Leaders in Optical Sensing
and Profiling Technology

GUVis-3511
Ground Based UV-Visible / PAR Radiometer

The Biospherical Instruments Inc. (BSI) GUVis-3511 radiometer (Figure 1) is the successor of the widely used GUV-511 and GUV-2511 ground-based ultraviolet (UV) monitoring instruments. While the GUV-2511 was limited to a maximum of seven channels, the GUVis-3511 is available with as many as 19 channels, which can be selected from over 35 wavelengths, ranging between 305 and 1,640 nm. The radiometer can also measure Photosynthetically Available Radiation (PAR: 400-700 nm).

The electronics of the instruments have been completely redesigned. They are now based on BSI's microradiometer technology, which features unprecedented performance with respect to dynamic range, linearity, speed, and expandability. The instrument also features a new irradiance collector covering the spectral range from the UV to the infrared (IR).

A shadowband accessory is available, which allows alternating measurements of global (sun + sky) and diffuse solar irradiance. These measurements allow the calculation of direct solar irradiance and related data products such as aerosol optical depth.

The instrument is based on technology introduced by the project "Optical Sensors for Planetary Radiant Energy" (OSPREy). OSPREy was a joint project between Biospherical Instruments and NASA to develop a state-of-the-art above-water radiometer system in support of current and next-generation ocean color satellite missions.

GUV radiometers were first produced in 1992 and are being used to monitor geographic variations in UV exposure in countries such as Argentina, Norway, and the United States. Similar to it's predecessors, the GUVis-3511 is suitable for use in long-term research programs. The GUVis will also afford retrieval of cloud optical thickness, total column ozone, and water vapor column — three crucial variables used in characterizing the solar spectrum.

Figure 1. GUVis-3511 radiometer (center) with BioSHADE drive (white cylinder on the right) and BioGPS (black dome in the background).

Key features

- Measures surface UV, visible, and infrared irradiance in up to 19 user-selectable wavebands and PAR
- Based on state-of-the-art microradiometer technology
- Features newly-designed irradiance collector with small cosine error from the UV to the IR
- Uses specialized, hard-coat, multicavity interference filters with excellent long-term stability
- Rugged, powder-coated aluminum housing
- Environmentally sealed and temperature-stabilized for long-term operation in harsh environments
- RS-232 serial or USB output for connection to a PC
- Windows®-based µLogger data acquisition software
- Optional BioSHADE shadowband accessory suitable for land and ship-based deployments
- Optional BioGPS Global Positioning System

Microradiometers — the heart of the GUVis-3511

The GUVis-3511 is based on microradiometers, a key technology developed by BSI with support from a NASA Small Business Innovative Research (SBIR) award. An individual microradiometer consists of a photodetector, preamplifier with controllable gain, high resolution (24 bit) analog-to-digital converter (ADC), microprocessor, and an addressable digital port. It is a fully functional sensor, resident on one small, thin, circuit-board assembly that is sleeved inside a shielded cylinder (Figure 2). Easily assembled with up to 19 microradiometers, the GUVis-3511 design affords an unprecedented amount of flexibility in wavelength selection and expandability.

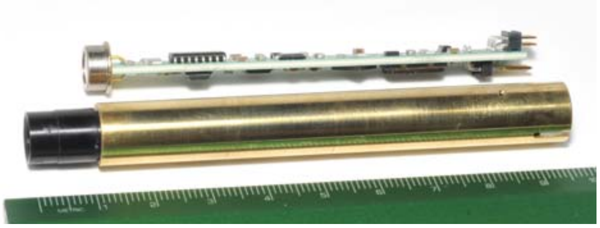


Figure 2. A side view of a microradiometer (top) showing the two-sided circuit board design, and a sleeved version with fore-optics attached (bottom). The ruler is marked in centimeters.

Because each microradiometer channel has an individual ADC, no multiplexer is required and no analog cabling is needed, eliminating a source of electronic leakage and improving reliability. All channels of a GUVis-3511 can be sampled synchronously at rates of up to 15 Hz. Photodiode current is converted to voltage with an electrometer amplifier with three gain settings, resulting in a dynamic range of over 10 orders of magnitude. Each microradiometer is also equipped with a temperature sensor located close to the photodetector.

BioSHADE — a shadowband for the GUVis-3511

BioSHADE is an accessory for BSI's line of above-water radiometers, including the GUVis-3511. The accessory can be used both for land and ship-based applications where the orientation of the shadowband axis relative to the Sun's position is not known. BioSHADE control is fully integrated in the µLogger data acquisition software. For example, the system can be programmed to measure global (sun + sky) irradiance with the shadowband stowed below the instrument's field of view for a certain amount of time, then perform a "sweep" of the shadowband, and finally return to measurements of global irradiance. Sampling rates and the frequency of sweeps are programmable via the software's GUI.

µLogger — GUVis-3511 data acquisition software

The GUVis-3511 is controlled by a dedicated software, called µLogger (Figure 3). This software provides a rich set of tools for the collection and real time display of data. The software also applies a calibration to the collected raw data. Measurements can be recorded in either Microsoft Access or ASCII text format. The data format can be tailored to a researcher's requirement.

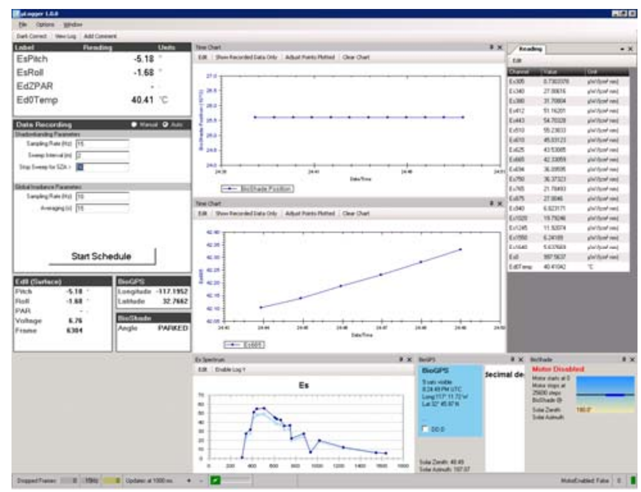


Figure 3. Graphical User Interface (GUI) of µLogger data acquisition software. The panels display basic system parameters such as sensor tilt, graphs of the system's measurements as a function of time or wavelength, the orientation of the shadowband, and real-time data in numerical form. The layout can be easily rearranged and optimized for each measurement task.

GUVis-3511 Processor — a data post-processing tool

GUVis-3511 Processor is a software tool for post processing of data acquired by µLogger. Software features include:

- the calculation of the direct irradiance from data collected during shadowband sweeps,
- the calculation of the aerosol optical depth and related parameters such as the Ångström coefficients,
- the calculation of the total ozone column,
- the calibration of the radiometer via the Langley technique, and
- the application of a residual cosine error correction to measurements of global irradiance.

Additional features are currently being added and will be available soon.

GUVis-3511 Specifications

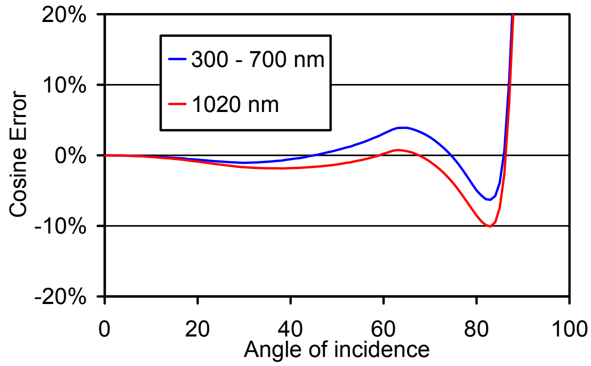
Collector:

- *Design:* multiple layer PTFE primary diffuser, integrating cavity, and PTFE secondary diffuser.
- *Collector Area:* 2.1 cm diameter.
- *Azimuthal Asymmetry*: < 1%.
- *Cosine Error*: see table and figure below.

Typical Cosine Error

Wavelength range	Solar zenith angle		
	< 60°	60-70°	80°
300-700 nm+	± 3%	± 4%	-7%
700-1050 nm	± 3%	± 4%	-10%
1640 nm	- 6%	-10%	-20%

+ The cosine error is virtually independent of wavelength between 300 and 700 nm.



Optical filters: see Microradiometer Specifications.

Wavelength Selection: up to 19 wavelengths can be selected from the following factory standard wavelengths (nm): 305, 313, 320, 330, 340, 380 395, 412, 443, 455, 465, 475, 490, 510, 520, 532, 550, 555, 560, 565, 589, 625, 650, 665, 670, 683, 694, 710, 749, 765, 780, 875, 940, 1020, 1245, 1640 and PAR. The 1245 and 1640 nm channels require an InGaAs detector. All other channels are based on Si detectors. Other wavelengths may be available.

Bandwidth: 10 nm full width at half maximum (FWHM), except 1245 and 1640 nm, which have 15 and 30 nm FWHM, respectively. Measurements of the instrument's response functions are available as an option.

Sampling rate: user selectable. Maximum rate for a 19-channel instrument is 15 Hz. Microradiometer firmware supports internal averaging.

Temperature stabilization: stabilized at 40° C (optional 50 °C) to within ±0.5°C, achieved via a heater and PID controller.

Radiometer Physical specifications:

- *Dimensions:* diameter 15.2 cm (6”), length without connectors: 35.6 cm (14”).
- *Housing material:* 6061-T6 aluminum, hard anodized and powder-coated.
- Environmental Temperature Range: -30 °C to +35°C (version with higher rating for deployment in the tropics are available – contact factory).

Cable: GSC-511 weather-resistant shielded cable; available in custom lengths up to 100 meters; must be ordered separately.

Instrument control unit:

- *Purpose:* power conditioning, temperature regulation, data output.
- *Dimensions:* 43 cm (W) x 30.5 cm (L) x 7 cm (H) (19” rack mount).
- *Material:* aluminum.
- *Power:* 85-264 VAC, 47-63 Hz, via IEC-320 power cord (included).

Communication to PC: RS232 at 115,200 baud or USB.

Software: Windows®-based μLogger data-acquisition software, output in MS-ACCESS or ASCII text format – see μLogger User's Manual.

Calibration: based on NIST-traceable, 1000-watt type FEL Standard of Spectral Irradiance. Can be calibrated using the Sun by intercomparison with a high-resolution scanning spectroradiometer. Annual calibration recommended.

Microradiometer Specifications

Detectors: Si (13 mm^2), or InGaAs (7 mm^2) photodiodes.

Photocurrent-to-Voltage Conversion: electrometer amplifier with three gain stages. (nominal gain ratios: 1, 200, and 40,000; actual gain ratios are determined for each microradiometer and stored in the firmware).

ADC: 24-bit bipolar: 4–125 Hz data rates.

Dynamic Range (usable): 10 decades

Linearity: measured on all microradiometers over a signal current range of $1x10^{-12}$ to $1x10^{-5}$ A using a programmable light source. Errors are typically <1% compared to a reference electrometer. Gain ratios are individually measured and programmed into each microradiometer.

Speed: ADC sample rate is programmable from 4–125 Hz, and normally set to 125 Hz, with averaging over the user-defined sampling period performed by the microradiometer.

Response Time: exponential change with a time constant of <0.01 s.

Time Required for Gain Change: <0.1 s.

Electronic Sensitivity: ADC resolution is 0.5 μV with a current resolution of <10^{-15} A. The saturation current is 160 μA. The 3-gain signal-range is 1.6×10^{11}, defined as the saturation signal divided by minimum resolvable signal.

Noise: Si detector has 15–20 fA of noise when ADC is sampling at 125 Hz and microradiometer is averaging of 25 samples.

Optical Sensitivity: expressed as Noise Equivalent Irradiance at 5 Hz sampling rate.

Wavelength [nm]	Noise Equivalent Irradiance [$\mu W\ cm^{-2}\ nm^{-1}$]
305	3×10^{-4}
412	1×10^{-4}
610	2×10^{-5}
1,020	4×10^{-5}
1,245	6×10^{-5}
1,640	3×10^{-5}

Dark Offsets: dark offsets are measured and set at the time of calibration for each gain level. Offsets can also be automatically measured and applied in the field to accommodate different temperature regimes.

Microradiometer Power: ±5 VDC at 4 mA.

Optical Filters: 10 nm full-width at half-maximum multicavity ion-deposited interference filters selected for greatest out-of-band blocking (typically 10^{-6}), minimum fluorescence, and maximum stability.

Data rate: sensor heads communicate at 115,200 baud, using RS-232 (half duplex). The Control Unit communicates at 115,200 baud with the PC using RS-232 or USB.

BioSHADE Specifications

The BioSHADE accessory is an option and not required for operation of the GUVis-3511.

Shadowband: radius: 9.6 cm (3.78 in); width: 2.54 cm (1 in).

Stepper motor: size 17 motor with 51,200 step resolution and home sensor. Shadowband position recorded in data file.

Stepper motor control: via microradiometer aggregator.

Power requirements: stepper motor: 12.2 V; control: 6.4 V.

Diameter stepper motor housing: 8.9 cm (3.5”).

BioGPS Specifications

The BioSHADE accessory is an option and not required for operation of the GUVis-3511.

Diameter stepper motor housing: 8.9 cm (3.5”).

Provided data: time (UT), latitude, longitude, number of satellites in view, computer clock updating via μLogger software.

Update rate: 1 second.

Accessories

GUVis-3511 may be custom-configured to meet a wide variety of research needs including wavelength selection, temperature set point, cable length, and custom channels. Additional accessories include:

- **Integrated spectrograph**. OSPREy instrument developments include the integration of a high-performance spectrograph beneath the cosine collector. Contact the factory for updates if your are interested in this hyperspectral feature.
- **Measurements of the spectral response functions.** Spectral characterization of every channel with BSI’s purpose-built spectral tester.
- **Measurement of the directional response of the irradiance collector.**

References

GUV radiometers have been introduced in 1992 and are being used in several UV monitoring networks around the world, including the National Science Foundation’s Polar UV Monitoring Network. Instruments have demonstrated their quality at the first international intercomparison of multiband filter radiometers, arranged in Oslo in 2005 [Johnsen et al., 2008]. A selection of papers concerning GUV measurements are provided below. Additional references are available at www.biospherical.com/nsf/references.asp.

Bernhard, G. et al. (2005). Real-time ultraviolet and column ozone from multichannel ultraviolet radiometers deployed in the National Science Foundation’s ultraviolet monitoring network. Optical Engineering, 44(4), 041011-1 - 041011-12.

Dahlback, A. (1996) Measurements of biologically effective UV doses, total ozone abundances, and cloud effects with multichannel, moderate bandwidth filter instruments. Appl.Opt., 35(33), 6514-6521.

Díaz et al. (2005). Multichannel radiometer calibration: a new approach, Appl. Opt., 44(26), 5374-5380.

Johnsen et al. (2008). Intercomparison and harmonization of UV Index measurements from multiband filter radiometers, J. Geophys. Res., 113, D15206, doi:10.1029/2007JD009731.

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