Biospherical Instruments Inc.

Optical Instruments for Environmental Monitoring

QCP-2300™, QCP-2350™ Series with *Logarithmically Compressed* Analog Voltage Output

Quantum Irradiance PAR Sensor

Measuring Irradiance in water over the PAR Spectral Region[1]

The QCP-2300 and QCP-2350 are **PAR sensor** with **logarithmically compressed analog voltage output**, which were specifically developed for data loggers with limited dynamic range. QCP-2300/2350 sensors measure Photosynthetically Active Radiation (PAR) with a cosine-corrected irradiance collector optimized for use in water. The sensor has a flat quantum response over the PAR spectral region (400–700 nm). The spectral response is shaped by a combination of absorbing glass and custom dichroic filters to accurately cover the PAR spectral region and block out-of-band radiation. These sensors compliment a selection of Biospherical Instruments' sensors with digital and analog-linear outputs and "scalar collectors." An overview of these additional models is provided on the last page.

PAR sensors normally encounter a very wide range of light levels as sunlight is exponentially attenuated with increasing depth in the ocean. Measurements performed near sunrise or sunset, or under overcast skies, increase the need for a large dynamic range even further. While many commercial data acquisition systems easily interface to analog voltage (e.g., 0-5 V) output sensors, they are often based on 12–16 bit digital to analog converters, which lack the resolution to digitize small signal levels with sufficient accuracy. To address this problem, Biospherical Instruments has developed a method of compressing the photocurrent as the logarithm of the incident light flux. Our first versions of the QCP-2300 used analog compression. The new redesigned QCP-2300/2350 sensors rely on an electrometer amplifier coupled to a highly-stable 24 bit analog to digital converter, microprocessor, and digital to analog converter to transfer the digitally-compressed signal to 0-5 V. This redesign resulted in lower current requirements (4 mA) and increased stability.

The sensors are designed for operation in natural waters to depths of up to 2,000, 6,800, and 10,000 meters, depending on model. A version that is rated for depths of up to 10,000 meters is also available. QCP-2300 and QCP-2350 models only differ by the underwater connector used. Custom-housed versions are also available for gliders and other undersea monitoring applications.

Key Features:

- Ideal to measure **light available for photosynthesis** on a **flat surface,** known as ***Photosynthetic Photon Flux Density*** (**PPFD**).
- Maximizes working conditions (low sun angle, clouds) with **extended dynamic range.**
- **Compact**, **rugged**, and **low-cost**.
- Designed to measure PAR irradiance to depths of up to **2,000, 6800, and 10,000 meters**.
- Low power consumption: < 5 mA at 6–15 volts DC.
- Versions **available for Teledyne Webb and iRobot gliders**. Other systems can readily be developed. Consult the systems manufacturer for details or consult Biospherical Instruments for new versions.

1 Several terms are in use to denote the physical quantity measured by a "*Quantum Irradiance PAR Sensor*" including: "*Photosynthetic Photon Flux Density*" (PPFD), "quantum flux density," and "PAR quantum irradiance."

QCP-2300 / QCP-2350 Specifications

Measurement Quantity

Quantum Irradiance for PAR (Photosynthetically Available Radiation or Photosynthetically Active Radiation). This quantity is typically referred to as PPFD (Photosynthetic Photon Flux Density). Alternative terms for PPFD are "quantum flux density," or "PAR quantum irradiance."

Optical Features

Irradiance Collector: Cosine-corrected acrylic diffuser optimized for in-water measurements.

Directional Response: Deviations from the ideal cosine response are:

< ±3% for incidence angles < 65°

< ±10% for incidence angles between 65° and 80°

Deviations from the ideal cosine response are substantially larger than indicated above if a QCP sensor is used in air. For in-air measurements a QCR sensor is recommended—see last page. Fig. 1 compares the directional response of an in-water QCP sensor with that of QSP sensors for measuring quantum *scalar* irradiance.

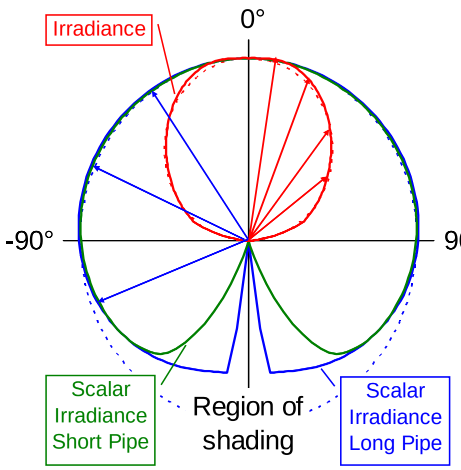

Fig 1. Comparison of the typical directional response of a QCP irradiance sensor (red) and two QSP scalar irradiance sensors, one equipped with a short (green) and one with a long (blue) light pipe. Thin broken lines indicate the ideal responses for the two geometries.

Spectral Response: Sensor approximates the spectral response of PAR. The ideal PAR response is zero below 400 nm and above 700 nm, and constant between 400 and 700 nm. No real sensors can emulate an instant transition from zero to a constant value at 400 and 700 nm. Each BSI PAR sensor is individually optimized to ensure that its spectral response falls within the lower and upper limits shown in Fig. 2.

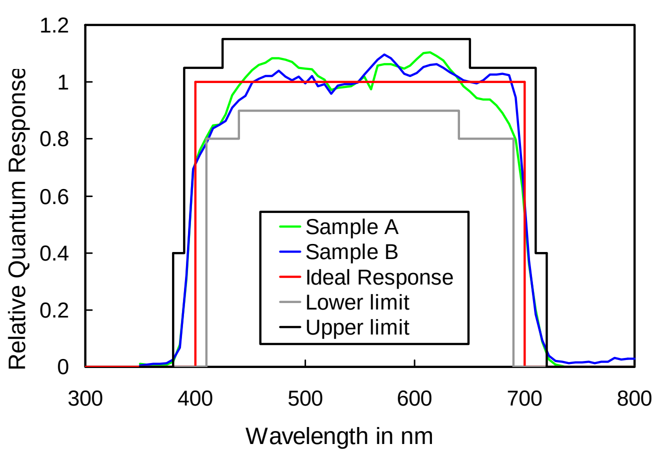

Fig 2. Typical spectral response of two PAR sensors (Sample A and B) compared with the ideal PAR response (red) and the acceptable range (lower and upper limit).

Electronic Features

Photodetector: High-reliability silicon photodiode designed for precision radiometry.

Time Constant: < 100 ms

Stability of dark reading: < 0.003 $\mu E\ m^{-2}\ sec^{-1}$ (0 to 50 °C)

Saturation: Sensors saturate at slightly less than 5 V, equivalent to about 6000 $\mu E\ m^{-2}\ sec^{-1}$ when immersed in water. The probe will report approximately 0 volts for readings within 1% of saturation as an indicator that saturation has occurred.

Responsivity temperature coefficient: < 0.05% / °C

Power Requirement: 6-15 V, < 5 mA

Output Impedance: 100 Ω

Determination of zero or dark reading: The dark reading is adjusted to 0 volts during calibration and slight drifts may occur with time or temperature. It is important to "dark correct" this sensor by capping the sensor so that it is completely dark, and recording the dark voltage. This offset should be subtracted from acquired data according to the transfer function shown below. We recommend to check the offset several times during a deployment for best performance.

Transfer Function:
Irradiance = Calibration factor x [10^(Light Voltage) - 10^(Dark Voltage)]

Physical specifications

Housing: Hard-anodized aluminum, rated to 2,000 meters (standard). Consult factory for other material options. The housings are connected via a 1 µF capacitor to ground potential.

Temperature range: -2 to 50 °C

Dimensions: 5.0 cm in diameter, 15.25 cm long, not including the connector.

Weight: 0.68 kg

Depth Rating: 2,000 meters (standard), 10,000 meters (optional)

Calibration

Each sensor is calibrated using a National Institute of Standards and Technology (NIST) traceable 1000-watt type FEL Standard of Spectral Irradiance using procedures recommended by NIST. Annual recalibration is strongly recommended.

Sensors are shipped with a calibration certificate listing calibration factors to convert raw data measured in water to calibrated data in units of $\mu E\ m^{-2}\ sec^{-1}$ or $\mu E\ cm^{-2}\ sec^{-1}$. An alternate pair of calibration factors is supplied for in-air measurements. Note that a µE or "microEinstein" is a micromole of quanta (6.023×10^{17} quanta). The software allows the user to change the calibration factor, along with other parameters such as sampling rate.

Options and Accessories

Connectors:

- **QCP-2300:** LSG-4-BCL (rated to depths up to 2,000 m)
- **QCP-2350:** MCBH-4-MP (rated to depths up to 6,800 m)
- **QCP-2300-HP:** XSG-4-BCL-HP (rated to depths up to 6,800 m)
- **QCP-2350-HP:** BH-4-MP (rated to depths up to 10,000 m)
- Other connector options available on special request.

Cables: Consult Biospherical for information on availability of cables.

QCR Series Surface Reference Sensors are available to compliment measurements made with the QCP in-water sensors. The use of surface reference sensors during a cast with a QCP sensor allows changes in light due to changes in cloud cover to be detected and flagged.

QSP Series Quantum Scalar Irradiance PAR Sensors are also available for in-water use and exhibit a scalar collector with uniform directional response (Fig. 1) instead of a cosine-corrected irradiance collector. Variants of these sensors with narrow band spectral response are also available—see last page or consult Biospherical Instruments.

OEM Versions are also available. SeaBird, Teledyne-Webb, and iRobot, for example, support versions that may not be listed here—for best results, we recommend consulting the system manufacturer for optimum compatibility.

Biospherical Instruments Single Channel Sensor Configurations

Biospherical Instruments manufactures a full line of optical instruments for environmental research, ranging from simple single channel sensors to complex systems consisting of multiple radiometers and deployment options.

Depending on their configuration, single channel sensors are identified by a three-letter model designator followed by a four-digit *series* number.

The first letter is either **"Q"** or **"M"** and identifies the spectral response of the sensor. PAR-sensors measuring Photosynthetically Available (or Active) Radiation use the letter **"Q"** to denote a *quantum* response. The letter **"M"** stands for *monochromatic* and is used for sensors that employ a narrow-band channel with a bandwidth of typically 10 nm. Other responses may be available including photopic and "blue light hazard" responses—consult BSI for details.

The second letter is either **"S"**, **"C"**, or **"R"** and indicates the sensor's collector geometry. The three letters stand for *scalar irradiance*, *cosine irradiance,* and *radiance*, respectively.

The third letter is either **"P", "L", or "R"** and indicates the environment of operation. **"P"** specifies *profiling* sensors used for continuous immersion, typically in marine operations. The letter **"L"** is used for *laboratory* operations or near-surface field operations, and **"R"** stands for *reference* or non-submerged radiometers. Monitoring incident (surface) irradiance on a ship's mast or next an aquaculture pond is a typical application of a *reference* sensor.

The four-digit number of the model designator indicates the electrical interface of the sensor such as digital output or analog output, and connectorization.

2100 series: 24 bit analog to digital converter with binary output, fixed sampling rate of approximately 4 Hz. Designed for use with "Logger 2100" software.

2150 series: 24 bit analog to digital converter with improved noise and stability, variable sample rates ranging from 250 Hz down to 1 sample average per hour. Calibrated ASCII output, with optional inclusion of temperature in the data stream. Ideal for integration in multi-parameter monitoring systems. Designed for use with "Logger 2150" software.

2200 series: Linear analog voltage (0-5 volts) output. >16 bit analog to digital converter is recommended for optimum performance.

2300, 2350 series: Compressed analog voltage output. Uses a 24-bit analog to digital converter to sample the signal, the logarithm is computed and the result is converted into an analog voltage (0-5 V) that can be satisfactorily digitized by most data acquisition systems.

Other options include specialized connectors, direct photodiode current output (**-PD**), housings tailored for specific platforms (gliders), and different operating depth options for cosine collector-equipped sensors. Be sure to consult the data sheet for the specific model you are interested in or discuss your application with Biospherical Instruments.

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*Specifications subject to change without notice