Biospherical Instruments Inc.

Optical Instruments for Environmental Monitoring

MPE-PAR with Digital Output

Quantum Irradiance PAR Sensor

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

The MPE-PAR (**M**ICRO Class, **P**rofiling (in-water), **E** (irradiance) **PAR** sensor) is a fifth-generation sensor that is sensitive over the Photosynthetically Active Radiation (PAR[1]) spectral range (400-700 nm). The MPE -PAR has been optimized for integration into Argo profiling floats and features low mass and low power consumption. It combines the huge dynamic range and excellent signal-to-noise ratio of Biospherical Instruments' (BSI) microradiometer technology with the proven performance and ruggedness of BSI's line of Q-Series PAR sensors. Similarly to the QCP-2150, it features an acrylic irradiance collector with a cosine-response optimized for use underwater to a depth of up to 2,000 meters, as well as a digital output, which allows simplified integration with other systems. The PAR spectral response is shaped by a combination of absorbing glass and custom dichroic filters for accurately covering the PAR spectral region with a flat quantum response while blocking unwanted out-of-band radiation. The MPE compliments a selection of BSI's scalar sensors which also feature digital or analog-linear outputs.

Key Features:

- **Huge dynamic range of ~10 orders of magnitude** (Fig 1.) enabled by a 24-bit ADC and a three-gain amplifier.
- **Low detection limit** of **2.5x10^{-10} µE cm^{-2} s^{-1}** in water; no saturation in full sunlight.[2]
- Optimized for profiling applications to **depths of 2,000 m.**
- **Low power consumption** (4.6 mA at 7 V).
- **Sensor temperature** available in the data stream.
- **Fast sampling:** rates of up to 250 Hz under certain conditions; time constant less than than 0.01 s.
- Options for **networking multiple sensors**.
- Binary, Hexadecimal, or ASCII text output for **easy integration with a variety of data acquisition systems**.
- **Adaptable for gliders, NKE profiling floats, BGC Argo floats, Teledyne Webb, and iRobot gliders**. Custom systems can be developed — contact support@biospherical.com for additional information.
- QCP-2150 emulation mode to enable use as a drop-in replacement to extend the dynamic range of PAR measurements in legacy CTD applications.

Also available in various 10 nm wide channels from 395–1000 nm. Consult Biospherical Instruments for custom sensors, including available wavebands below 395 nm.

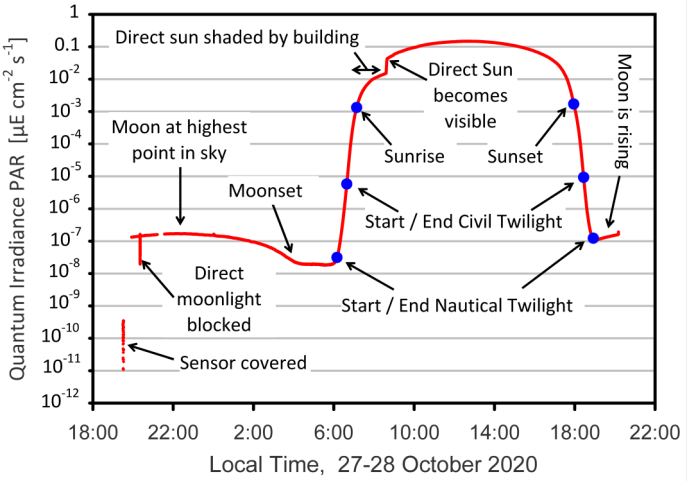

Fig.1. Time series measurements of moonlight and sunlight for illustrating the detection limit and dynamic range of an MPE sensor. Measurements were performed in San Diego between 27 and 28 October 2020 with the MPE sensor mounted vertically and facing the zenith. The sky was clear and the waxing gibbous Moon had 90% of the lunar disk illuminated. At the start of the measurement (at 19:42) the sensor was covered. The lowest detection limit (defined as the standard deviation of calibrated measurements with the sensor covered) was 1.8x10^{-10} µE cm^{-2} s^{-1}. When the Moon was at its highest point in the sky (51° above the horizon at 22:22), PAR was 1.7x10^{-7} µE cm^{-2} s^{-1}, which is approximately 3 orders of magnitude above the detection limit. Skylight (with direct moonlight blocked) was well above the detection limit. The maximum PAR measurement at local solar noon (with the Sun 44° above the horizon) was 0.15 µE cm^{-2} sec^{-1}, which is almost 9 orders of magnitude above the detection limit and well below the saturation limit of 4 µE cm^{-2} sec^{-1}.

[1] The community of practice uses a variety of terms to denote the physical quantity measured by a "*Quantum Irradiance PAR Sensor*" including: "*Photosynthetically Active* (or *Available) Radiation*" (PAR), "*Photosynthetic Photon Flux Density*" (PPFD), "quantum flux density," and "PAR quantum irradiance."

[2] A *microEinstein* (µE) is a micromole (6.023x10^{17}) of quanta.

MPE-PAR Specifications

Measurement Quantity

Spectrally integrated PAR 400-700 nm irradiance with a flat quantum response, also known as Photosynthetic Photon Flux Density (PPFD), 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 (Fig. 2) for in-water measurements are:
< ± 3% for incidence angles < 65°
< ± 13% for incidence angles between 65° and 80°

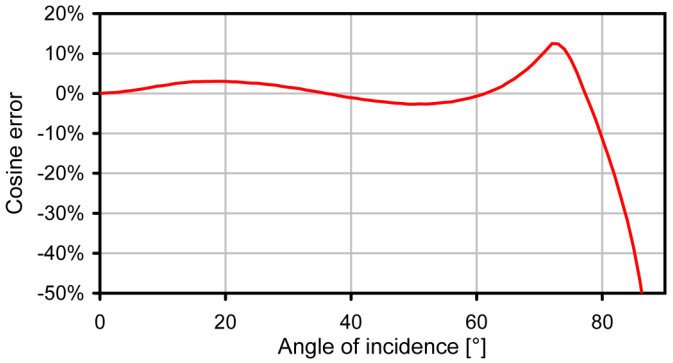

Fig 2. Cosine error of a MPE-PAR sensor measured in water.

Spectral Response: The sensor approximates the ideal spectral response of PAR. Each MPE sensor is individually optimized to ensure that its spectral response falls within the lower and upper limits shown in Fig. 3. (The ideal PAR quantum response is zero below 400 nm and above 700 nm, with an instantaneous transition from zero to a constant value at 400 and 700 nm.)

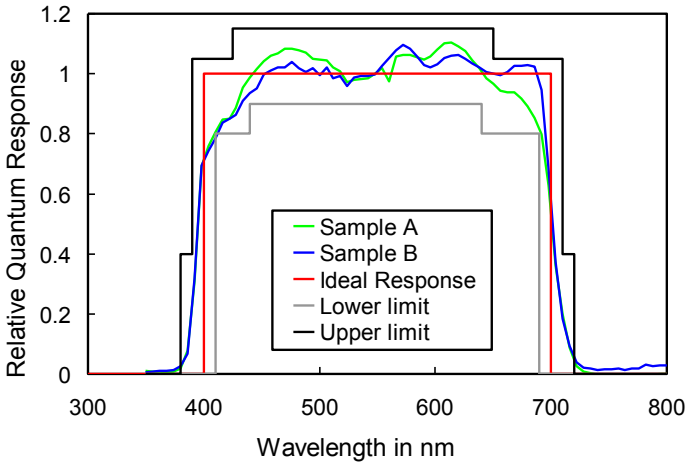

Fig. 3 Typical spectral response of two PAR sensors (Sample A and B) compared with the ideal PAR response (red) and the acceptable range (lower and upper limit).

Electronic Specifications

Technology: The sensor is based on BSI's proprietary microradiometer technology consisting of a microprocessor, addressable digital port, photodetector, 3-stage preamplifier, and 24 bit analog-to-digital converter. Electronics are sleeved inside a shielded cylinder for insulation from electromagnetic and radio frequency interference. An internal temperature sensor supports algorithmic correction of any drift in photodetector dark current.

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

Dynamic range: Approximately 10 orders of magnitude (Fig. 1).

Detection limit: typically 2.5x10^{-10} µE cm^{-2} s^{-1}.

Dark current temperature coefficient: typically ±7x10^{-11} µE cm^{-2} s^{-1} per °C.

Temperature Compensation: A dedicated digital temperature sensor monitors the temperature of the microradiometer and can be used for algorithmic temperature compensation of recorded data. Temperature data are included in the data stream and have a resolution of 0.41 °C.

Saturation: 4 µE cm^{-2} s^{-1} when immersed in water.

Responsivity temperature coefficient: less than 0.05% per °C.

Time Constant: Less than 0.01 s, limited by maximum sampling rate of 250 Hz. Effective resolution decreases as the sampling rate increases; fast sampling rates also require higher baud rates.

System bandwidth: Nominally 20 Hz for a sine wave source function.

Warm Up Time: 3 seconds.

Power Requirement: Supported supply voltage: 6–36 V DC. Current: 4.6 mA for supply voltage of 7 V, and 1.1 mA for supply voltage of 36 V.

Physical Specifications

Housing: Hard-anodized aluminum. Consult factory for other material options.

Depth Rating: 2,000 m.

Operational temperature range: –2 to 45 °C. Units typically perform satisfactorily for temperatures above –10 °C.

Dimensions: Housing: Cylindrical housing with 3.0 cm (1.2 in) diameter, 18.5 cm (7.3 in) length, not including the connector. **Cosine collector:** 5.1 cm (2.0 in) diameter.

Weight: 0.28 kg (0.62 lb) in air, 0.12 kg (0.26 lb) in salt water.

Connector: Subconn (MacArtney Underwater Technology) MCBH4M Micro-series connector. Other connector options are available on request.

Cable: BSI cable model QSC-2104 (neoprene jacketed cable with no internal reinforcement) or QSC-2150 (Waterproof red jacketed cable rated at 225 kg to support the sensor). The "Dry" cable ends are terminated with a DB-9F serial connector. Custom cable configurations to support OEM integration are available.

Data format

Communications Interface: RS-232. Supported baud rates: 9600, 19200, 38400, 57600, 115200, 230400; no parity, 8 data bits, 1 stop bit.

Numerical Format: Binary (4 byte IEEE-754 single precision floating point), hexadecimal, or ASCII decimal. Sample rates faster than 10 Hz work best using binary format.

Delimiter: comma, space, or tab.

Parameters transmitted: Light signal (0.000000 – 160000.0), temperature (°C).

Modes of Operation: Free-running continuously at a desired rate, or polled at a desired interval. Optional power-on header output is user-configurable.

Calibration: National Institute of Standards and Technology (NIST) traceable 1000-watt type FEL Standard of Spectral Irradiance. Annual recalibration is strongly recommended.

Software : The sensor can either be operated with a generic terminal emulation program (e.g. HyperTerminal or RealTerm), or with BSI's µLoggerLight software. Because the sensor can be configured to output in ASCII text, any program that can interface with a serial port and can parse ASCII text can be used to operate the instrument and record data, including LabView.

Typical ASCII output data stream: Example displayed below is irradiance in µE cm^{-2} s^{-1} and temperature in °C, comma separated, with an end-of-line terminator of CR,LF:
.013016, 16.06
.012990, 16.06

Typical Hexadecimal output data stream: Example displayed below shows model, measurement, and serial number, tab separated, with irradiance and temperature transmitted in hexadecimal:
MPE<tab>PAR<tab>002425<tab>0xB6B7F427<tab>0x41CCDBE5
MPE<tab>PAR<tab>002425<tab>0x3798E251<tab>0x41CCDBE5