



# PHYTO-PAM

## Phytoplankton Analyzer

### 4-Wavelengths Chlorophyll Fluorometer

- Differentiating between green algae, diatoms and cyanobacteria
- Three alternative Emitter-Detector Units for laboratory and field applications
- Measuring the concentration of active chlorophyll down to 0.1  $\mu\text{g Chl/l}$
- Assessment of effective quantum yield and relative electron transport rate
- Automatized recordings of light response curves of Yield and ETR
- PhytoWin Software for system control, data acquisition and analysis via PC



The PHYTO-PAM Phytoplankton Analyzer not only allows to determine the content of active chlorophyll in natural surface waters down to 0.1  $\mu\text{g Chl/l}$ , but also to differentiate between differently pigmented groups of algae (green algae, diatoms and cyanobacteria). Furthermore, the photosynthetic performance and light-adaptational state of the various types of phytoplankton can be assessed.




Fluorescence is excited alternately at high repetition rates by  $\mu\text{s}$  pulses of 470, 520, 645 and 665 nm light originating from light emitting diodes (LED). A miniature Photomultiplier-Detector serves for extremely sensitive fluorescence detection. It is protected against light damage by automatic switch-off circuitry.

Three alternative system versions with different Emitter-Detector units are available for different applications:

- I. Laboratory version with Optical Unit ED-101US/MP featuring standard 10 x 10 mm cuvette
- II. Portable version PHYTO-ED for field applications featuring  $\varnothing$  15 mm cuvette
- III. Fiberoptics Version PHYTO-EDF for periplan/microphytobenthos measurements

As the Power-and-Control Unit contains a rechargeable battery, in principle all three versions are portable.

## Major features of Systems I, II and III

	 System I (for laboratory applications)	 System II (for field applications)	 System III (Fiberoptics version)
Power-and-Control Unit <b>PHYTO-C</b>	■	■	■
Measuring LED-Array-Cone <b>PHYTO-ML</b>	■		
Actinic LED-Array-Cone <b>PHYTO-AL</b>	■		
Photomultiplier-Detector <b>PM-101P</b>	■		
Optical Unit <b>ED-101US/MP</b>	■		
Stand with Base Plate <b>ST-101</b>	■		
Emitter-Detector Unit <b>PHYTO-ED</b>		■	
Emitter-Detector-Fiberoptics Unit <b>PHYTO-EDF</b>			■
Miniature Magnetic Stirrer <b>PHYTO-MS</b>	□		
Spherical Micro Quantum Sensor <b>US-SQS</b>	□	□	□
Temperature Control Unit <b>US-T</b>	□		
Stirring Device <b>WATER-S</b>		□	

■ Basic System   □ Accessory

### System I

System I is best suited for laboratory applications, because all electro-optical components are mounted on a relatively heavy stand. However, as the Control Unit PHYTO-C is equipped with a large battery, in principle System I can also be used for on-deck and field work. A possible advantage with respect to the other versions is the open design and flexibility of the **Optical Unit ED-101US/MP** which allows to change filters and to apply differently colored Actinic LED-Array-Cones. Illumination within the 10 x 10 mm cuvette is more homogenous than in the compact PHYTO-ED. Further advantages are availability of the Temperature Control Unit US-T and of the Miniature Magnetic Stirrer PHYTO-MS. These features render System I best suited for basic research on phytoplankton photosynthesis.

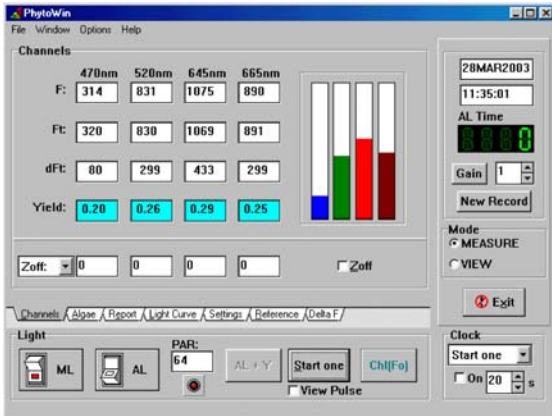
### System II

In the case of the **PHYTO-ED** all electro-optical components are contained in a compact metal box which is sealed against splash water. This system is best suited for field and on-deck work. Due to the more compact optical design, the sensitivity is somewhat higher than in System I. Hence, System II can be particularly recommended for work with open ocean water at chlorophyll contents below 0.5 µg/l.

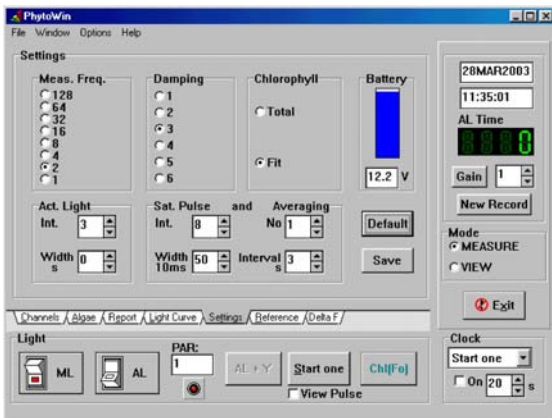
### System III

The Fiberoptics version **PHYTO-EDF** is suited for all applications involving photosynthetic organisms growing on surfaces. It can be particularly recommended for the study of periphyton, micro-phytobenthos and microbial mats. Due to the fiber-optics and the relatively small sample area the sensitivity is distinctly lower than with the two other versions. However, e.g. in sediments chlorophyll content is much larger than in the water column and in most practical cases sensitivity is much higher than required.

# Windows-Software PhytoWin



Channels window



Settings window

The PHYTO-PAM is a microprocessor controlled measuring system which is operated under PC-control using the dedicated PhytoWin-software. Data display and data analysis occurs on seven "windows" with the following features:

- **Channels:** Original, unbiased fluorescence information at 4 different excitation wavelengths
- **Algae:** Deconvoluted fluorescence information for green algae, diatoms and cyanobacteria based on previously recorded reference excitation spectra
- **Report:** File in which all measured data and instrumental settings are stored, which can be edited by the user and exported into other programs
- **Light Curve:** Graphic display of light response curves; effective quantum yield and relative electron transport rate (ETR) as a function of PAR
- **Settings:** Controls for instrumental settings, like measuring pulse frequency, actinic intensity, saturation pulse width and intensity, clock interval, damping, number of averages, etc.
- **Reference:** Display of reference excitation spectra of green algae, diatoms and cyanobacteria, previously recorded with the same instrument
- **Delta F:** Special measuring mode restricted to assessment of variable fluorescence induced by repetitive saturation pulses; for ultrasensitive measurement of active chlorophyll

## Accessories



The **Miniature Magnetic Stirrer PHYTO-MS** can be mounted into the bottom port of the Optical Unit ED-101US/MP of System I.



For System I the **Temperature Control Unit US-T** is available. It consists of a Peltier-controlled Heat-Transfer Rod and a separate Power-and-Control Unit.



The **Spherical Micro Quantum Sensor US-SQS** is available for measuring photosynthetically active radiation (PAR) within the cuvettes of Systems I and II.



For System II the **Stirring Device WATER-S** is available, which is placed on top of the Emitter-Detector box PHYTO-ED and features an internal battery.

# Technical Specifications

## System I (for lab. applications)

### Basic System

#### Power-and-Control Unit PHYTO-C

**Microcontroller:** RISC processor

**User interface:** Pentium-PC with Windows-Software PhytoWin; connection via RS 232, 19200 baud; keyboard operation; monitor screen display

**Data output:** Display and print-out via PC; analog output of four channels (original fluorescence data), 0 to 5 V

**Power supply:** Built-in rechargeable sealed lead-acid battery 12 V/7.2 Ah; Battery Charger MINI-PAM/L (100 to 240 V AC)

**Power consumption:** Basic operation 350 mA; with all LED light sources turned on, max. 800 mA

**Dimensions:** 31 cm x 16 cm x 33.5 cm (W x H x D), with carrying handle

**Weight:** 6.1 kg

#### Windows-Software PhytoWin

**PC Requirement:** Pentium 600 MHz processor (minimum); 128 MB RAM (minimum); Windows 98, Me, 2000 or XP

#### Measuring LED-Array-Cone PHYTO-ML

**Design:** Array consisting of 25 measuring light LEDs peaking at 470, 520, 645 and 665 nm, as well as 12 actinic light LEDs peaking at 655 nm (max. intensity  $600 \mu\text{mol quanta m}^{-2}\text{s}^{-1}$  PAR), with light-guiding perspex cone narrowing beam down to  $\varnothing$  13 mm; with short-pass filter ( $\lambda < 695$  nm) at cone-exit; mounted in black-anodized aluminum housing

**Dimensions:**  $\varnothing$  59 mm, length 190 mm

**Weight:** 630 g (incl. cable, 1.5 m long)

#### Actinic LED-Array-Cone PHYTO-AL

**Design:** Array consisting of 37 actinic LEDs peaking at 655 nm, (max. intensity  $2000 \mu\text{mol quanta m}^{-2}\text{s}^{-1}$  PAR), with light-guiding perspex cone narrowing beam down to  $\varnothing$  13 mm; with short-pass filter ( $\lambda < 695$  nm) at cone-exit; mounted in black-anodized aluminum housing

**Dimensions:**  $\varnothing$  59 mm, length 190 mm

**Weight:** 600 g (incl. cable, 1.5 m long)

#### Photomultiplier-Detector PM-101P

**Design:** Mounted in aluminum housing containing pulse-signal preamplifier; featuring on/off push-buttons and special circuitry for automatic overload switch-off; with light-tight Filter Box and adapter for mounting on Optical Unit

**Signal detection:** Miniature photomultiplier with high red sensitivity (type H6779-01, Hamamatsu)

**Detector filter:** Combination of three filters passing wavelengths above 710 nm, optimized for low background signal

**Dimensions:** 100 mm x 66 mm x 108 mm (L x W x H)

**Weight:** 490 g (incl. cable, 1.5 m long)

#### Optical Unit ED-101US/MP

**Design:** Black-anodized aluminum body with central 10x10 mm standard glass cuvette; for attachment of Measuring LED-Array-Cone and Photomultiplier-Detector at right angle; featuring perspex-light-guide between cuvette and Detector Filter Box; three additional optical ports to attach Actinic LED-Array-Cone (optional) and Miniature Magnetic Stirrer (optional); light-tight hood with injection hole

**Mounting:** On special Stand with Base Plate ST-101

**Weight:** 850 g

#### Stand with Base Plate ST-101

**Design:** Heavy base plate made from laminated wood (39.5 cm x 30 cm x 2 cm); with stand bar  $\varnothing$  15 mm, height 76.5 cm (dividable in two parts)

**Weight:** 2.8 kg

## Accessories (optional)

#### Miniature Magnetic Stirrer PHYTO-MS

**Design:** Based on rotating magnetic field; connecting to Power-and-Control Unit; with special adapter plug to be mounted in bottom port of Optical Unit

**Weight:** 20 g (incl. cable, 1 m long)

#### Spherical Micro Quantum Sensor US-SQS

**Design:**  $\varnothing$  3 mm diffusing sphere coupled to  $\varnothing$  1 mm single plastic fiber connected via ST-fiber coupler with amplifier box (battery-driven); featuring special holder for mounting on standard 10 x 10 mm glass cuvette; to be connected to AUX-input of Power-and-Control Unit; can be operated alternatively in conjunction with the Light Meter LI-189 or LI-250 (LI-COR)

#### Temperature Control Unit US-T

Power-and-Control Unit US-T/R

**Display and control range:** 0 °C - 50 °C

**Accuracy of control:**  $\pm 0.2$  K

**Operating voltage:** 11 V DC - 14 V DC (via AC adapter)

**Ambient temperature range:** 0 °C - 50 °C

**Dimensions:** 105 mm x 90 mm x 130 mm (W x H x D)

**Weight:** 0.9 kg

#### Heat-Transfer Rod US-T/S

**Maximal possible temperature difference between Peltier Heat-Transfer Rod and ambient temperature:** with cooling  $\Delta T = -20$  K; with heating  $\Delta T = 30$  K

**Cooling / heating rate:** ca. -3 K/min / 4 K/min

**Dimensions:**  $\varnothing$  55 mm, 110 mm height

**Cable length:** 130 cm

**Weight (incl. cable):** 0.3 kg



## System II (for field applications)

### Basic System

#### Power-and-Control Unit PHYTO-C

see System I

#### Emitter-Detector Unit PHYTO-ED

**Design:** Metal housing with cables connecting to the Power-and-Control-Unit PHYTO-C; featuring measuring chamber with  $\varnothing$  15 mm quartz cuvette; housing Measuring and Actinic/Saturation Pulse LED Arrays, Photomultiplier Detector and Pulse Signal Preamplifier

**Measuring LED Array:** Total of 18 LEDs for pulse modulated Measuring Light peaking at 470, 520, 645 and 665 nm, focused on bottom part of quartz cuvette via 18 individual short-pass filters ( $\lambda < 695$  nm)

**Actinic LED Array:** Total of 16 LEDs for Actinic Light/Saturation Pulses peaking at 655 nm, focused on bottom part of quartz cuvette; actinic intensity up to 2000  $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$  of photosynthetically active radiation (PAR); Saturation Pulse intensity up to 4000  $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$

**Signal detection:** Photomultiplier detector based on Photosensor Module H6779-01 (Hamamatsu) with high red sensitivity, featuring pulse preamplifier and automatic overload switch-off; fluorescence detection at wavelengths  $> 710$  nm; optimized for low background signal by special filter combination

**Dimensions:** 115 mm x 90 mm x 80 mm (L x W x H)

**Weight:** approx. 0.6 kg (incl. cables 0.6 m long)

### Accessories (optional)

#### Spherical Micro Quantum Sensor US-SQS

see System I

#### Stirring Device WATER-S

**Design:** Miniature stirring motor in plastic housing with adapter to mount on top of the Emitter-Detector Unit PHYTO-ED; equipped with disposable perspex stirring paddle; self-contained unit featuring long-life 3 V Lithium Battery; potentiometer for adjustment of stirring rate

**Dimensions:** 80 mm x 50 mm x 30 mm (L x W x H)

**Weight:** 95 g (incl. battery)

## References

**Schreiber U, Gademann R, Bird P, Ralph PJ, Larkum AWD and Kuehl M (2002):** Apparent light requirement for activation of photosynthesis upon rehydration of desiccated beachrock microbial mats. *J Phycology* 38: 1-10

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**Nicklisch A and Köhler J (2001):** Estimation of primary production with Phyto-PAM-fluorometry. *Ann Report Inst Freshw Ecol Inland Fish Berlin* 13: 47-60

**Schreiber U (1998):** Chlorophyll fluorescence: New instruments for special applications. In: *Photosynthesis: Mechanisms and Effects* (Garab G. ed) Vol. V, pp. 4253-4258

**Kolbowski J and Schreiber U (1995):** Computer-controlled phytoplankton analyzer based on 4-wavelengths PAM chlorophyll fluorometer. In: *Photosynthesis: from Light to Biosphere*. (Mathis P. ed.), Vol. V, pp. 825-828

## System III (Fiberoptics version)

### Basic System

#### Power-and-Control Unit PHYTO-C

see System I

#### Emitter-Detector-Fiberoptics Unit PHYTO-EDF

**Design Emitter-Detector box:** Metal housing with cables connecting to the Power-and-Control-Unit PHYTO-C; containing Measuring and Actinic/Saturation Pulse LEDs, miniature fiber couplers with SMA-fiber connectors, Photomultiplier and Pulse Preamplifier; separate 9-armed fiberoptics

**Dimensions:** 115 mm x 90 mm x 95 mm (L x W x H)

**Weight:** approx. 600 g (incl. cables 0.6 m long)

**Measuring LEDs:** Total of 4 LEDs for pulse modulated Measuring Light peaking at 470, 520, 645 and 665 nm, focused by miniature collimating lenses via 4 individual short-pass filters ( $\lambda < 695$  nm) on entrance of  $\varnothing$  1 mm single plastic fibers with SMA-connectors

**Actinic LEDs:** Total of 4 LEDs for Actinic Light/Saturation Pulses peaking at 655 nm focused by miniature collimating lenses via 4 individual short-pass filters ( $\lambda < 695$  nm) on entrance of  $\varnothing$  1 mm single plastic fibers with SMA-connectors; actinic intensity up to 1300  $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$  of photosynthetically active radiation (PAR); Saturation Pulse intensity up to 2600  $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$

**Signal Detection:** Photomultiplier detector based on Photosensor Module H-6779-01 (Hamamatsu) with high red sensitivity; featuring pulse preamplifier and automatic overload switch-off; fluorescence detection at  $\lambda > 710$  nm; optimized for low background signal by special filter combination

**Fiberoptics:** 8 arms with  $\varnothing$  1 mm single plastic fibers with SMA-adaptors to be connected to Measuring Light and Actinic Light connectors on top side of Emitter-Detector box; central  $\varnothing$  1.5 mm fiber with adaptor to detector input; length 105 cm; joint end with special endpiece featuring  $\varnothing$  4 mm perspex light mixing rod, length 50 mm

**Special Stand:** Heavy base plate made from laminated wood (39.5 cm x 30 cm x 2 cm); with stand bar  $\varnothing$  15 mm, height 76.5 cm (dividable in two parts); weight 2.8 kg; featuring special holder for fiberoptics endpiece, dark-box for shielding sample from ambient light

### Accessories (optional)

#### Spherical Micro Quantum Sensor US-SQS

see System I



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