CubeSat spectroradiometer calibration with a laser-based tunable radiance source

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We have developed an SI-traceable laser-based tunable radiance source for the calibration of spectroradiometers. As a demonstration of the calibration method, a CubeSat spectrometer has been calibrated for radiance in the UV-VIS wavelength range. For comparison, the spectrometer has also been calibrated with a traditional setup based on a calibrated diffuser and a FEL lamp. Both routes show good agreement within the combined measurement uncertainty. The laser-based approach could be an interesting alternative to the traditional method, not only because of reduced measurement uncertainty, but also because it directly allows for characterization of the instrumental spectral response function and stray light effects, reducing calibration time and cost.

INTRODUCTION

SI-traceable calibration of satellite instruments, such as spectroradiometers, gets increasingly important in space-based observation for various reasons. First, requirements on measurements in terms of accuracy, dynamic range and wavelength range get more and more demanding. Second, long-term observations require SI-traceability for comparability of data records that are acquired over a long time-interval (decades) and with different instruments. Traditionally, radiance response calibration is performed with a FEL lamp, combined with a calibrated diffuser as a radiance source. The disadvantages of such a source are the limited lifetime of the FEL lamp and its large spectral width. Additional measurements are therefore required to determine stray light characteristics and the instrumental spectral response function (slit function) of the spectroradiometer.

In this contribution we present the application of a laser-based tunable radiance source for the calibration of spectroradiometers. Such sources have been shown to be an interesting alternative to lamp-based sources, as e.g. demonstrated for the calibration of spectral (ir-)radiance responsivity of detectors [1]. As demonstration of the calibration method, a CubeSat spectroradiometer (TROPOLITE BB, TNO [2]) has been calibrated in the UV-VIS wavelength range with this source. For comparison the spectroradiometer has also been calibrated with a radiance source based on a FEL lamp and a diffuser.

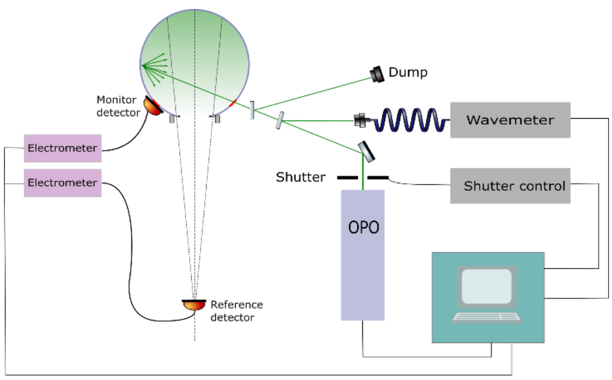

Figure 1. Schematic of laser-based radiance source.

SPECTROMETER CALIBRATION WITH A LASER BASED RADIANCE SOURCE

The radiance source consists of a 30 cm-diameter integrating sphere, that is fed with the light from a tunable nanosecond optical parametric oscillator (OPO) offering a wide tuning range (210 nm – 2400 nm). The integrating sphere is equipped with a monitor detector to measure the irradiance at the sphere wall, accounting for any potential source instability. A schematic of the setup is shown in **Figure 1**. More details on the design requirements can be found in [3]. The radiance source is calibrated with a reference detector that is positioned at a well-defined distance from the sphere aperture (**Figure 2**). Both the reference detector and the integrating sphere are equipped with calibrated apertures. The radiance emitted from the integrating sphere's exit aperture is determined from the measured flux and the geometry of the system. This calibration is performed as a function of wavelength by tuning the laser. The signals from reference detector and monitor detector are measured simultaneously with a charge meter, thus linking the emitted radiance from the sphere aperture to the monitor detector signal. Charge meters are used here because of the pulsed nature of the source [1].

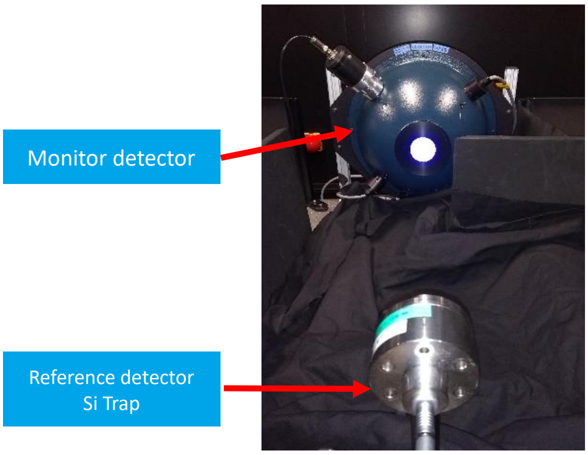

Figure 3. Setup for the calibration of radiance from the integrating sphere with a reference trap detector.

As an additional check of the method and to estimate residual stray light effects, the calibration of the source has been performed at 2 positions of the reference detector (50 cm and 75 cm from the source). The measured radiance at both positions agrees within 0.2% for wavelengths ranging from 250 nm to 950 nm. Here the reference detector is a Si trap detector traceable to the absolute cryogenic radiometer of VSL. The total measurement uncertainty of the source radiance calibration is preliminary estimated to be about 1%.

The TROPOLITE spectroradiometer has been calibrated with the laser-based radiance by positioning it in front of the radiance source (replacing the reference detector in **Figure** 2). The calibration is performed by tuning the OPO from 370 nm to 480 nm in steps of 10 nm. The measurement range is determined by the operating range of the TROPOLITE instrument. For each wavelength setting a set of images is acquired by the spectroradiometer, while the current from the monitor detector is measured simultaneously.

VALIDATION OF THE METHOD

To validate the laser-based method, a traditional calibration of the TROPOLITE instrument has been performed with a FEL lamp with a setup schematically shown in **Figure 3**. The FEL lamp has been calibrated by VSL for spectral irradiance with an uncertainty of (2% - 3%, k=2, wavelength dependent). To convert the lamp irradiance into radiance a diffuser is used. The diffuser has been applied for several satellite instrument calibrations and has been thoroughly characterized. The calibration has been performed for various distances between FEL lamp and diffuser. A preliminary analysis of the TROPOLITE calibration data shows that the traditional method and the laser-based method agree within 1-2% over the full wavelength range.

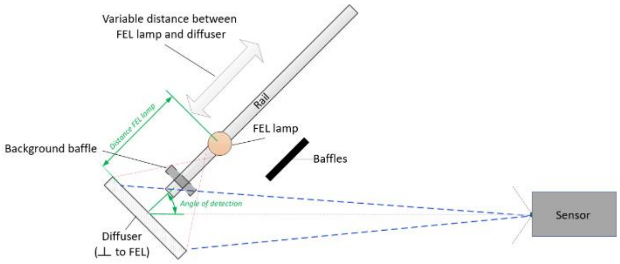

Figure 2. Schematic of a setup for calibration of a spectroradiometer (the sensor on the right-hand side) with an FEL lamp and a diffuser.

CONCLUSIONS

We have developed a tunable laser-based radiance source, which was successfully applied for the calibration of a CubeSat spectroradiometer. The results were validated by comparison with a traditional FEL lamp-based calibration. The laser-based approach not only delivers radiance calibration, it also offers the opportunity to simultaneously measure other instrument characteristics such as stray-light effects and the instrument spectral response function.

This work was funded by the European Metrology Programme for Innovation and Research (EMPIR), Project 16ENV03, MetEOC-3, 'Further metrology for Earth Observation and Climate'. EMPIR is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States.

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