

- ✓ Reproducible cultivation results
- ✓ Minimal manual or intrusive operations
- ✓ Transparent and easy process control and data logging
- ✓ Safe starter culture preparation, holding and transfer

FPA LABORATORY PHOTOBIOREACTOR

Patented Flat Panel Airlift (FPA) Photobioreactor
for the cultivation of microalgae biomass

THE FLATPANEL AIRLIFT PHOTOBIOREACTOR

The FPA Photobioreactor is a panel type reactor that operates following the principle of an airlift-loop-reactor in which air or a gas is used for mixing and displacement of the fluid inside the reactor and, for creating a pressure differential that allows the recirculation – the looping – of the fluid back to the bottom of the reactor via vertical downcomers.

With a Subitec FPA Photobioreactor a gas mixture, consisting mainly of air and a small fraction of CO₂ is bled into the reactor through a special gassing membrane at the bottom of the reactor. The gas flow through the gassing membrane creates the airlift action, i.e. an evenly distributed flow of bubbles across the length of the airlift sections of the reactor.

The bubbles rise toward the top of the reactor, mixing the fluid across the specially designed static mixers while constantly moving the fluid toward the headspace of the reactor where the fluid is recirculated to the bottom of the reactor through the vertical downcomers.

As such, the culture suspension is continuously circulated within the reactor; ascending through the static mixers of the airlift section and descending through vertical 'downcomer' channels. The purpose of the static mixers is to force the flow of the culture suspension across the reactor surface from the illuminated side to the unlit side of the reactor.

This complete intermixing of the culture suspension provides constant cultivation conditions throughout the reactor whereas the continuous circulation of the culture suspension inside the static mixers enables excellent light supply to all cells of culture suspension. These design features together provide an increase in productivity and culture density, both of which are key factors for industrial scale production and beneficiation of microalgae at equitable cost.

KEY BENEFITS OF THE SUBITEC FPA TECHNOLOGY

- High Productivity, up to 3g/l and 500g/m² per day
- High culture density up to 20g/l
- Long cultivation campaigns, up to 12 months
- Suitable for both continuous and batch operation
- Consistent product (biomass) quality
- Easy and effective process control





FPA LABORATORY PHOTOBIOREACTOR

The Laboratory Units consisting of a Subitec FPA Photobioreactor, that is in a self-supporting mounting frame and includes all the necessary componentry, piping, fittings and instruments for cultivation of microalgae under constant, reliable and reproducible conditions.

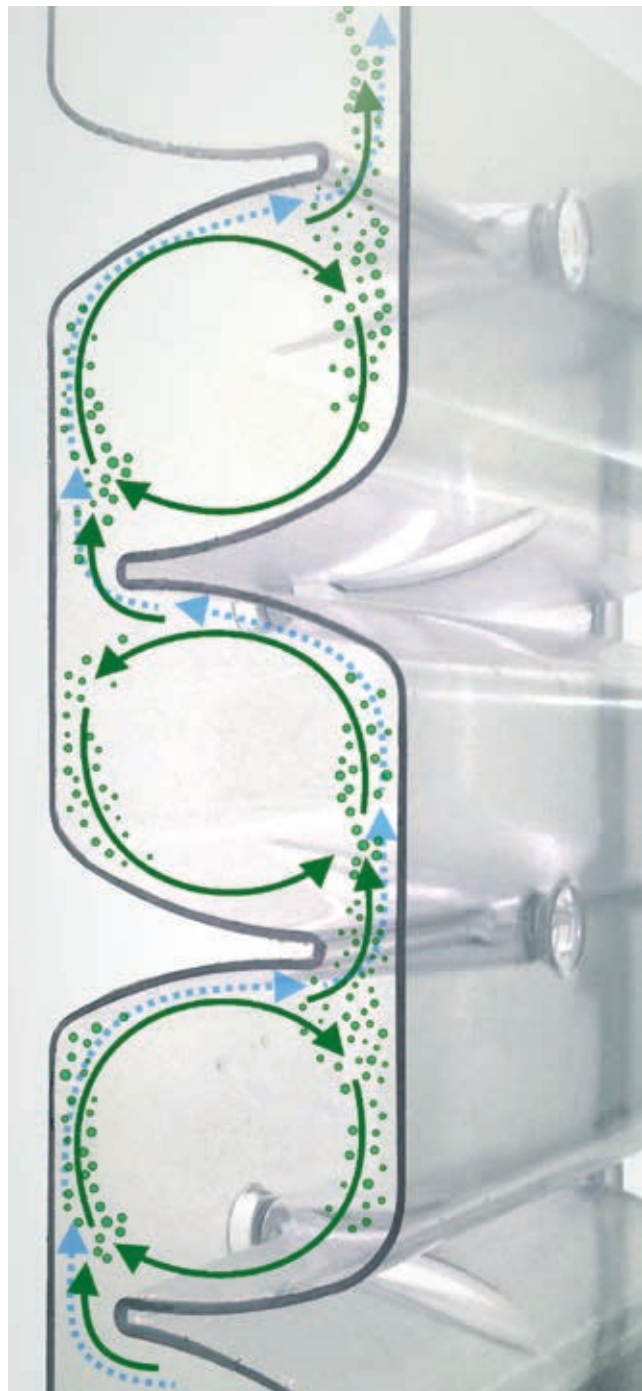
Offering three versions and a selection of different optional features and peripheries provide excellent flexibility to customize the equipment to satisfy various user and operating requirements.

CHARACTERISTIC FEATURES

- ✓ Air lift system, complete intermixing without shear stress
- ✓ Sterile filtration of media before introduction into the reactor
- ✓ Sterile sampling line allows drawing of samples safely for analysis
- ✓ Sterile filtration of air and CO₂ mixture entering the reactor through the gassing membrane assembly
- ✓ Automatic temperature control of culture media (heating and cooling)
- ✓ Automatic pH (CO₂) control
- ✓ Cleaning and disinfection for multiple uses and various microalgae species
- ✓ Automatic process control, alarms and data storage

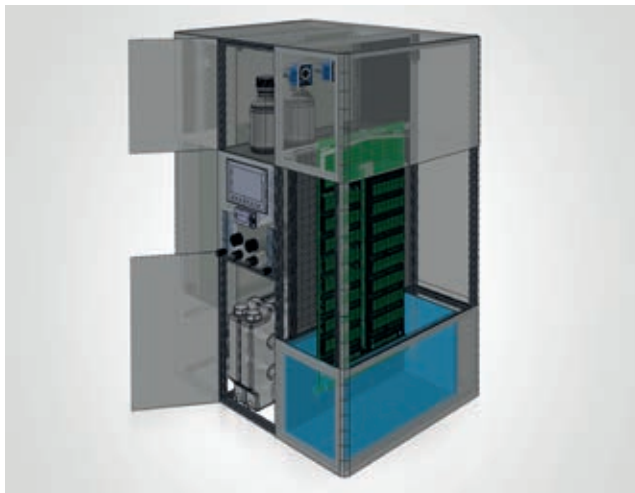
ADDITIONAL FEATURES

- Media cart for convenient media preparation and transfer
- Media pump
- Harvesting container
- External Chiller



Functionality of Subitec FPA Photobioreactors
Cross section of a Laboratory FPA Reactor

SUBITEC FPA REACTORS



FPA6L

H 1300 x W 900 x D 700 [mm]

Capacity 6 Liters



FPA28L

H 1800 x W 1600 x D 400 [mm]

Capacity 28 Liters



FPA180L

H 3000 x W 3300 x D 1300 [mm]

Capacity 180 Liters



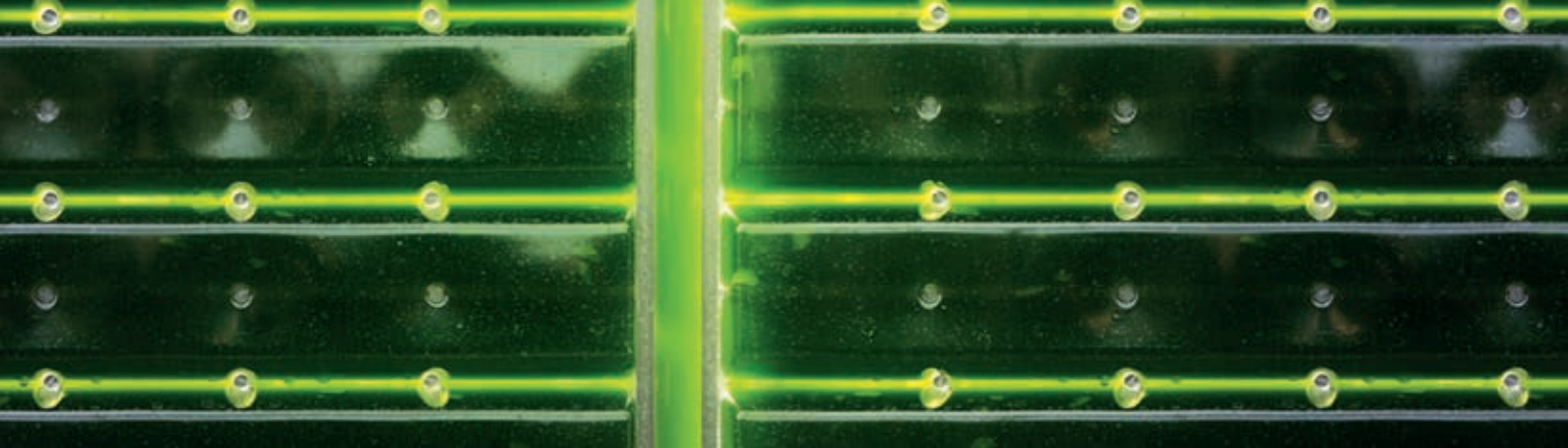
FPA28L4

H 2000 x W 1800 x D 1400 [mm]

Capacity 100 Liters

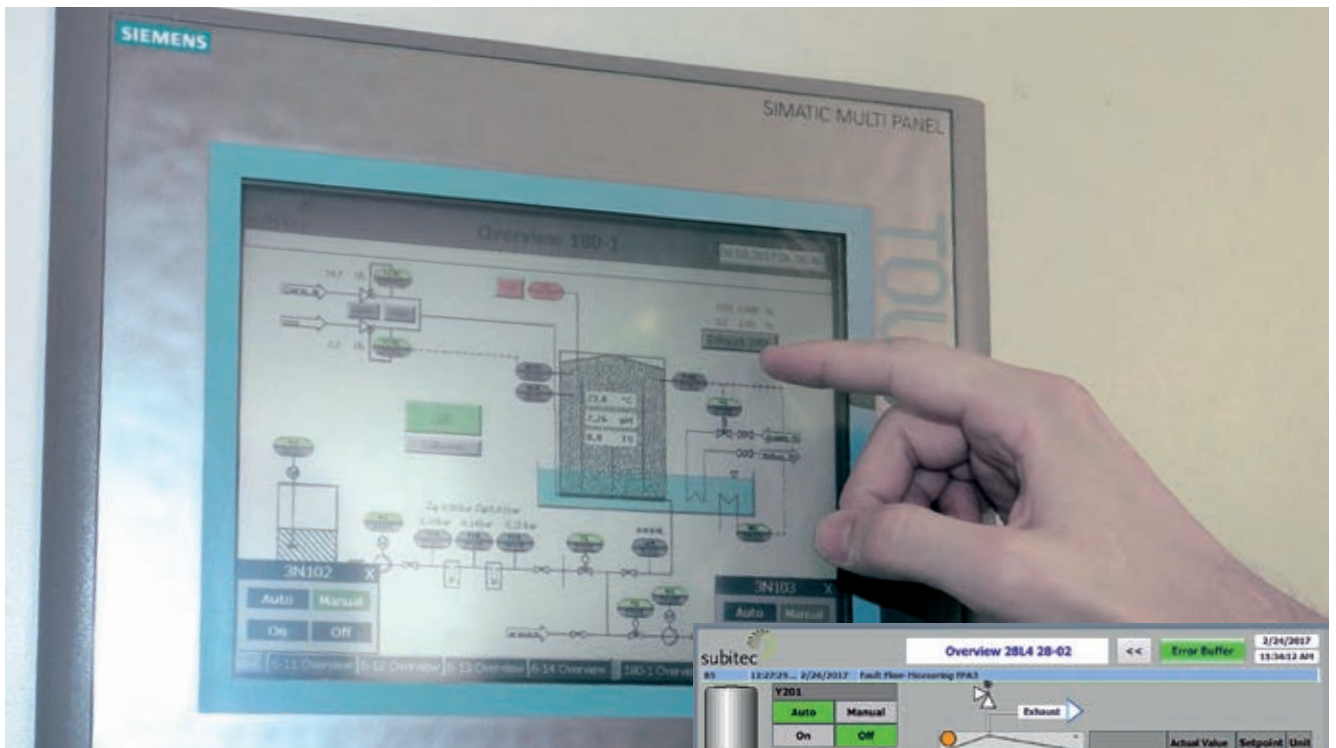
The Single Unit Laboratory Photobioreactors are integrated systems for cultivating microalgae. The systems are designed for scientific and industrial research and development. They are also used for cultivating pre-cultures and inoculum for the next process stage in a scale-up cultivation process or, as part of the inoculation chain in a production process.

The FPA28L4 unit of four 28 FPA photobioreactors combines the benefits of the integrated single units with the conveniences of cultivating up to four microalgae species simultaneously under identical conditions or a variation of automation levels. This provides an economical solution for a multitude of applications.



Subitec FPA Reactors	Manual	Semi-Automatic	Automatic
EQUIPMENT ASSEMBLY			
Aluminium Housing	Optional	✓	Optional
Stainless Steel Housing	—	Optional	✓
REACTOR SYSTEM			
Reactor FPA, Material PVC	✓	✓	✓
Reactor FPA, Material PETG	Optional	Optional	Optional
Reactor FPA, Material PMMA	Optional	Optional	Optional
Tubing and Sampling System	✓	✓	✓
LIGHTING SYSTEM			
Dimmable lighting system	Optional	✓	✓
High Pressure Sodium Vapor Lamp	Optional	Optional	Optional
TEMPERATURE SYSTEM			
Cooling / Heating	Optional	✓	✓
MEDIA FEED			
Media Feed Method	Manual	Manual	Automatic
HARVESTING			
Harvesting method	Manual	Manual	Automatic
GAS SUPPLY			
Gas Mix Unit	✓	✓	✓
Air Flow Control Method	Manual	Manual	Automatic
CO ₂ Flow Control Method	Manual	Automatic	Automatic
Exhaust System	✓	✓	✓
INSTRUMENTATION			
Temperature and pH Probe	✓	✓	✓
Turbidity Probe	—	Optional	Optional
Exhaust Analyzer	—	Optional	Optional
ELECTRIFICATION			
Operator Interface	Display	Touch Screen	Touch Screen
Control System	—	Controller	CPU/PLC
Transmitter Data Storage	Optional	✓	✓
Operator PC	—	—	Optional

AUTOMATION



Different automation levels

On-screen view of process parameters

Subitec offers automation of a variety of process operations and the automatic control of a multitude of process parameters. Automatic temperature control of the cultivation media is standard for the Subitec laboratory units. The control of the pH value during a cultivation routine by automatic flow control of CO₂ via mass flow controller is one of the standards for the semi-automatic and automatic laboratory units.

The Subitec operating interface gives the user an on-screen overview of all process parameters and intuitive operation of all setting options. It also offers a programmable interface for adjusting process set points, warning values and alarm values and the visualization of these. The Subitec Software



allows – depending on the chosen equipment – the automatic control of light regiments, e.g. day-night cycles, light intensity variation based on cell density. With the Subitec Software, online non-invasive turbidity measurement allows automatic aeration rate control and/or CO₂ flow control. The Subitec Software allows for an automatic harvest routine based on time intervals or cell densities based measurements of the turbidity sensor. All process parameters are displayed in clear curves and stored for later use.

PROVEN TECHNOLOGY

Over the years the FPA panel has proven its performance in single and two-stage cultivation processes with various algae species. Subitec reactors are suitable for fresh water and marine algae.

Subitec has performed numerous cultivation studies and other experiments with different algae species using FPA reactor technology. Even today, testing new algae species and finding the right cultivation

parameters is among the many day to day research and development activities that are performed at the Subitec laboratories.

The following is a listing of typical algae that has been cultivated and processed in Subitec FPA reactors both outdoors with sunlight and indoors with artificial light.

Excerpt of Cultivated Microalgae

Type	Species	Maximal culture density [g ⁻¹]	Average volumetric productivity [g ⁻¹ per day]
Marine	Isochrysis sp. (Clone T-iso)	10	0.5
	Tertraselmis suecica	16	0.6
	Platymonas subcirdiformis	12	0.5
	Rhodomonas baltica	1.9	0.4
	Nannochloropsis salina	9.5	0.8
	Nannochloropsis gaditana	6.3	0.7
	Diacronema lutheri (Paylova)	4.6	0.3
Brakish	Phaeodactylum tricornutum	16	0.9
	Nannochloropsis oculata	13	1
	Porphyridium purpureum	8.1	0.5
Freshwater	Chlorella vulgaris	12	0.8
	Chlorella sorokiniana	20	1.3
	Haematococcus pluvialis	4.5	0.3
	Chlamydomonas reinhardtii	13	0.7
	Scenedesmus obliquus	8.5	0.6
	Spirogyra sp.	14	0.5
Cyanobacteria	Arthrospira platensis (Spirulina)	5	0.5
	Thermosynechococcus elongatus	8	2
	Synechococcus elongatus	3.5	0.4
	Cyanobacterium cf. aponinum	10.5	0.8

All data without prejudice

SUBITEC – MORE THAN 20 YEARS OF KNOW HOW IN MICROALGAE CULTIVATION SYSTEMS

Subitec GmbH is a German biotech company headquartered in Stuttgart, specialized in process engineering, equipment and services for the cultivation and industrial scale production of microalgae. Established as a spin off from the Fraunhofer Institute, Subitec looks back at more than 20 years of experience with microalgae. Subitec is developer and technology owner of the unique and patented photobioreactor technology – the Flat Panel Airlift Reactor (FPA).

induced by static mixers depicts the key for the success of the FPA-reactor. Subitec's photobioreactor is available in sizes of 6, 28 and 180 Liter.

Subitec's track record includes the supply of equipment and services to major laboratories and research institutes and the design and construction of pilot plants and large scale production plants for commercial customers. Subitec's equipment is used for cultivating high value microalgae that



Production Systems



Laboratory Equipment



Expertise and Services

The FPA-reactor prevents disadvantages based on their design of conventional photobioreactors. The systematic technology advantage leads to a range of benefits. Hereby, the patented stream guidance

find application in e.g. aquaculture, cosmetics and healthcare. Subitec cooperates with established national and international customers in various projects.

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