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|  | **Technical Handbooks of FRM4VEG Instrumentation**  **(TR-1): SQ-110 PAR Sensor**  version 1.0  National Physical Laboratory  University of Southampton  EOLAB  28 May 2020 |
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# Acronyms

|  |  |
| --- | --- |
| **Abbreviation** | **Stands for** |
| ESA | European Space Agency |
| FRM4VEG | Fiducial Reference Measurements for Vegetation |
| LAI | Leaf Area Index |
| NIST | National Institute of Standards and Technology |
| PAR | Photosynthetically Active Radiation |
| PPFD | photosynthetic photon flux density |

# Introduction

## Purpose and Scope

This document forms part of deliverable D-60 of the European Space Agency (ESA) project ‘Fiducial Reference Measurements for Vegetation (FRM4VEG)’ and it should be used as a guide to operating the SQ-110 PAR Sensor. Its purpose is to provide an instrument technical description, together with information about maintenance and calibration history, pre-deployment uncertainties estimates, and steps required to achieve the FRM status.

The document is organized into 7 key sections:

* **Section 1** provides a summary of the document.
* **Section 2** overviews the technical characteristics of the instrument together with a description of its functioning.
* **Section 3** ….
* **Section 4** describes the procedures that need to be followed when using the instrument.
* **Section 5** lists useful advices for care and storage of the instrument as provided by the manufacturer.
* **Section 6** lists the reasons for and solutions to common problems with the use of the instrument.
* **Appendix A:** …

# Technical Description

## Overview

The SQ-110 is a self-powered quantum sensor that measures photosynthetically active radiation (PAR) and it is calibrated for use in sunlight. The sensor housing design features a fully potted, domed-shaped head making the sensor fully weatherproof and self-cleaning. [1]

Table 1: Technical characteristics of the SQ-110 PAR Sensor[1]

|  |  |
| --- | --- |
| **Characteristic** | **Details** |
| Power Supply  Sensitivity  Calibration Factor (Reciprocal of  Sensitivity)  Calibration Uncertainty  Calibrated Output Range  Measurement Repeatability  Long-term Drift (Non-stability)  Non-linearity  Response Time  Field of View  Spectral Range  Spectral Selectivity  Directional (Cosine) Response  Temperature Response  Operating Environment  Dimensions  Mass  Cable | Self-powered  0.2 mV per µmol m-2 s -1  5 µmol m-2 s -1 per mV  ± 5 %  0 to 800 mV  Less than 0.5 %  Less than 2 % per year  Less than 1 % (up to 4000 µmol m-2 s -1 )  Less than 1 ms  180°  410 to 655 nm (wavelengths where response is greater than 50 % of maximum)  Less than 10 % from 469 to 655 nm  ± 5 % at 75° zenith angle  0.06 ± 0.06 % per C  -40 to 70 C; 0 to 100 % relative humidity; can be submerged in water up to depths of 30 m  24 mm diameter, 33 mm height  90 g (with 5m of lead wire)  5 m of two conductor, shielded, twisted-pair wire; TPR jacket (high water resistance, high UV stability, flexibility in cold conditions); pigtail lead wires; stainless steel (316), M8 connector located 25 cm from sensor head |
|  |  |
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## Theory of Operation

Apogee Instruments SQ series quantum sensors consist of a cast acrylic diffuser (filter), photodiode, and signal processing circuitry mounted in an anodized aluminum housing, and a cable to connect the sensor to a measurement device. Sensors are potted solid with no internal air space, and are designed for continuous PPFD measurement in indoor or outdoor environments. SQ-110 series sensors output an analog voltage that is directly proportional to PPFD under sunlight. The voltage signal from the sensor is directly proportional to radiation incident on a planar surface (does not have to be horizontal), where the radiation emanates from all angles of a hemisphere. [1]

# Calibration History and Uncertainty Budget

# Instrument Operation

The following instrument operation instructions are adapted from those provided by the manufacturer [1].

## Measurements

Mount the sensor to a solid surface with the nylon mounting screw provided to prevent galvanic corrosion. To accurately measure PPFD incident on a horizontal surface, the sensor must be level.

Connect the sensor to a measurement device (meter, datalogger, controller) capable of measuring and displaying or recording a millivolt signal (an input measurement range of approximately 0-500 mV is required to cover the entire range of PPFD from the sun). In order to maximize measurement resolution and signal-to-noise ratio, the input range of the measurement device should closely match the output range of the quantum sensor. Don’t connect the sensor to a power source. The sensor is self-powered and applying voltage will damage the sensor. [1]

## Calibration traceability

Apogee SQ series quantum sensors are calibrated through side-by-side comparison to the mean of transfer standard quantum sensors under a reference lamp. The reference quantum sensors are recalibrated with a 200 W quartz halogen lamp traceable to the National Institute of Standards and Technology (NIST). [1]

# Care and Storage

The following care and storage advice is adapted from that provided by the manufacturer [1]:

1. Moisture or debris on the diffuser is a common cause of low readings. The sensor has a domed diffuser and housing for improved self-cleaning from rainfall, but materials can accumulate on the diffuser (e.g., dust during periods of low rainfall, salt deposits from evaporation of sea spray or sprinkler irrigation water) and partially block the optical path. Dust or organic deposits are best removed using water or window cleaner and a soft cloth or cotton swab. Salt deposits should be dissolved with vinegar and removed with a soft cloth or cotton swab. Never use an abrasive material or cleaner on the diffuser.
2. Although Apogee sensors are very stable, nominal accuracy drift is normal for all research-grade sensors. To ensure maximum accuracy, we generally recommend sensors are sent in for recalibration every two years, although it is often possible to wait longer according to particular tolerances. To determine if the sensor needs recalibration, the Clear Sky Calculator (www.clearskycalculator.com) website and/or smartphone app can be used to indicate the total shortwave radiation incident on a horizontal surface at any time of day at any location in the world. It is most accurate when used near solar noon in spring and summer months, where accuracy over multiple clear and unpolluted days is estimated to be ± 4 % in all climates and locations around the world. For best accuracy, the sky must be completely clear, as reflected radiation from clouds causes incoming radiation to increase above the value predicted by the clear sky calculator. To determine recalibration need, input site conditions into the calculator and compare total shortwave radiation measurements to calculated values for a clear sky.

# Troubleshooting

Reasons for and solutions to common problems with the LAI-2200C are provided by the manufacturer [1]:

Table 2: Reasons and solutions to common problems with the SQ-110 PAR Sensor[1]

|  |  |
| --- | --- |
| **Problem** | **Solution** |
| Independent Verification of Functionality  Compatible Measurement Devices (Dataloggers/Controllers/Meters)  Cable Length  Modifying Cable Length  Unit Conversion Charts | A quick and easy check of sensor functionality can be determined using a voltmeter with millivolt resolution. Connect the positive lead wire from the voltmeter to the white wire from the sensor and the negative (or common) lead wire from the voltmeter to the black wire from the sensor. Direct the sensor head toward a light source and verify the sensor provides a signal. Increase and decrease the distance from the sensor head to the light source to verify that the signal changes proportionally (decreasing signal with increasing distance and increasing signal with decreasing distance). Blocking all radiation from the sensor should force the sensor signal to zero.  SQ-100 and SQ-300 series quantum sensors are calibrated with a standard calibration factor of 5.0 µmol m-2 s -1 per mV, yielding a sensitivity of 0.2 mV per µmol m-2 s -1 . Thus, a compatible measurement device (e.g., datalogger or controller) should have resolution of at least 0.2 mV in order to provide PPFD resolution of 1 µmol m-2 s -1.  When the sensor is connected to a measurement device with high input impedance, sensor output signals are not changed by shortening the cable or splicing on additional cable in the field. All Apogee sensors use shielded, twisted pair cable to minimize electromagnetic interference. For best measurements, the shield wire must be connected to an earth ground. This is particularly important when using the sensor with long lead lengths in electromagnetically noisy environments.  See Apogee webpage for details on how to extend sensor cable length.  It is possible to convert the PPFD value from a quantum sensor to other units, but it requires spectral output of the radiation source of interest. Conversion factors for common radiation sources can be found on the Unit Conversions page in the Support Center on the Apogee website. |
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###### Appendix

# Applicable and Reference Documents

[1] Apogee Instruments, “Quantum Sensor Owner’s Manual”, Utah, USA, 2020.