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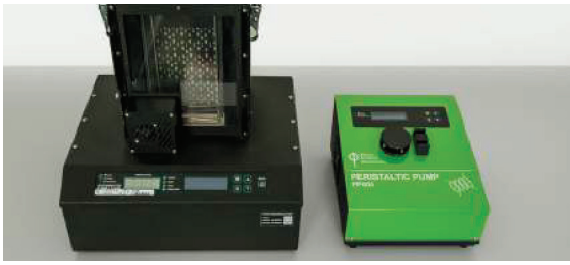
Multi-Cultivator MC-1000 54

Multi-Cultivator MC-1000 is a cost-effective small scale cultivation device developed for cultivation of multiple samples of algae, bacteria or cyanobacteria. Multi-Cultivator MC-1000 consists of 8 cultivation vessels, where up to 85 ml of suspension can be maintained under controlled light, temperature and aeration conditions. Illumination can be regulated for each vessel independently.

Photobioreactor FMT 150 56

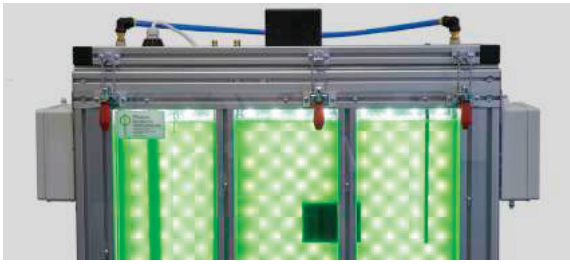
Photobioreactors FMT 150/400, FMT 150/1000 and FMT 150/3000 feature a unique combination of the cultivator and computer controlled monitoring device. FMT 150/400, FMT 150/1000 and FMT 150/3000 differ in the capacity of their cultivation vessels – 400 ml, 1,000 ml and 3,000 ml respectively. All Photobioreactor models may be supplied with a number of useful accessories – sensors, stirrers, pumps, etc.



Large-Scale Photobioreactors 58

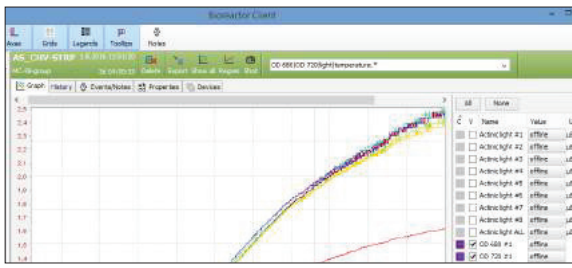
Large-volume bioreactors are manufactured with respect to customer's specific needs and they come with a number of useful accessories. Two basic versions feature:
– 25-liter cultivation tank
– 100-liter cultivation tank

Cultivation tanks may be built as modular systems containing number of optional modules and may be cascaded to increase the total volume up to 1,000 l.



PBR Control Software 60

New control software is intended for the product line comprising Multi--Cultivators, small- and large-scale Photobioreactors. The software provides intuitive and dynamic interface for real-time visualization of recorded data and also online remote access via internet. Number of advanced custom cultivation protocols can easily be set through the user-friendly adjustment of individual parameters.



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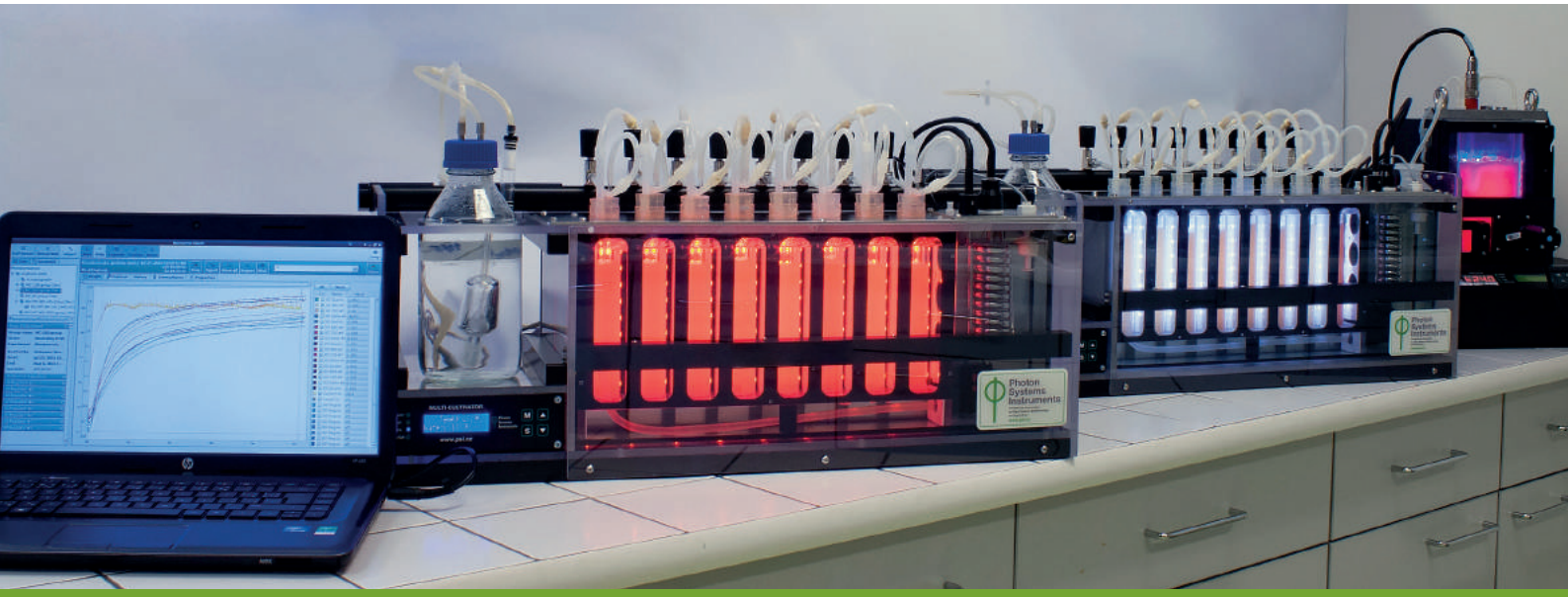


Multi-Cultivator MC-1000

Multi-Cultivator MC-1000-OD is a cost-effective small scale cultivation device developed for cultivation of multiple samples of algae, bacteria or cyanobacteria. Multi-Cultivator MC--1000-OD consists of 8 cultivation vessels, where up to 85 ml of suspension can be maintained under controlled light, temperature and aeration conditions. The cultivation vessels are immersed in a temperature controlled water bath. All vessels can be bubbled with air or selected gas (optional) of different flow rate through a manually adjustable valve manifold. Each vessel is separately illuminated by an array of cool white LEDs (optionally warm white, red, or blue LEDs) that generate incident PPFD up to 1,000 $\mu mol.m^{-2}.s^{-1}$ (optionally up to 2,500 $\mu mol.m^{-2}.s^{-1}$). The illumination is independently adjustable for each cultivation vessel in intensity, timing and modulation which allows to set unlimited number of user defined light protocols. The growth of cultivated organisms is automatically monitored by measuring of optical density at two wavelengths of 680 nm and 720 nm.

Turbidostatic version of Multi--Cultivator MC-1000-OD allows to control the biomass growth via OD680 or OD720 independently in each vessel. The pre-set optical density can be modified at a constant level or in a different range automatically depending on the conditions during the experiments.

Multi-Cultivator MC-1000-OD-MULTI is a multi-color instrument version, in which each cultivation slot is furnished with illumination of different color. Covered is the spectrum from 405 nm to 730 nm.

Multi-Cultivator MC-1000-OD-MIX is a mixed-color instrument version which allows to combine up to 4 different LED colors within each cultivation slot for definition of specific spectra.

APPLICATION

- Synchronous multi-well cultivations
- Laboratory applications requiring multiple experimental variants
- Different organisms testing and comparing
- Testing in diverse cultivation conditions
- Controlled cultivation and growth dynamics monitoring of up to 8 different organisms

KEY FEATURES

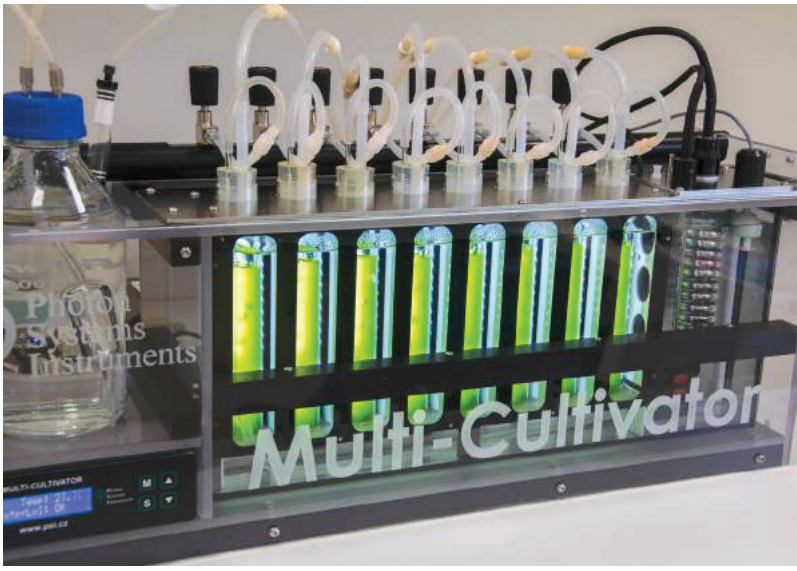
- Highly precise multi-well cultivation instrument for synchronous growth of algae, bacteria or cyanobacteria
- Flat, rectangular water reservoir nesting eight independently illuminated slots for cultivation in test vessels
- Autoclavable round-shaped glass test tubes
- LED technology illumination adjustable in intensity, timing and modulation
- Illumination for each test tube is independently controllable
- Temperature and light control via user defined protocols that support also diurnal regime or flashing light
- Manually controlled aeration gas is humidified and distributed into each test-tube
- Optical density reading
- Different multicolor version of the device (optional)
- Turbidostatic module (optional)

CONTROL SOFTWARE

- User defined protocol writing
- Real time data visualization and analyses in graphs
- Remote control of the experiment via internet

TECHNICAL SPECIFICATION

- **Number of Test Tube Slots:** 8
- **Test Tube Volume:** 100 ml (maximum recommended working volume of each test tube is 85 ml)
- **Volume of Water Reservoir:** 5 liters
- **Precision Controlled Temperature:**
  from approximately 5 °C above ambient temperature up to 60 °C
  15 °C – 60 °C (optional; with Cooling Unit AC-625)
- **Heating System:** One 150 W cartridge heater
- **LED Lighting:**
  Light intensity adjustable in the full range up to 1,000 $\mu mol.m^{-2}.s^{-1}$ (optionally up to 2,500 $\mu mol.m^{-2}.s^{-1}$)
- **Standard single color version:** cool white illumination. Optional: warm white, red, blue
- **Multi-color versions:** Single-color slots (405, 450, 470, 540, warm white, 590, 660, 730 nm)
- **Light Path:** 27 mm
- **Light Regime:** Static or dynamic
- **Online Measured Parameters:** Optical density, temperature
- **Optical Density Measurement:** Real time measurement of OD by two LEDs (720 nm, 680 nm) per a culture vessel; time intervals of OD measurements may be specified
- **Optical Path for OD Measurement:** 27 mm
- **Controlled Flow of Bubbled Air:** Manual via manifold valves
- **Controlled Composition of Bubbled Air:** Optional with purchase of Gas Mixing System GMS 150
- **BIOS:** Upgradeable firmware
- **Communication Port:** USB A-B
- **Material:** Glass, stainless steel, silicon gasket, polycarbonate
- **Dimension:** 80.5 × 35 × 21 cm
- **Weight:** 13 kg
- **Electrical:** 110 – 240 V AC



Photobioreactor FMT 150

Photobioreactor FMT 150 features a unique combination of the cultivator and computer controlled monitoring device. The Photobioreactor FMT 150 combines a flat cultivation vessel with the built-in fluorometer and densitometer. It is primarily designed for high-content, precise phototrophic cultivation of algae, cyanobacteria and bacteria. Light intensity and spectral characteristic as well as temperature and aeration gas composition can be set with high accuracy. Cultivation conditions can be dynamically varied according to user-defined protocol and continuously online monitored. Programmable light, temperature, gas, and medium regime can oscillate with various amplitudes and frequencies according to user-defined time steps from milliseconds to hours. Continuous-flow turbidostatic cultivation can be used for the stabilization of the suspensions and optical density control. In addition to the turbidostatic pump, up to 7 peristaltic pumps for different chemostat or pH-stat cultivation can be linked to the Photobioreactor for highly precise control of cultivation conditions.

The growth of the cultures is monitored by the integrated densitometer (OD680, OD720). Chlorophyll content of the culture can also be monitored continuously by the difference of optical densities at 680 and 720 nm. The instantaneous physiological state of the culture is measured by the Photosystem II quantum yield F_V/F_M.

Photobioreactor function can be enhanced by the additional gas modules: Gas Mixing System GMS 150 providing optimal control of input gas concentration; and gas analyzer MS GAS-100 intended for complex analyses of gases and volatiles including isotopes, solvents and volatile organics in headspace and liquid phase as well.

KEY FEATURES – MONITORING

- Integrated Double-Modulation Fluorometer with online measurement and recording of chlorophyll fluorescence parameters, such as F_0, F_T, F_M, F'_M, $(F'_M-F_T)/F'_M$
- Integrated online optical density measurement (OD680, OD720)
- Continuous temperature control
- Continuous pH monitoring
- O_2 electrode to measure concentration of dissolved O_2 (optional)
- CO_2 electrode to determine dissolved CO_2 concentration (optional)
- Highly precise gas mixing system for aeration (optional)
- Monitoring of medium consumption during a turbidostatic cultivation (optional)

CULTIVATION

- Autoclavable flat glass cultivation vessel: 400 ml, 1,000 ml or 3,000 ml
- Programmable light, temperature, gas, and medium regime. Time steps from milliseconds to hours
- Both static and changeable temperature
- Bubble humidifier for stable culture volume
- Controlled flow rate and composition of the sparging gas with GMS 150
- Magnetic stirring
- Anaerobic cultivation via gas tight lid and N_2 sparging
- Turbidostat, chemostat or pH-stat cultivation control

TECHNICAL SPECIFICATION

- **Online Measured Parameters:** Chlorophyll fluorescence, OD, pH, temperature, O_2, CO_2, medium consumption during turbidostatic cultivation
- **Vessel Capacity:**
  400 ml (FMT 150/400)
  1,000 ml (FMT 150/1000)
  3,000 ml (FMT 150/3000)
- **Precision Controlled Temperature (depending on ambient conditions):**
  5–75 °C (FMT 150/400)
  10–75 °C (FMT 150/1000 and FMT 150/3000)
- **Cooling and Heating System:**
  200 W Peltier element (FMT 150/400 and FMT 150/1000)
  400 W Peltier element (FMT 150/3000)
- **LED Lighting:** Light intensity adjustable in the full range up to 1,500 $\mu mol.m^{-2}.s^{-1}$ (optionally up to 3,000 $\mu mol.m^{-2}.s^{-1}$). Bi-color light panels available (separate color control)
- **Light Path:** 24 mm (FMT 150/400); 61 mm (FMT 150/1000 and FMT 150/3000)
- **Light Regime:** Static or dynamic
- **Optical Density Measurement:** Real time measurement of OD by two far-red LEDs (680 nm, 720 nm). Time intervals of OD measurements may be specified
- **Chlorophyll Fluorescence Measurement:** Blue excitation light and red-orange excitation light
- **Optical Path for OD and Chlorophyll Fluorescence Measurement:** 24 mm
- **Controlled Flow Rate and Concentration of Sparging Gas:** Optional
- **Pumps:** Up to 8 peristaltic pumps
- **Optional Probes:** O_2, CO_2 and others
- **BIOS:** Upgradeable firmware
- **Communication Port:** USB A-B
- **Material:** Glass, stainless steel, silicon gasket
- **Dimension:**
  41.5 × 35 × 31 cm (FMT 150/400 and FMT 150/1000)
  50 × 35 × 31 cm (FMT 150/3000)
- **Weight:**
  15.5 kg (FMT 150/400)
  17.5 kg (FMT 150/1000)
  28 kg (FMT 150/3000)
- **Electrical:** 90–240 V AC

CONTROL SOFTWARE

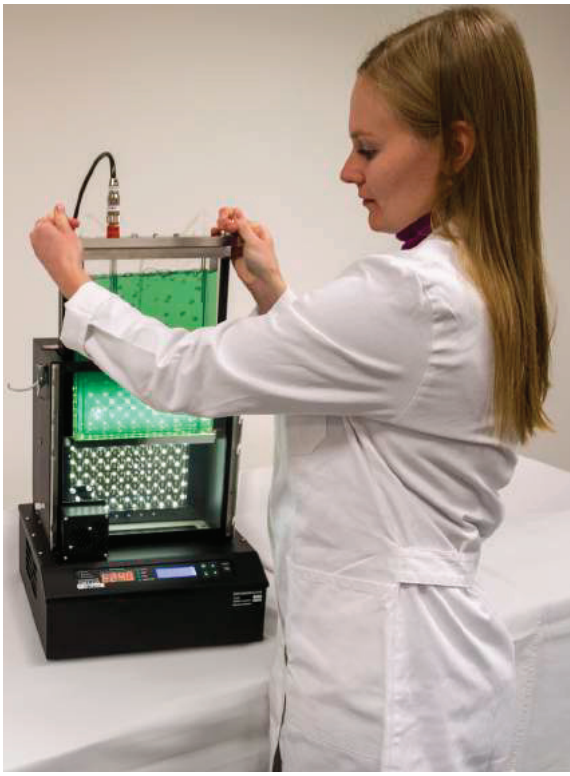
- User defined protocol writing
- Real time data visualization and analyses in graphs
- Remote control of the experiment via internet

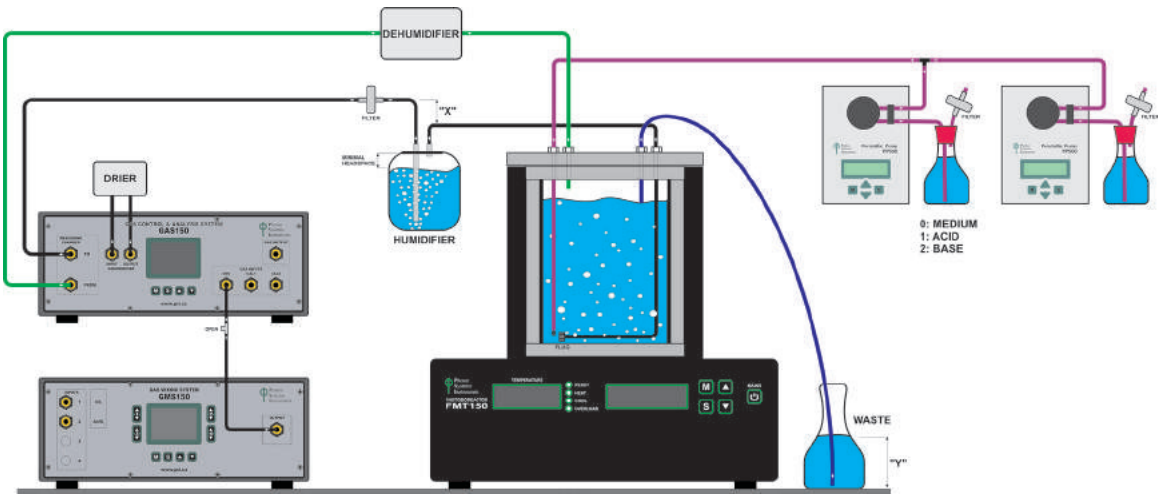
LED ILLUMINATION

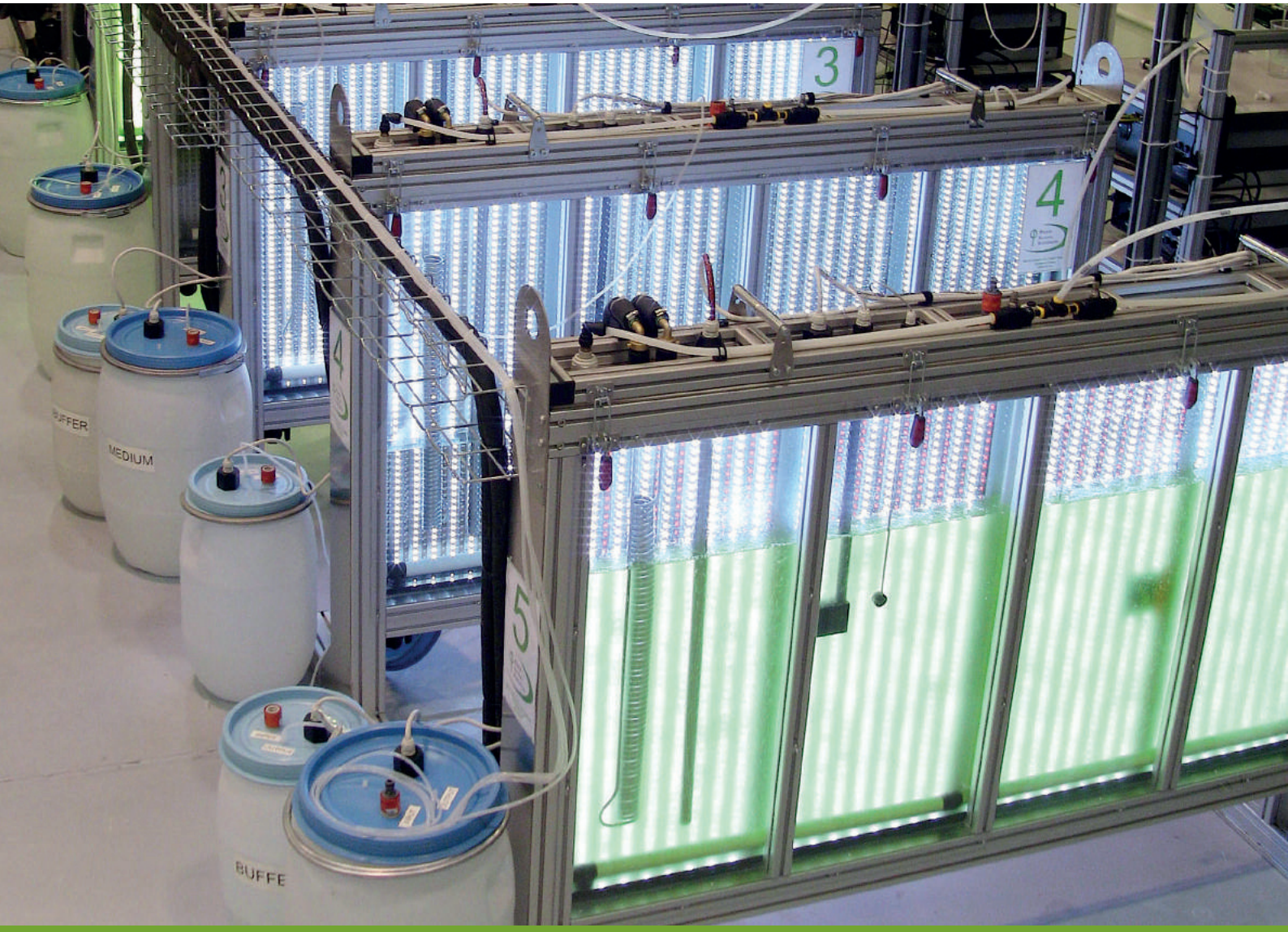
- Bi-color LED panel (white-red or blue-red typically) with separately controllable channels. Other color combination on request
- Homogeneous illumination over the whole flat vessel
- Controllable light intensity up to 1,500 $\mu mol.m^{-2}.s^{-1}$ (optionally up to 3,000 $\mu mol.m^{-2}.s^{-1}$)
- Both static and fluctuating light regimes. Day/night cycles
- Additional front light panel for higher intensity or different light color

APPLICATION

- Precision cultivation of photoautotrophic microorganisms
- Cultivation conditions optimization and yield improvement
- Photosynthesis research
- Stress physiology, detection of biotic and abiotic stress
- Study of diurnal or metabolic rhythms
- Study of secondary metabolites production
- Ecotoxicological research
- Ecological research, microorganisms interactions, population dynamic
- Environmental modeling







Large-Scale Photobioreactors

PSI **Large-Scale Photobioreactors** are systems that create a controlled artificial environment for large-scale monitored growing and harvesting of photosynthetic organisms, mostly algae and cyanobacteria. The core of the standard Photobioreactor system is a flat glass cultivation tank (25 l or 100 l in volume) with an integrated temperature regulation and bubble stirring system for the aeration of the culture. The cultivation tanks may be cascaded to increase the total volume up to 1,000 l. Illumination is provided by flat LED panel that generates a highly uniform irradiance flux. Continuous-flow turbidostatic cultivation can be used for the stabilization of the biomass suspensions via optical density control. Programmable light, temperature, gas, and medium regime can oscillate with various amplitudes and frequencies according to user-defined experimental protocols.

The growth of the cultures is monitored by the integrated densitometer (OD720, 680 nm). The instantaneous physiological state of the culture is measured by the Photosystem II quantum yield F_V/F_M with integrated PAM Fluorometer. Supplementary sensors for monitoring and control of pH/T, O_2, CO_2 are available.

Photobioreactor function can be enhanced by the additional gas module Gas Mixing System GMS 150 providing optimal control of input gas concentration and flow rate.

The entire Photobioreactor system is connected to an external Control unit with a computer running control software that defines and controls experimental conditions and also enables remote control via internet.

Regard to a broad experience concerning the development and production of diverse Photobioreactors systems, PSI offers also development and manufacturing of **customized Large-Scale Photobioreactors** comprising of various cultivation tanks and other accessories.

03 / Photobioreactors

CULTIVATION VESSEL

- Flat construction with light path of 6.5 cm
- Working volume of 25 l or 100 l per one unit
- Glass cultivation tank with stainless steel frame. Cultivation tank is not autoclavable
- Gas-tight vessel lid with gas and electronics fittings
- Gas sparging system

LIGHT MODULE: LED-BASED ILLUMINATION

- Bi-color white-red LED panel with separately controllable colors. Other color combination on request
- 25 l PBR: PPFD up to 500 $\mu mol.m^{-2}.s^{-1}$ for white and up to 200 $\mu mol.m^{-2}.s^{-1}$ for red light channel (standard)
- 25 l PBR: light intensity up to 2,000 $\mu mol.m^{-2}.s^{-1}$ for both light channel together (optionally)
- Both static and fluctuating light regime. Day/night cycles
- Solar simulation

ADDITIONAL MODULES

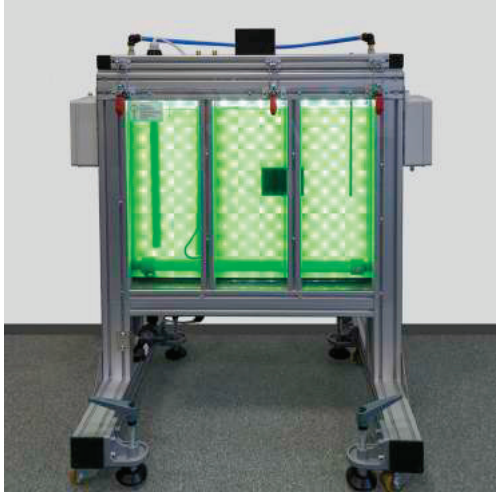
- Optical module: PAM fluorometer with blue and red-orange excitation; Turbidometer 680 and 720 nm (OD680, 720)
- Electrode module for connection of pH/T, dO_2, CO_2 probes
- Fluidic modules: Turbidostat module, Chemostat module, pH-stat module
- Cooling module widens the range of cultivating temperature to 15–60 °C (ambient temperature not exceeding 30 °C)
- Gas module: Gas Mixing System GMS 150

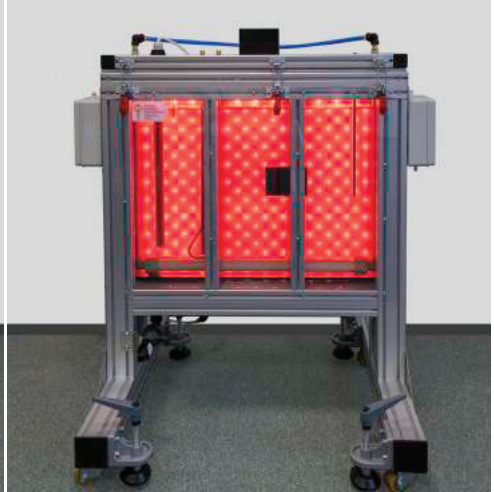
CONTROL SOFTWARE

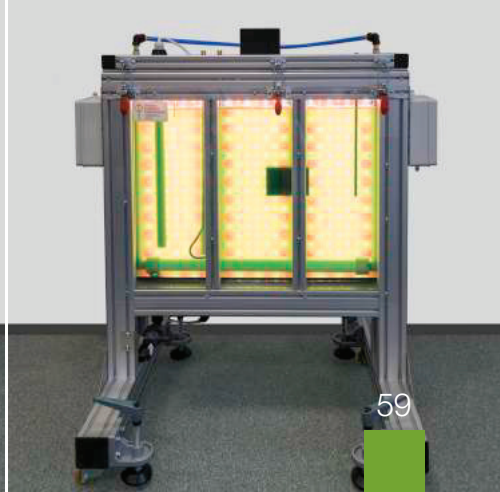
- User defined protocol writing
- Real time data visualization and analyses in graphs
- Remote control of the experiment via internet

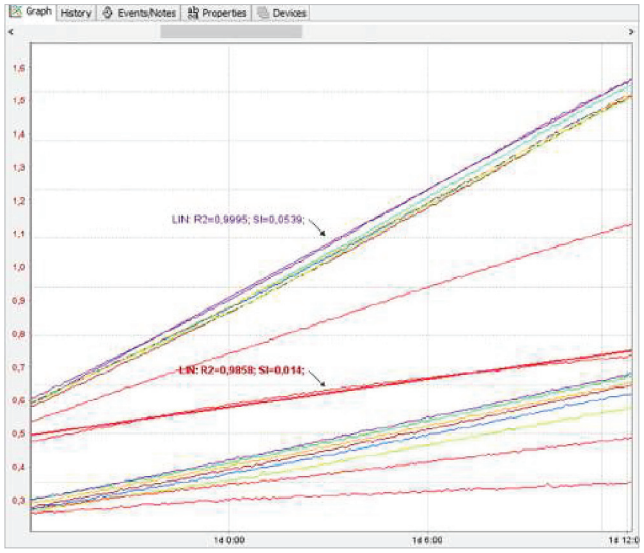
CUSTOMIZED LARGE-SCALE PHOTOBIOREACTORS

- Vertical Tubular Airlift Photobioreactor is a modular system scalable between 100 – 1,000 l. Ambient or artificial LED illumination. Monitoring of OD680, 720 and chlorophyll fluorescence. Additional probes: pH/T, dO_2, CO_2
- Stainless 1,000 l Photobioreactor. Temperature controlled cultivation tank with the immersed LED lighting and integrated sparging system. Monitoring of OD680, 720 and chlorophyll fluorescence. Additional probes:pH/T, dO_2, CO_2
- Modular Helical Tubular Photobioreactor (250 l per one unit) with a degassing system. Ambient or artificial LED illumination. Monitoring of OD680, 720 and chlorophyll fluorescence. Additional probes: pH/T, dO_2, CO_2









PBR Control Software

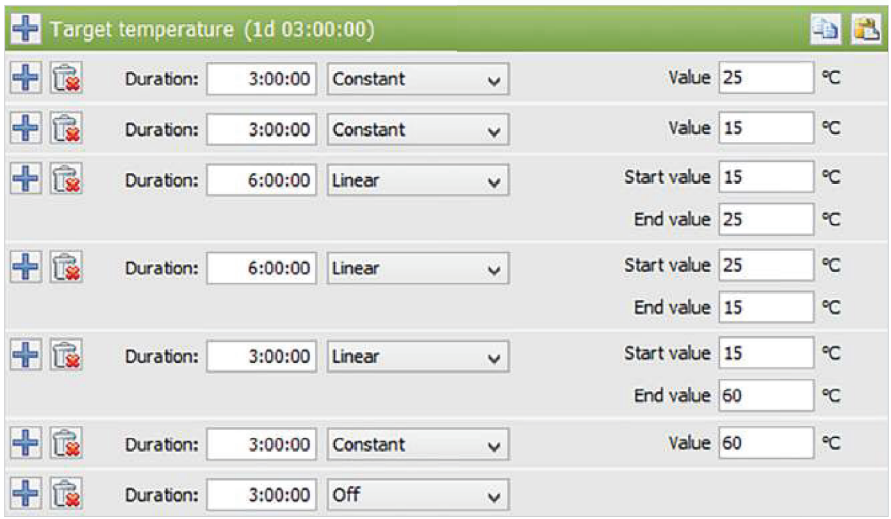
New **PBR Control Software** is our universe solution developed for wide range of PSI cultivation devices comprising Multi-Cultivators and small- and large-scale Photobioreactors. The software provides intuitive and dynamic interface for real-time visualization of recorded data and also online remote access via internet. Number of advanced custom cultivation protocols can be easily set through the user-friendly adjustment of individual parameters. Also java scripting for specific modification of the controlled parameters is available. In addition, storing data into database is implemented, including intelligent searching in the database and user-friendly multiple experiment export function into MS Excel or OpenOffice.

Advanced data analysis functions are included such as regression analysis and dynamic real-time calculation of growth rates for defined periods.

The PBR control software is available in two versions: Basic and Advanced. The major difference is that the advanced version comprises additional features and is optimized for simultaneous control of different and multiple cultivation devices such as Multi--Cultivators as well as Photobioreactors from one PC. Software controlled communication with additional devices such as Gas Mixing System GMS150, Turbidostatic module and additional pumps are also supported.

KEY SOFTWARE FEATURES

- Full control (setting and editing) of experimental conditions
- Real time visualization and filtering of experimental parameters and measured data (OD680, OD720, chlorophyll fluorescence, cultivation parameters, etc.)
- Real-time regression analysis of growth rates
- Storage of data in a database
- Multiple data handling functions (filtering, searching, multiple export)
- Online changes to protocols recorded in protocol history



BASIC VERSION

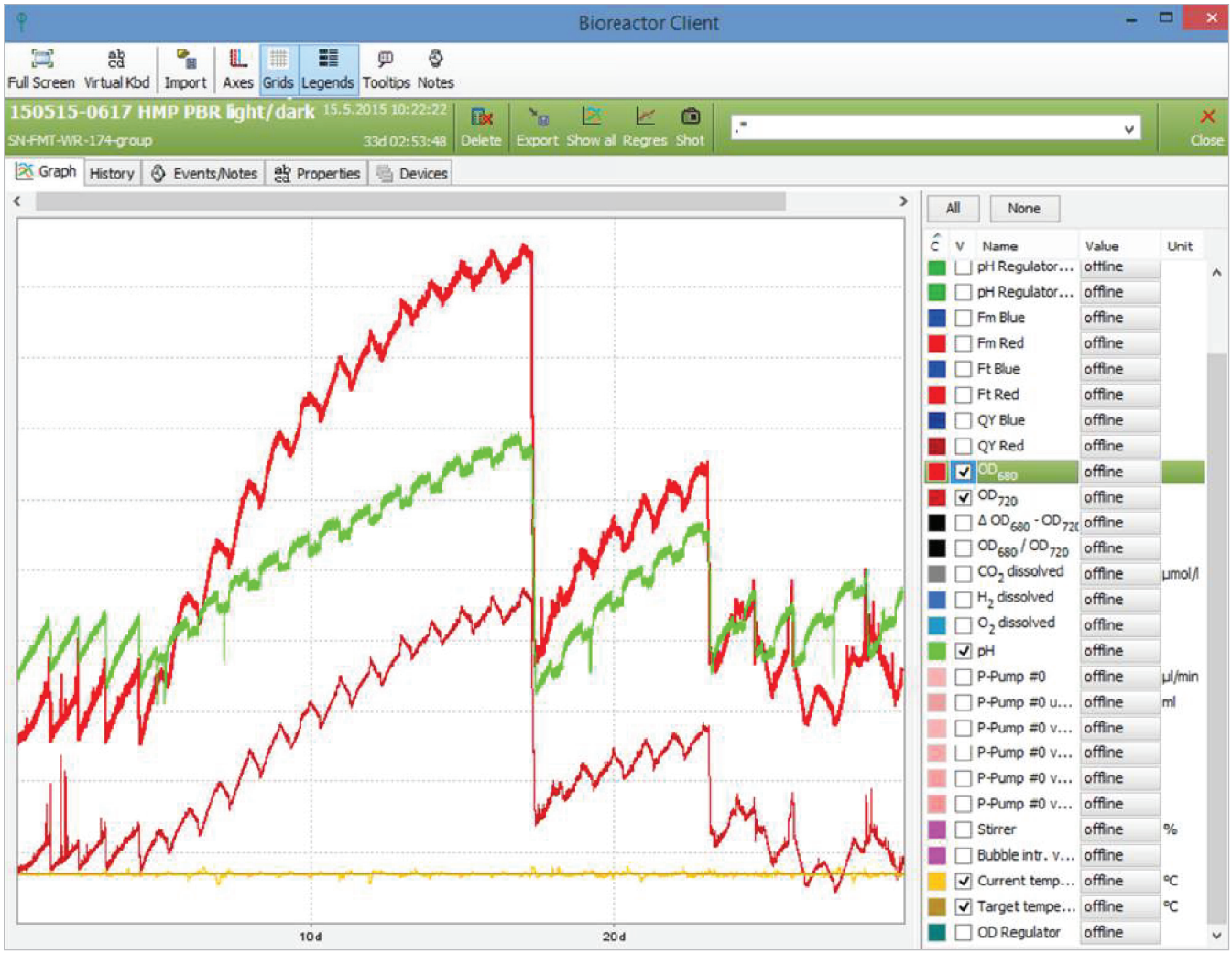
- User friendly GUI, clear graph tooltips, legend panels
- Support of turbidostatic, chemostat and pH-modules
- Set up of custom cultivation protocols
- Change in protocol of running experiment and restoration after laptop reboot
- Accessory calibrations
- Basic linear regressions in experimental graph
- Export of the experiments to MS Excel/OpenOffice
- Recorded experiments filtering
- Online software upgrades

ADVANCED VERSION

- All features of the Basic version
- Scripting support in protocol
- Advanced regression analysis in experimental graph
- Scheduling of the experimental start
- Import of old experiments
- E-mail notifications
- Additional peristaltic pumps support
- Support for Gas Mixing System GMS 150
- Unlimited multi-license

LIST OF SOFTWARE--CONTROLLED PARAMETERS

- Full control of light regime for each cultivation color independently
- Temperature
- OD measurement at 680 and 720 nm
- Chlorophyll fluorescence parameters (F_0, F_m, QY)
- pH, O_2 and CO_2
- Sparging gas
- Magnetic stirrer
- Turbidostatic, chemostat and pH-stat cultivation
- Medium consumption for turbidostatic mode
- Additional pumps



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