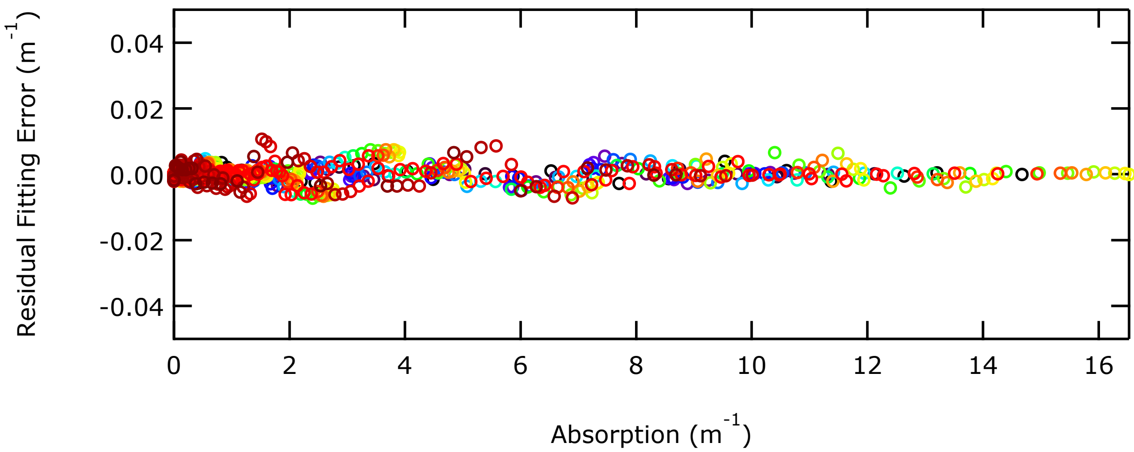
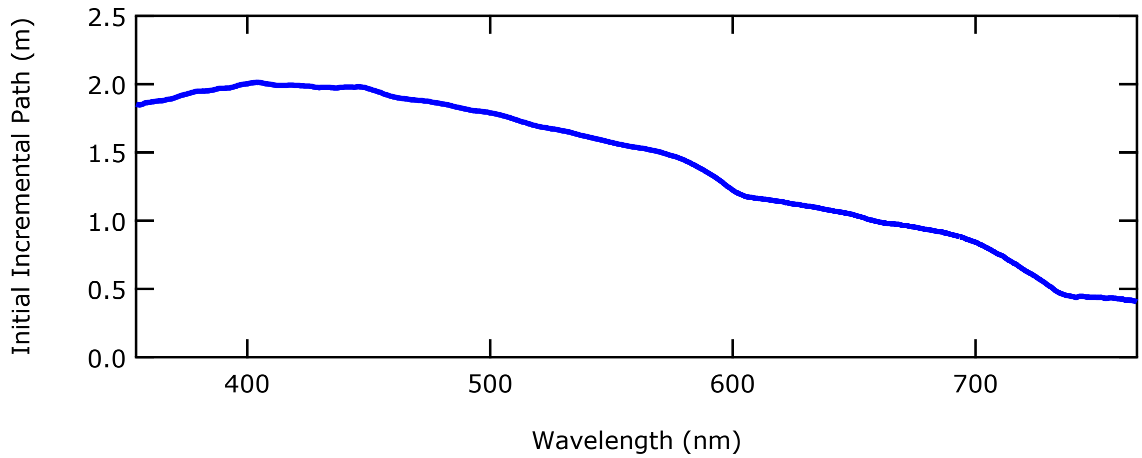


10. Residual Fitting Error



11. Incremental Path in Pure Water



12. Pressure Transducer Calibration