Biospherical Instruments Inc.

Optical Instruments for Environmental Monitoring

MPS-PAR with Digital Output

Quantum Scalar Irradiance PAR Sensor

Measuring Scalar Irradiance in Water over the PAR Spectral Region

The MPS-PAR (**M**ICRO Class, **P**rofiling (in-water), **S** (Scalar irradiance) **PAR** sensor) is a fifth-generation sensor that is sensitive over the Photosynthetically Active Radiation (PAR) spectral range (400-700 nm). The MPS-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 QSP-2150, it features a spherical collector made of solid Teflon® 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 MPS 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 **2.5×10^{-9} µE cm^{-2} s^{-1}** in water; no saturation in full sunlight.[1]
- 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 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.
- QSP-2150 emulation mode to enable use as a drop-in replacement to extend the dynamic range of PAR measurements in legacy CTD applications.

The MPS is also available in various 10 nm wide channels from 395–1,000 nm. Consult Biospherical Instruments for custom sensors, including available wavebands below 395 nm.

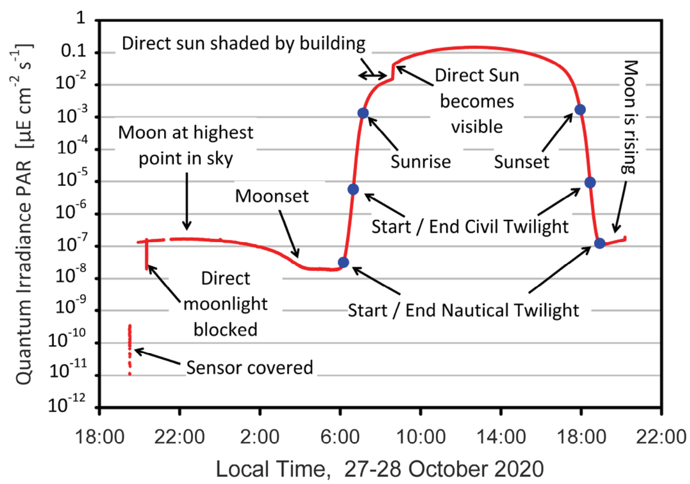

Fig.1. Time series measurements of moonlight and sunlight for illustrating the detection limit and dynamic range of MICRO class sensors. Measurements were performed in San Diego between 27 and 28 October 2020 mounted vertically and facing the zenith. The sky was clear and the waxing gibbous Moon had 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 1.8×10^{-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 1.7×10^{-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}. Note: Measurements shown were performed with a MPE-PAR sensor, the cosine irradiance version of a MICRO class sensor. The dynamic ranges of MPS-PAR and MPE-PAR sensors are identical but their detection limits differ.

[1] A *microEinstein* (µE) is a micromole (6.023×10^{17}) of quanta.

MPS-PAR Specifications

Measurement Quantity

Quantum Scalar Irradiance for PAR (Photosynthetically Available Radiation or Photosynthetically Active Radiation) with a flat quantum response over the PAR range. This quantity is sometimes also referred to as PPFFR (Photosynthetic Photon Flux Fluence Rate), SPPFD (Spherical Photosynthetic Photon Flux Density), quantum flux density, or photon flux fluence rate.

Optical Features

Scalar irradiance Collector: Solid Teflon® sphere, optically connected to the main housing by a short stainless-steel encased glass light pipe. The spherical collectors are available in diameters of 1.9 cm (3/4”) or 1.3 cm (1/2”).

Directional Response: Each instrument’s directional response is measured and optimized in air before final calibration. Deviations from the ideal uniform response for sensors are:

< ±3% for incidence angles < 90°
< ±10% for incidence angles < 125°

Radiation is partially blocked by the housing between 140° and 180°. The directional response of the MPS refers to dataset “Scalar Irradiance Short Pipe“ in Fig. 2. Individual directional response plots are available as an option.

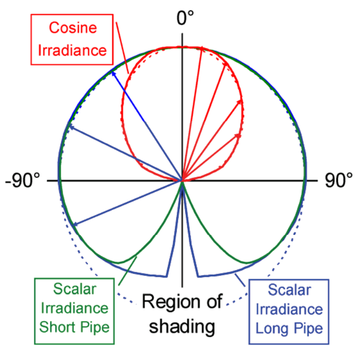

Fig 2. Typical directional responses of MICRO class scalar irradiance sensors with short (green) and long (blue) light pipe, and a MPE-PAR irradiance sensor (red). Thin broken lines indicate the ideal responses for the three geometries.

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 PAR sensor is individually optimized to ensure that its spectral response falls within the lower and upper limits shown in Fig. 3.

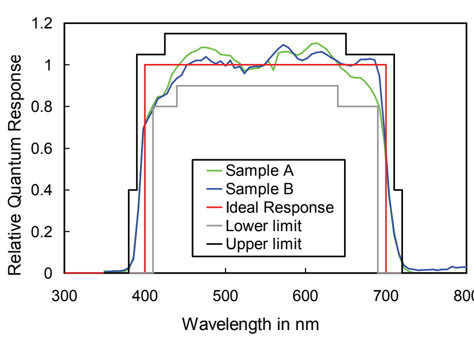

Fig 3. Typical spectral response of two PAR sensors (Sample A and B) compared with the ideal PAR response (red) and the acceptable range (lower and upper limit).

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 2.5×10^{-9} μE cm^{-2} s^{-1}.

Dark current temperature coefficient: typically $\pm7\times10^{-10}$ 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: 40 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 of Housing: Cylindrical housing with 3.0 cm (1.2 in) diameter, 19.5 cm (7.7 in) length, not including the connector.

Weight: 0.28 kg (0.62 lb) in air, 0.13 kg (0.29 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, Calibration, and Software

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 scalar 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:

MPS<tab>PAR<tab>002425<tab>0xB6B7F427<tab>0x41CCDBE5
MPS<tab>PAR<tab>002425<tab>0x3798E251<tab>0x41CCDBE5