KALIBREERIMISTUNNISTUS
CALIBRATION CERTIFICATE

EAK EN ISO/IEC 17025 K025

Tunnistuse nr ja kuupäev: *Certificate No and Date:*	K8-008-25 / 2025-02-12
Tellimuse nr ja kuupäev: *Order No and Date:*	T8-024-24 / 2024-10-14
Tellija: *Customer:*	School of Marine Sciences, University of Maine 5706 Aubert Hall, Orono, ME 04469-5706, USA
Mõõtevahend: *Measuring instrument:*	Hyperspectral radiometer
Tootja: *Manufactured by:*	Satlantic Inc., Canada
Tüüp: *Type:*	HyperOCR
Seerianumber: *Serial number:*	370
Kalibreeritud: *Date of Calibration:*	2024-10-29
Meetod: *Method used:*	M804:28.02.2022 – Calibration of radiometers. Irradiance

Allkirjad:
Signatures:

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Labori juhataja *Head of Laboratory*

Ilmar Ansko
Koostaja(d) *Compiled by*

Dokument koosneb kalibreerimistunnistusest 3 lehel ning on välja antud ühes (1) allkirjastatud eksemplaris.
The document consists of a Calibration Certificate on 3 pages in one (1) signed copy

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1. Kalibreerimisvahendid *Calibration equipment*

1. Quartz tungsten halogen lamp FEL-TO-1, Tartu Observatory, Estonia, S/N 7
2. Shunt resistor 10 mΩ, P310, S/N 009009
3. Multimeter (shunt and lamp voltage) Agilent 3458A, S/N MY45043877
4. Power supply for lamp L.O.T.-Oriel GmbH 69935 / LSN 597, S/N 166
5. Contactless distance probe LTO-1, (500.0±0.1) mm, S/N 001
6. Optical rail in light tight enclosure
7. Alignment laser XCL S/N 001

2. Jälgitavus *Traceability*

The measurement results are traceable to the units of SI through the standards of national metrology institutes: the quartz tungsten halogen lamp is calibrated at Tartu Observatory and traceable to MIKES-Aalto MRI (Finland) and multimeter Agilent 3458A at AS Metrosert (Estonia). Temperature and distance measurements are traceable to corresponding national standards of Metrosert Ltd. (Estonia).

3. Kalibreerimisobjekti kirjeldus *Description of the calibration object*

The calibrated spectrometer was a Satlantic HyperOCR irradiance hyperspectral radiometer based on a Zeiss Monolithic Miniature Spectrometer (MMS-1) module in a water-tight housing. Zeiss MMS-1 with a concave holographic grating covers the spectral range of approx. (300..1150) nm, has a 3.3 nm wavelength step and spectral resolution of 10 nm. It contains a Hamamatsu silicon diode array sensor with 256 pixels. The optical input is formed as a transmission cosine diffuser, diameter of 25 mm, mounted in front of the fibre optic input of the MMS-1. The radiometer is equipped with an internal mechanical shutter to take the dark readings. Manufacturer has provided wavelength scale of the radiometer as a function of pixel number n = (2..256) with a spectral accuracy of 0.3 nm.

4. Kalibreerimismeetodi kirjeldus *Description of calibration method*

For determination of the spectral irradiance responsivity $R_E(\lambda)$, the radiometer was calibrated against a 1000 W quartz tungsten halogen (QTH) FEL source placed at the distance of 500 mm from the front surface of the radiometer's cosine corrector. Three baffles (Ø60 mm aperture) were placed between the lamp and the radiometer in order to reduce the ambient stray light. A Ø60 mm shutter between the lamp and the radiometer compartments was used during the background measurements. The lamp current and voltage were measured by using four-wire sensing: one pair of cables for feeding current to the lamp, and the other to measure the voltage drop on the lamp. The lamp current was stabilized by using feedback from the calibrated shunt resistor. The operating conditions of the standard lamp are listed in Table 1. The lamp was allowed to stabilize for 20 minutes before the calibration measurements. The values of the lamp current and voltage as well as the ambient temperature, relative humidity and atmospheric pressure were recorded continuously during the pre-heating and measurement phases.
The QTH lamp and radiometer under calibration were aligned to a common horizontal optical axis using a dual-beam self-balancing alignment laser. The lamp was aligned by using a special jig

while for the radiometer, a flat mirror in front of the cosine corrector was used to get the back-reflection of the laser beam. Distance between the lamp socket's reference plane and the radiometer's cosine corrector was measured with a laser-guided contactless distance probe.
While measuring the lamp irradiance, 40 raw spectra (digital counts) were recorded using a fixed integration time, followed by the same number with the shutter between the lamp and the radiometer closed. The radiometer was configured to measure every fourth spectrum with the internal shutter closed. The process was repeated for different integration time. Data processing for each source included the following steps: averaging of the raw spectra (with the nearest internal shutter measurement subtracted first), background signal subtraction, normalization to the common integration time, correction for the non-linearity, division by the lamp irradiance.

5. Tulemused *Results*

The spectral responsivity coefficients are enclosed to the report as device calibration datafiles and a HyperCP datafile 'CP_SAT0370_RADCAL_20241029104402.txt'.

6. Mõõtemääramatus *Measurement uncertainty*

Uncertainty analysis has been carried out according to the ISO Guide to the Expression of Uncertainty in Measurement, and to the EA guide EA-4/02. The uncertainty estimate combines the contributions originating from the spectral irradiance of the standard QTH lamp, including data from the calibration certificate, from interpolation of the spectral irradiance values to the designated wavelengths of the radiometer, from instability of the lamp due to working time elapsed after calibration, from contribution to the spectral irradiance due to setting and measurement of the current of the lamp, from measurement of the distance between the lamp and input aperture of the radiometer, and from reproducibility of the alignment. Uncertainty contributions for the array spectroradiometer include repeatability and reproducibility of the lamp and dark measurements. The measurement results are valid at the time of calibration. The reported uncertainty does not include an estimate of long-time variations of the calibrated radiometer. The expanded uncertainties in the datafies are given for the coverage factor of $k = 2$.

7. Keskkonnatingimused *Environmental conditions*

The environmental conditions in the laboratory during the measurements are given in Table 1.

Table 1. Environmental and operating conditions.

Ambient Temperature [°C]	21.0 ± 1.0
Relative humidity [%]	50± 5
Operating conditions of the standard lamp no 7	
Current [A]	8.1000 ± 0.0008
Voltage [V]	105.6
Burning Time [h:min]	00:55
Distance [mm]	500.0 ± 0.2