Overview of Low-Budget Photobioreactors

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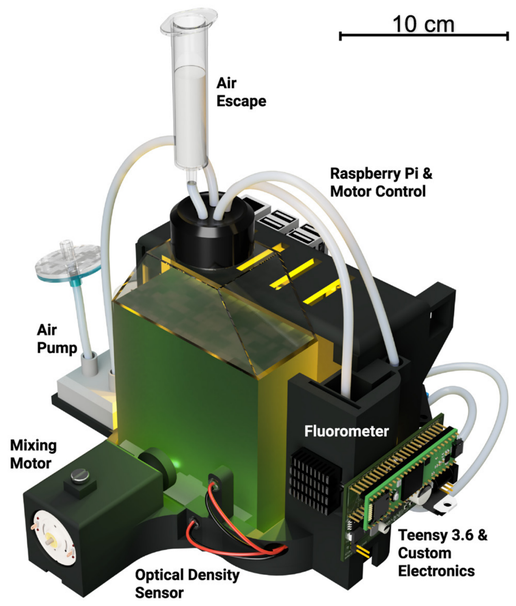
A **bioreactor** is a manufactured device that supports a biologically active environment where specific conditions are carefully controlled. A **photobioreactor** (PBR) is a bioreactor that utilizes a light source to cultivate phototrophic microorganisms. These organisms (e.g. microalgae, cyanobacteria) use photosynthesis to generate biomass from light and carbon dioxide. Photobioreactors differ in supported functionality (e.g. optical density, pH) and controlled properties (e.g. culture irradiance, temperature, gas composition), their shape, size, and volume, ranging in size from millilitres to cubic metres. Also, the particular construction and quality of sensors have an effect on the sensitivity of the instrument and the precision of the measurement. Small-scale photobioreactors for the cultivation of photoautotrophic microbes are required for precise characterization of the growth parameters of wild-type and engineered strains of these organisms, for their screening, and for the optimization of culture conditions.

Photobioreactors FMT 150 feature a combination of the bench-top cultivator and computer-controlled monitoring device. The product line comprises three instruments that differ in the cultivation vessel capacity - 400 ml, 1 and 3 l. All Photobioreactor models may be supplied with a number of useful accessories that facilitate to meet wide range of special experimental conditions.

PHOTON SYSTEMS INSTRUMENTS

- Cultivation of photoautotrophic and heterotrophic microorganisms
- Flat cultivation vessel with a short light path for an optimal illumination
- Standard bi-color LED panel, optionally up to 4 illumination colors
- Highly precise control of cultivation conditions (illumination, temperature, aeration, etc.)
- Optical density (OD 680, OD 720) and Chlorophyll-a fluorescence monitoring
- Variable cultivation strategies (batch, pH-stat, turbidostatic, anaerobic, etc.)
- Light Intensity – 1.500 - 3.000 μmol.m^{-2}.s^{-1}
- Supported colours – red/blue, red/white
- Temprature range 5-75 °C
- Compact design, easy handling

Phenobottle is an open-source Raspberry-Pi based photobioreactor for cultivating and assessing physiology (photosynthesis & productivity) in microscopic algae. The device can be used to cultivate both green algae and cyanobacteria while continuiously (and non-invasively) probing photosynthetic and growth phenotypes.

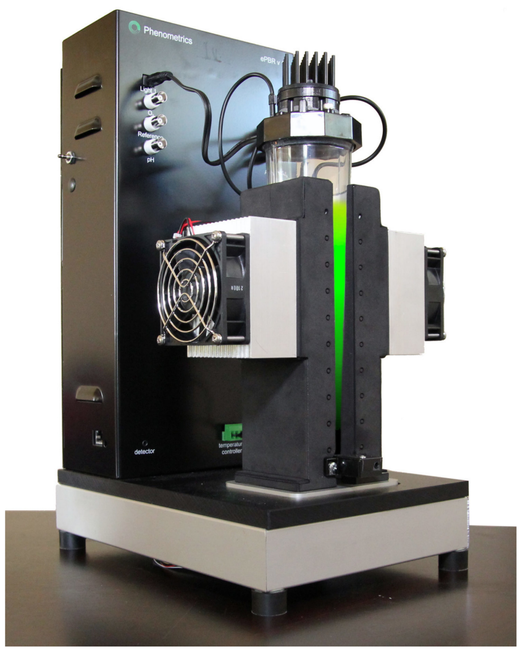


Phenobottle
An Open Souce Photobioreactor

- Growth light quality – red, green and blue, 8-bit individual adjustment for each channel
- Culture Vessel – 250 mL
- Growth light intensity – up to 200 μE (can be increased if needed).
- Mixing – vertical mixing using magnetic stirrer (adjustable intensity)
- Bubbling – included bubbling motoor solenoid control for external supply of CO_2
- Sampling rate of fluorometer – 8 μs at 12-bits (can be overclocked)

The PBR102-F™ bioreactor is a compact bench-top photobioreactor that was specifically designed for the optimization and study of the growth of microalgae and cyanobacteria. It provides for a great number of algal growth conditions to be controlled, monitored, and recorded by computer, for accurate emulation of local environmental conditions, determination of optimal growth conditions, or both.

Phenometrics



- Variable light intensity up to full sunlight ($>$ 3000 μmol photons m^{-2}.s^{-1})
- Culture Vessel: 700 mL, 150-650 mL working volume
- Active cooling and heating: 5-50 °C
- Ability to control and adjust light and temperature over diurnal cycles
- Measure and control pH via the software
- Mixing by magnetic stirrer or bubbling (sparging)
- Ability to control CO_2 and other gasses
- Continuous measurement of turbidity to estimate growth rates
- Ability to vary conditions in complex ways by user-customized scripting
- Customizable with specialized probes/configurations
- Mixing through active magnetic stirring and/or gas sparging

Chi.Bio photobioreactor is an all-in-one experimental automation device for characterisation and manipulation of biological systems. Its broad feature set allows researchers to perform and automate many common experimental protocols from synthetic, systems, and evolutionary biology, without requiring any additional laboratory hardware. It can operate as a Turbidosotat or Chemostat to regulate cell growth.

- Culture temperature regulation from ambient temperature to 55 °C
- 12-25 ml working volume
- Six LED outputs of varying wavelength across the visible range + 285nm UV LED
- Magnetic stirring with adjustable speed
- Measurement of culture optical density/growth rate
- Measurement of multiple orthogonal fluorescent protein concentrations *in situ*
- Actuation of optogenetic systems
- Growth regulation (turbidostat functionality) via measurement of culture optical density and input of fresh/removal of waste media
- Dynamic culture variation/chemical induction using two additional input pumps

Characterisation of biological organisms can be a rather laborious and exhaustive process considering the variety of assumed parameters (e.g. irradiance, temperature) and their admissible ranges that need to be explored. Such exploration often requires a tremendous amount of experiments to be executed, which accumulates in experimental time. Running the experiments in parallel can save a lot of time. However, that requires multiple (often dozens) bioreactors, which can get rather costly when using professional industrial devices. Additionally, exploring huge parameter space on an approximate level (i.e. using less precise sensors) can provide enough overall insight, which can be then validated using targeted experiments in the most interesting regions of the space. For that, low-budget alternatives can be used to provide a solution with multiple, although less precise devices, allowing to run such experiments in parallel.

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