

GFS-3000

Portable Gas Exchange & Fluorescence System



Combining Precise CO₂ Analysis with Fluorescence & P700 Measurements

WALZ
Mess- und Regeltechnik

GENERAL FEATURES OF THE GFS-3000

The portable GFS-3000 is a high precision system for the assessment of plant photosynthesis (CO₂-uptake) or respiration (CO₂-release) and transpiration – also in combination with optical measurements.

Gas exchange measurements rely on the basic principle that changes in CO₂ and H₂O concentrations are determined when air passes through a climate controlled chamber containing a plant sample.

The Portable Gas-Exchange and Fluorescence System GFS-3000 enables wide range climate control.

All environmental parameters relevant for plant photosynthesis (CO₂, H₂O, temperature, light, ventilation and flow) can be controlled automatically and over the full physiological range. Experimental protocols for automatic light-curves or automatic CO₂-curves can be easily programmed.

The GFS-3000 is suitable for controlled laboratory settings as well as demanding field conditions. Optional fluorescence modules further expand the system's capability.

The GFS-3000 perfectly complements with other Walz systems giving access to numerous aspects of photosynthesis research.



MAIN COMPONENTS GFS-3000

The basic system package GFS-3000 consists of:

- Control Unit 3100-C containing the CO₂ and H₂O analyzer, as well as all components required for the CO₂, H₂O and flow control
- Standard Measuring Head 3010-S featuring high application flexibility containing the ventilation system, temperature and light control
- LED Light Source 3040-L with an LED array providing 90% red and 10% blue light
- AC Power Supply 3020-N for laboratory use
- Two LiFePO₄ Battery Units 3035-A for field work and Battery Charger LC-03

OPTIONAL COMPONENTS AND ACCESSORIES

- LED-Array/PAM-Fluorometer 3055-FL for illumination of the leaf area and fluorescence measurements
- Fiberoptics PAM-Fluorometer 3050-F to analyze fluorescence in sunlight
- Miscellaneous accessories such as cuvettes and adapter plates offering user-specific application options
- Accessories for product combinations with other Walz systems

GFS-3000FL

The modified system package GFS-3000FL contains the LED-Array/PAM-Fluorometer 3055-FL instead of the LED Light Source 3040-L. All other components remain the same as in the basic system package GFS-3000. In terms of price, GFS-3000FL offers an interesting option to combine gas exchange and fluorescence measurements.

Also, the complete equipment will be modified on customer request.

MAIN COMPONENT CONTROL UNIT 3100-C

The Control-Unit 3100-C contains the CO₂ and H₂O analyzer, as well as all components required for the CO₂, H₂O and flow control.

GAS ANALYZER

The Control Unit 3100-C of the GFS-3000 contains a high accuracy non-dispersive 4-channel infrared gas analyzer for the determination of CO₂ (0-3000 ppm) and H₂O (0-75000 ppm) with 20 cm optical path length, 6 ml gold plated cells. The specially developed dual-frequency chopper technology allows simultaneous assessment of differential and absolute signal.

The analyzer is optimized for a very stable and accurate differential signal. The differential zero is indicated, allowing clear information about the stability of the measurement.

Due to the separation of analyzer and measuring head, the measuring head temperature does not influence the analyzer.

CO₂ CONTROL

The integrated CO₂ control ranges from 0 to 2000 ppm CO₂. The CO₂ supply can be filled from cartridges. One cartridge contains 8 g, and provides CO₂ (340 ppm, standard flow rate) continuously for more than 48 hours. The actual CO₂-reserve is indicated. Alternatively an external CO₂-cylinder equipped with pressure reducer (6 bar) can be directly attached to the control unit.



Close up on frontpanel



Internal panel-PC running GFS-Win



Silica gel, humidifier granules and soda lime for H₂O and CO₂ control



High capacity LiFePO₄ Battery Unit provide longer operation duration

FLOW CONTROL

Air flow through the cuvette is exactly adjusted between 300-1400 $\mu\text{mol s}^{-1}$ by a membrane pump controlled by a high precision electronic mass flow-meter. The mechanical flow indicators directly show flow balance and cuvette tightness.

HUMIDITY CONTROL

The humidity control for drying and humidifying ranges from 0 to nearly 100% r.h. It consists of a drying and humidifying column and an automatic valve.

POWER SOLUTIONS

The Control Unit 3100-C can be operated using various power solutions such as LiFePO₄ Battery Units 3035-A, car batteries (12-24 V) or the AC Power Supply 3020-N. The newly designed LiFePO₄ battery power system provides advantages like longer operation duration, longevity and trouble-free shipment.

Two LiFePO₄ Battery Units 3035-A can be connected simultaneously to the control unit, resulting in a total operation time of 6 to 9 hours. A compartment at the bottom of the control unit provides room for one battery system.

ACCESSORIES

- DC-DC Converter for former models of the control unit
- Outdoor set with sun protection shield

MAIN COMPONENT STANDARD MEASURING HEAD 3010-S

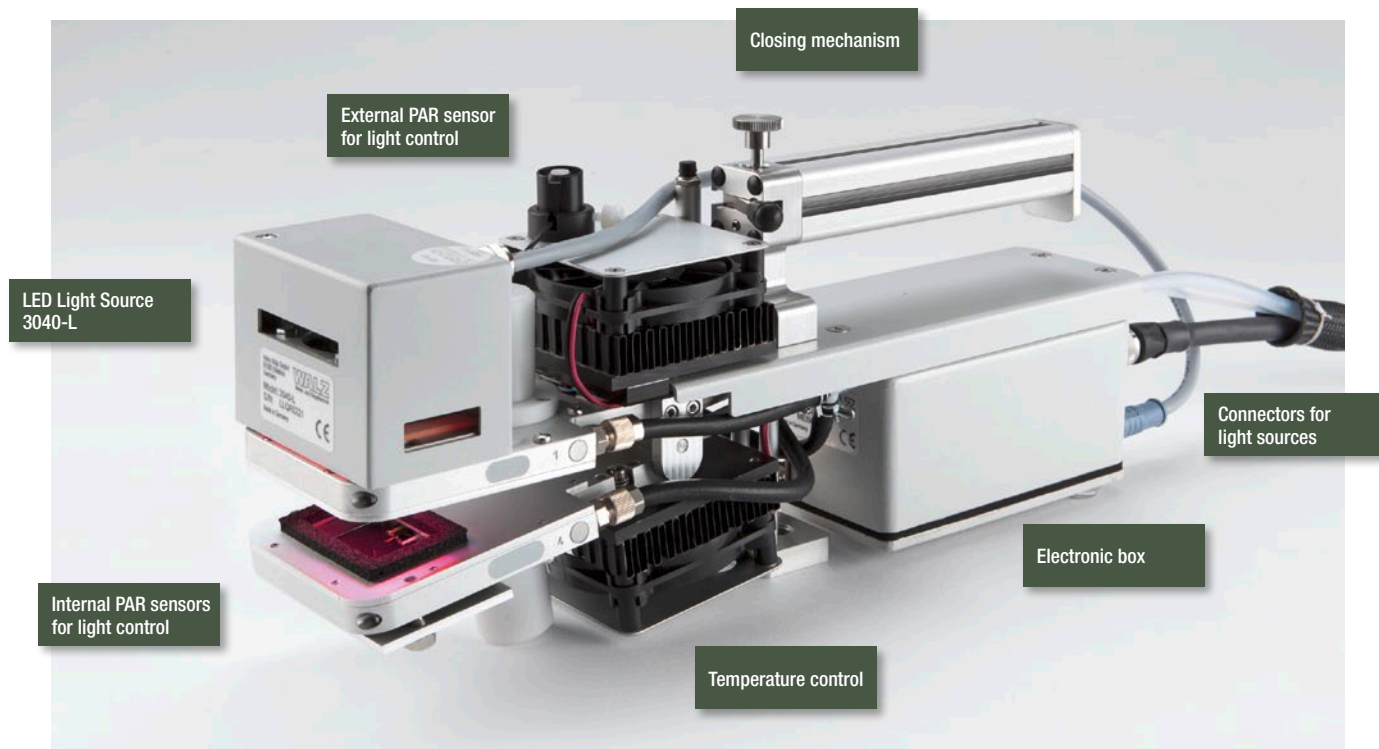
The design of the 3010-S offers maximum flexibility. The measuring area can be adapted with special plates; the cuvette can be modified for conifers, lichens, *Arabidopsis* plants or specific requirements.

The Standard Measuring Head 3010-S features a clamp-on cuvette with a large measuring area of 8 cm² and a convenient closing mechanism. The symmetrical construction allows separate assessment of upper and lower leaf surface.

3010-S provides wide temperature-, light- and ventilation-control as well as a trigger button for the manual start of a user program.

The configuration of 3010-S can be changed easily. Adaptation of the measuring area, modification with various cuvettes as well as complete conversions for specialized applications are possible.

The circuitry for the temperature and light control, the ventilation system and the sensor electronics are located in the detachable electronics box.



Standard Measuring Head 3010-S with Light Source 3040-L and darkening plate connected



TEMPERATURE

The 3010-S has four temperature sensors: One Pt100 sensor per each cuvette half, a thermocouple for leaf temperature and a Pt100 for the external temperature.

The temperature control can be switched between three modes: Constant cuvette temperature, constant leaf temperature, or temperature variation parallel to ambient temperature regime with an adjustable offset. The last mode is especially well suited to assess plant responses in future temperature regimes.

Due to the high performance elements of temperature control, the cuvette temperature can be decreased by up to 10 K. Maximum temperature reached is 50 °C.

VENTILATION

Both sides of the 3010-S feature a high-speed impeller for effective ventilation of the air surrounding the leaf.



LED Light Source 3040-L (left) and LED-Array/PAM-Fluorometer 3055-FL (right)

LIGHT

The 3010-S has three sensors for photosynthetic active radiation (PAR): One cosine corrected Mini Quantum Sensor MQS-B/GFS, located on top of the measuring head, and two additional sensors located inside each cuvette half. Light can be provided with the LED Light Source 3040-L to the upper or lower side of the cuvette.

The light control can be either set to a constant PAR level between 0 and 2000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ or to track the ambient PAR. The same light control- and additional PAM measurement-options are supplied by the LED-Array/PAM-Fluorometer 3055-FL.

TRIGGER BUTTON

The trigger-button serves to store measuring points or starts a user program, while holding the measuring head.

EASE OF INTERCHANGEABILITY

Each measuring head contains its own calibration data, and can be freely exchanged between systems.



Lichens/Mosses Cuvette 3010-V40



Conifer Cuvette 3010-V80



Arabidopsis Chamber 3020-A



Lichens/Mosses Cuvette 3010-V32 here used to measure gas exchange of a small animal



Cuvette-modification on customer request



Leaf area adapters

FLEXIBILITY

The configuration of 3010-S is simply alterable requiring only a few accessories. The measuring area can easily be modified with area adapter plates. Additional flexibility is provided by various cuvettes e.g. for conifers or lichens/mosses or a small chamber for the analysis of the complete above-ground part of *Arabidopsis* plants.

We also provide a modified cuvette for the assessment of surfaces like bark or stones. The electronics box is detachable and can be used for self-built measuring chambers.

ACCESSORIES

- Various leaf area adapter plates
- Lichens/mosses cuvettes
- Conifer cuvette
- Arabidopsis chamber
- Compact tripod

FLUORESCENCE COMPONENTS

PAM-FLUOROMETER 3055-FL & 3050-F

The long lasting experience in PAM fluorometry of Heinz Walz GmbH is embedded in the PAM fluorometers 3055-FL and 3050-F.

The PAM fluorometry with the saturation pulse method provides detailed information on the light-energy usage of photosystem II and therefore adds important information on primary photosynthetic reactions to the gas exchange data.

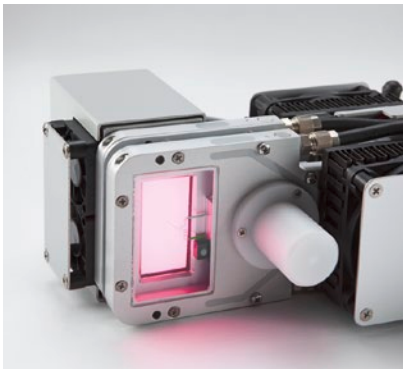
Two fluorescence components are available, which can be directly operated with the system in the field. The LED-Array/PAM-Fluorometer 3055-FL that also illuminates the sample area and the Fiberoptics PAM-Fluorometer 3050-F for use in ambient light.

LED-ARRAY/PAM-FLUOROMETER 3055-FL

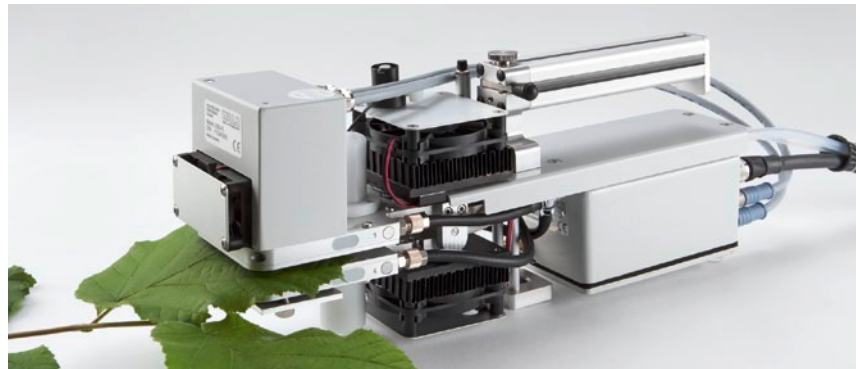
The LED-Array/PAM-Fluorometer 3055-FL collects the fluorescence information with six detectors on up to 8 cm² sample area. Therefore it allows measurements with the complete sample area of the Standard Measuring Head 3010-S. Its LED array provides actinic red and blue light, saturating light pulses and far-red LEDs to determine the Fo' fluorescence. 3055-FL connects with a simple snap-on mount to the Standard Measuring Head 3010-S, allowing optical control when positioning the leaf in the cuvette. The 3055-FL is included in the system package GFS-3000FL.

FIBEROPTICS PAM-FLUOROMETER 3050-F

To analyze fluorescence in ambient light, the Fiberoptics PAM-Fluorometer 3050-F can be attached to the Standard Measuring Head 3010-S. It employs a blue LED for measuring light and the saturating light pulses, and also features far-red illumination for Fo' determination.



3055-FL illuminating 8 cm² leaf area



LED-Array/PAM-Fluorometer 3055-FL connected to the Standard Measuring Head 3010-S



Fiberoptics PAM-Fluorometer 3050-F connected to the Standard Measuring Head 3010-S



Dark Leaf Clips 3010-DLC

ACCESSORY

DARK LEAF CLIPS 3010-DLC

For the determination of the maximum fluorescence signal (F_m), the leaf needs to be dark acclimated. The additional light-weight

Dark Leaf Clips 3010-DLC, with positioning aid and sliding shutters, made from sun reflecting material, fit to the measuring area of the Standard Measuring Head 3010-S.

OPERATION & GFS-WIN SOFTWARE

The GFS-3000 can be controlled via the integrated panel-PC or an USB connected external-PC, featuring the same user-friendly GFS-Win software.

The integrated panel-PC features a large color display (10 cm x 13 cm) with touch screen and background illumination, which is clearly readable in direct sunlight.

Beginners are able to operate the GFS-Win software with minimal training. The well-thought-out software structure allows comfortable adjustment of measuring conditions as well as demonstrative data display.

Settings window: serves to enter measuring conditions.

Chart window: each magnitude can be displayed, the mouse cursor indicates the given measured value.

Values window: shows all present values

Report window: displays the stored values and recalculates data with a new leaf area or weight.

Program window: easy programming of user-defined protocols, e.g. CO₂-curves or light-curves.

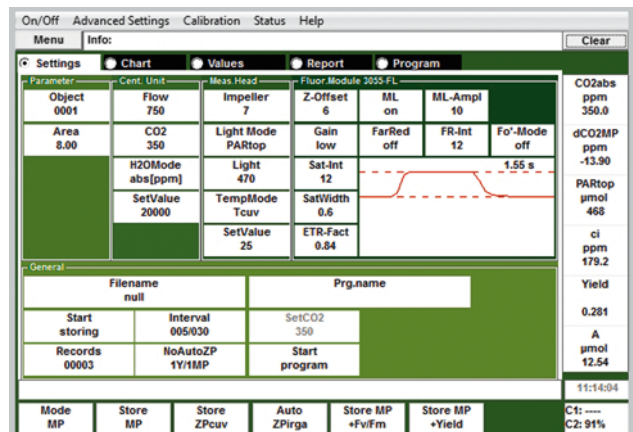
Quickview column: always visible for user-defined display of present values.

Users are guided with illustrated tutorials in more sophisticated procedures e.g. calibrations. The control of the instrument from an external PC allows descriptive demonstrations of on-time experiments in classes or lectures.

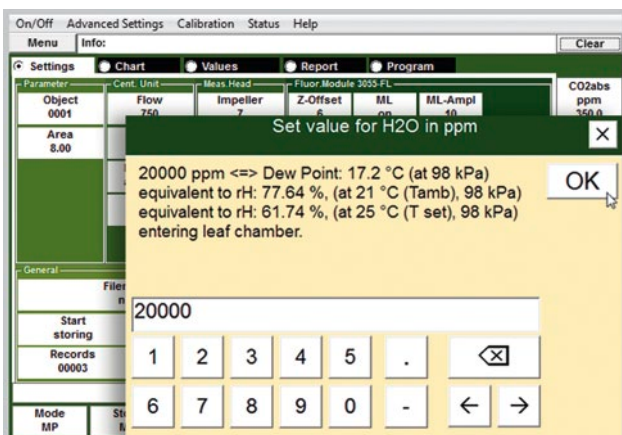
Free software updates are available on our website to keep your instrument always up-to-date on latest developments.



Color screen with touch panel, well readable in sunlight



Settings window for easy determination of measuring conditions



Dialog box to set H₂O value

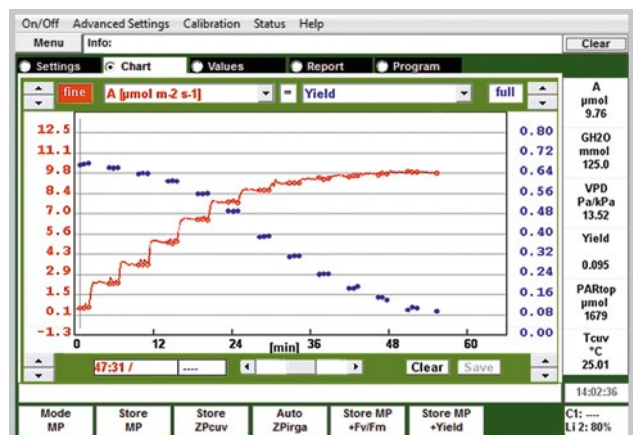


Chart window displaying results measured by GFS-3000 equipped with the LED-Array/PAM Fluorometer 3055-FL

SYSTEM COMBINATIONS WITH THE GFS-3000

The GFS-3000 perfectly complements with other Walz systems. Analysis of PSI and PSII photochemistry or wide area fluorescence imaging combined with gas exchange measurements extend the analysis approach, giving new access to numerous aspects of photosynthesis research.

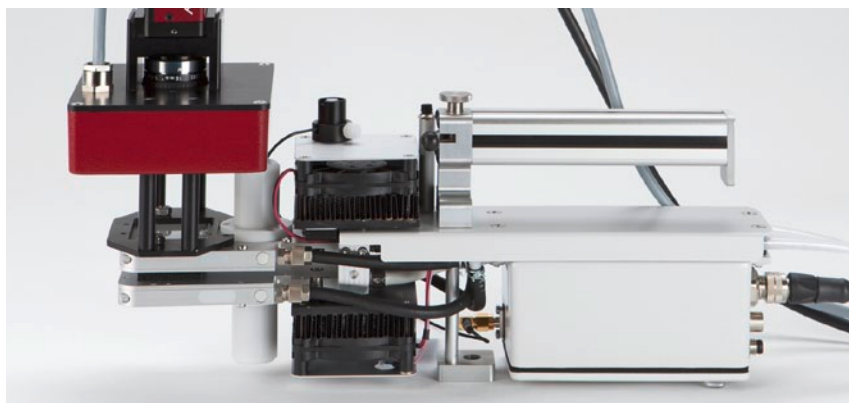
GFS-3000 & IMAGING-PAM

Most physiological heterogeneities, or differences in genotypes, only become clearly visible in fluorescence images under changing CO₂, O₂ or temperature conditions, all of which can be easily applied with a gas exchange system.

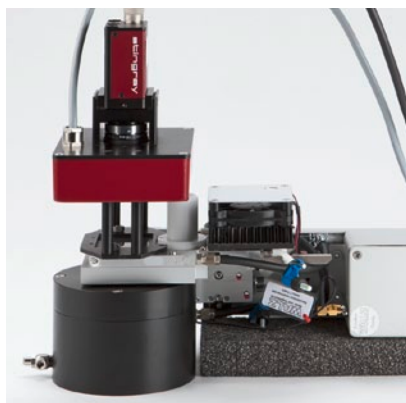
Therefore we offer the combination of IMAGING-PAM M-Series matching the GFS-3000. The imaging MINI version can be equipped with the adapter IMAG-MIN/GFS, so that it connects to the Standard Measuring Head 3010-S with a simple but firm snap-on mount. This connection even enables imaging of objects located in various specialized cuvettes.

On the larger scale, imaging can be carried out using an imaging MAXI version in combination with the large spaced Gas-Exchange Chamber 3010-GWK1, merging imaging and gas exchange analysis over a measuring area of 10 x 13 cm.

The software of both systems (GFS-Win and ImagingWin) operate in synchrony on one laptop exchanging data between each other. This allows automatic imaging during light curves or CO₂-curves controlled by GFS-Win.



IMAGING-PAM MINI-Head connected with snap-on mount to Standard Measuring Head 3010-S



IMAGING-PAM MINI-Head connected to the 3010-S modified with the Arabidopsis Chamber 3010-A



IMAGING-PAM MAXI-Head LED-Array



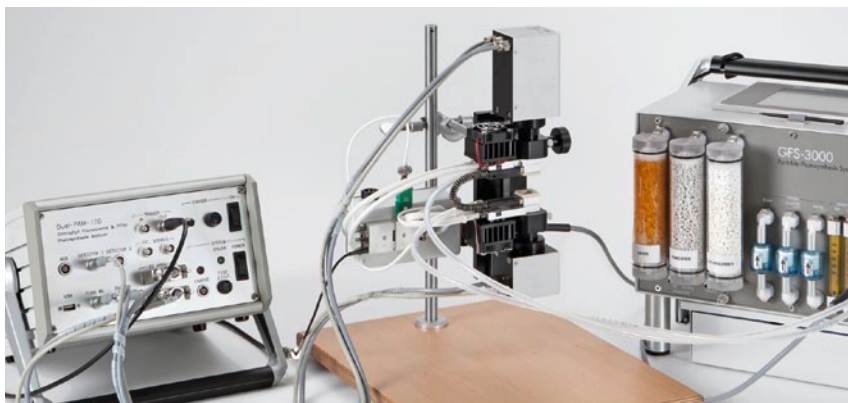
IMAGING-PAM MAXI-Head combined with Gas-Exchange Chamber 3010-GWK1

GFS-3000 & DUAL-PAM-100

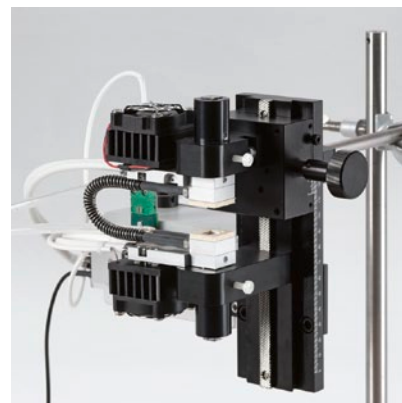
The most sophisticated combination of Walz instruments is the GFS-3000, together with the P700 & Chlorophyll Fluorescence Measuring System DUAL-PAM-100, using the specially designed DUAL-PAM Gas-Exchange Cuvette 3010-DUAL.

This setup is the first commercially available system allowing simultaneous analysis of PS I and PS II photochemistry simultaneously with CO₂ gas exchange. The 3010-DUAL enables control of temperature and gas composition. Hence, the wide range of information provided by the DUAL-PAM-100 can be obtained under climate controlled conditions concurrent with gas exchange data.

The small area of the 3010-DUAL (1.3 cm²), makes it very suitable for experiments on single *Arabidopsis* leaves. Also the P515/535 Emitter and Detector, which enable the DUAL-PAM-100 to measure the electro-chromic carotenoid shift and "light scattering", is compatible with the cuvette 3010-DUAL.



GFS-3000 with DUAL-PAM Gas-Exchange Cuvette 3010-DUAL and DUAL-PAM-100



DUAL-PAM Gas-Exchange Cuvette 3010-DUAL

GFS-3000 & GAS EXCHANGE CHAMBER 3010-GWK1

The Gas-Exchange Chamber 3010-GWK1 can be operated stand alone or with the GFS-3000, replacing the Standard Measuring Head 3010-S. The top of the chamber can be designed according to customer request. The gas-exchange chamber provides a big range in temperature control:

More than 10 K below ambient temperature and up to 60 °C. On special request this range can be extended to 75 °C.

The Illumination Unit RGBW-L084 complements the 3010-GWK1. Individually adjustable colors red, green, blue and white with high power LEDs illuminate together with a maximum output of 2000 μmol m⁻² s⁻¹ PAR or better.

The area of the 3010-GWK1 is designed to match the imaging area of the IMAGING-PAM M-Series Maxi version.

Please consider using 3010-GWK1 in combination with the GFS-3000, that the maximum flow of the GFS-3000 is 1.9 l/min. Leaf samples producing too much humidity can limit the systems capabilities.



Gas-Exchange Chamber 3010-GWK1



Gas-Exchange Chamber 3010-GWK1, top view showing sample area and sensors



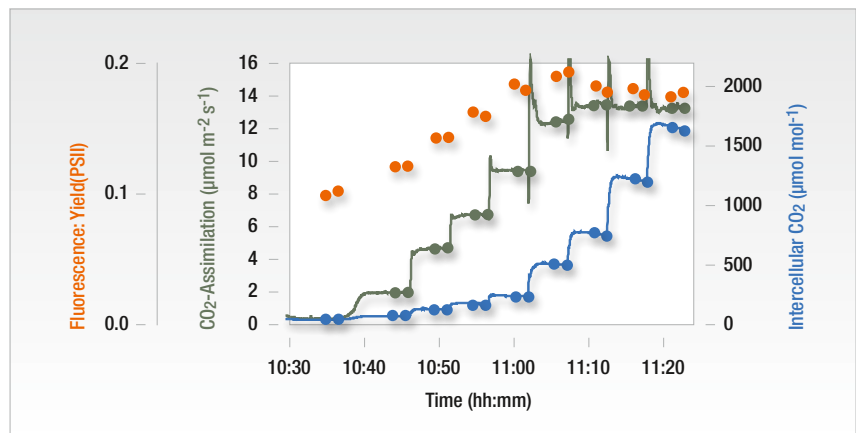
Changing light conditions with LED-Panel RGBW-L084

EXAMPLES OF APPLICATION WITH THE GFS-3000

Typical applications of the GFS-3000 are the assessment of CO₂-assimilation, H₂O-conductance or CO₂-respiration in dependence on CO₂-concentration, intercellular CO₂-concentration, light, temperature, humidity or time of day.

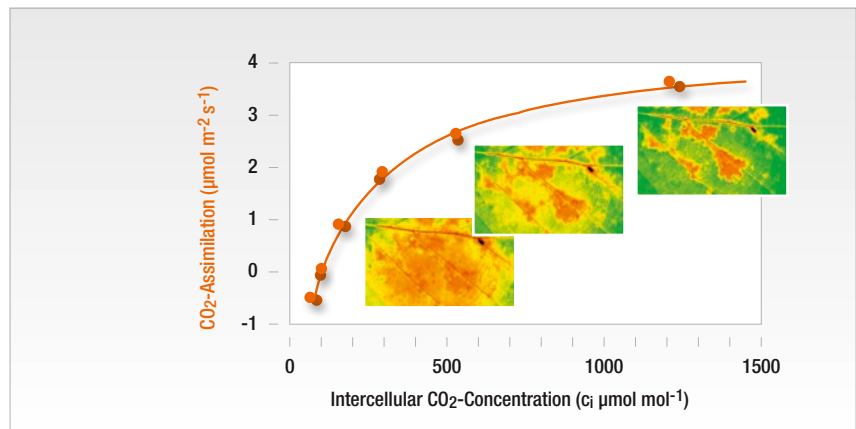
PRUNUS CERASUS: **CO₂-CURVE**

CO₂-assimilation, intercellular CO₂-concentration and Yield (PSII) of *Prunus cerasus* during a CO₂-curve. The CO₂ concentration was step-wise increased. In the steady state of each step the photosynthesis was recorded and a saturating pulse given to measure the yield of PSII. For the dCO₂ and dH₂O zero values, the trace was repeated with an empty chamber and data recalculated with GFS-Win.



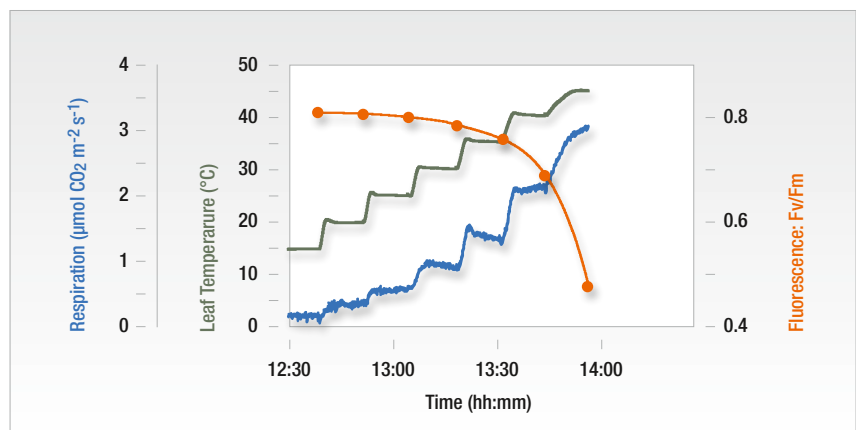
FAGUS SYLVATICA: **GAS EXCHANGE WITH FLUORESCENCE IMAGING**

Result of a combined measurement using the GFS-3000 together with the IMAGING-PAM on a dry-stressed *Fagus sylvatica* leaf. The dependence of CO₂-assimilation on the intercellular CO₂-concentration has been plotted. The patchiness in the fluorescence images is the more pronounced the higher the CO₂-concentration.



NICOTIANA TABACUM: **TEMPERATURE-DEPENDENCE OF DARK-RESPIRATION**

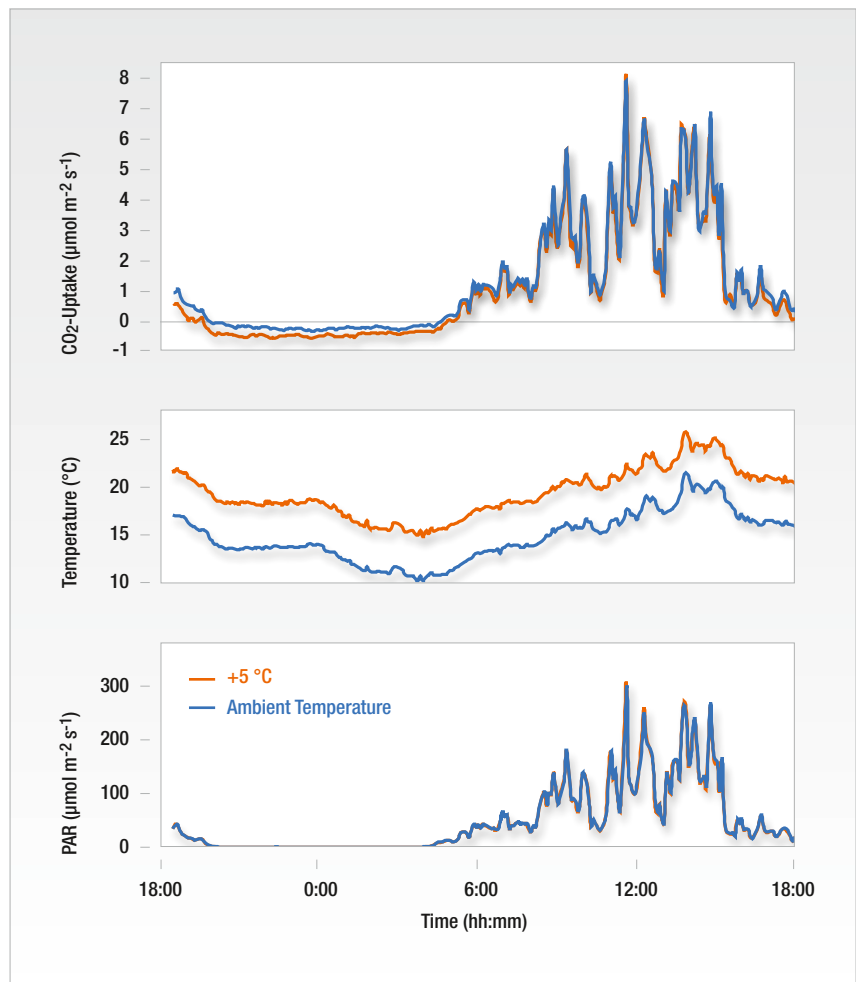
The temperature of a tobacco leaf was increased in steps from 15 to 45 °C in the dark. The dark-respiration increased while Fv/Fm measured with the LED-Array/PAM-Fluorometer 3055-FL decreased markedly at temperatures above 30 °C.



SOLANUM LYCOPERSICUM: TWIN-MEASUREMENT WITH DIFFERENT TEMPERATURE REGIMES USING TWO GFS-3000

The temperature control of the Standard Measuring Head 3010-S allows the assessment of gas exchange in an increased temperature regime but otherwise unchanged conditions. Here we demonstrate a twin measurement, where one leaflet was kept at ambient conditions, while the other had an increased temperature regime (+5 °C). As can be seen in the upper panel, the night-respiration is increased at high temperatures; also, at low light levels, the uptake of CO₂ is lower in the increased temperature regime than under unchanged conditions.

Scientific publications on our website
(GFS-3000/publications):



BASIC COMPONENTS

CONTROL UNIT 3100-C

Design: Aluminum housing featuring an integrated PC module, large graphical color-display well readable in sun-light with touch screen, 4-channel CO₂/H₂O gas analyzer, flow control, CO₂ control (supplied via small cartridges or cylinders) and H₂O control (for drying and humidifying). Pneumatic connectors for air inlet, measuring head and four vents. Sockets for cable connections: Cuvette: Standard Measuring Head 3010-S, DUAL-PAM Gas-Exchange Cuvette 3010-DUAL or Gas-Exchange Chamber 3010-GWK1; Aux in: two Auxiliaries; Comp (RS 485): additional component; USB (USB 2.0): USB storage device, USB null modem cable (USB-NMC), or other USB device; Battery DC/in: two LiFePO₄ Batteries 3035-A, AC Power Supply Unit 3020-N, or external DC (12-24 V)

CO₂/H₂O GAS ANALYZER

Design: 4-channel CO₂/H₂O absolute NDIR gas analyzer, separate cuvettes for CO₂ and H₂O

CO₂ measurement: Simultaneous absolute and differential measurements, absolute range: 0 to 3000 ppm, cuvette length 20 cm, cuvette volume of one cell 6 cm³, gas-filled detector

H₂O measurement: Simultaneous absolute and differential measurements, absolute range: 0 to 75000 ppm, cuvette length 20 cm, cuvette volume of one cell 6 cm³, pyroelectric detector (solid state)

Max. noise in absolute mode: <0.2 ppm CO₂ and <30 ppm H₂O

Resolution: 0.01 ppm CO₂, 1 ppm H₂O

Linearization:

CO₂ absolute: Max. error between 0 and 600 ppm: 12 ppm, above 600 ppm: 2% of measured value. Deviation of differential CO₂ zero with changing CO₂: Typ. less than 0.5 ppm

H₂O absolute: Max. error between 0 and 15000 ppm: 330 ppm, above 15000 ppm: 2% of measured value. Deviation of differential H₂O zero with changing H₂O: Typ. less than 150 ppm

Correction: Signal is corrected for temperature, pressure and H₂O-effect on CO₂ signal

Barometric air pressure measurement: Range 60 to 110 kPa, accuracy ±0.1%

OTHER SPECIFICATIONS OF THE CONTROL UNIT 3100-C

Pneumatic time delay: Delay between analyzer and Standard Measuring Head 3010-S is 2.5 s at standard flow rate

Mass flow measurement: Thermal mass flow meter, range 0 to 1500 μmol s⁻¹, accuracy ±1%

Integrated user interface: Panel PC NX800LX/500 MHz with graphical color-display 640 x 480 dots (effective display area 13 cm x 10 cm) with backlight (well readable in direct sun-light), touch screen, USB 2.0 connector, and audio speaker

Data storage capacity: 4 GB compact flash card

CO₂ control: Integrated CO₂-control range 0 to 2000 ppm, CO₂ supply via CO₂ cartridges (8 g CO₂, provide more than 48 h continuous supply at 350 ppm, reserve is indicated) or via CO₂ cylinder with pressure reducer

H₂O control: Integrated H₂O control via step motor for humidifying and drying, range 0 to nearly 100% r.h. (noncondensing)

Measured and calculated parameters: CO₂ absolute, CO₂ difference, H₂O absolute, H₂O difference, flow, ambient pressure, 2x auxiliaries, cuvette temperature (upper and lower half), leaf temperature, ambient temperature, PAR in upper part of the cuvette, PAR in lower part of the cuvette, external PAR, evaporation, VPD, H₂O conductance, net photosynthesis, intercellular CO₂ concentration. Recalculation of stored data is possible. In combination with PAM Fluorometer (GFS-3000FL): Fo, Fm, Fm', F, Fo', Fv/Fm (max. PS II quantum yield), ΔF/Fm' = Y(II) (effective PS II quantum yield), qP, qL, qN, NPQ, Y(NPQ), ETR (i.e. PAR x ΔF/Fm')

PC interface: USB 2.0

Auxiliaries: Two analog inputs, range 0 to 4095 mV

Power supply: Field replaceable rechargeable LiFePO₄ Battery Units 3035-A 12.8 V / 15 Ah (2x 7.5 Ah), external DC: 12-24 V, AC Power Supply 3020-N for laboratory operation

Operating time: 3 to 4.5 hours typ. with one LiFePO₄ Battery Unit 3035-A, 6 to 9 hours typ. with two LiFePO₄ Battery Units 3035-A

Operating temperature: -5 to 45 °C

Dimensions: 43 cm x 28 cm x 27 cm (L x W x H)

Weight: 12.1 kg (incl. LiFePO₄ Battery Unit 3035-A)

STANDARD MEASURING HEAD 3010-S

Design: Universal measuring head featuring small-sized cuvette volume (40 ml), wide range temperature control and effective ventilation. Electronics box detachable for custom-built cuvettes, upper and lower cuvette halves pneumatically separated with one impeller each for upper and lower parts, interchangeable adapter plates for different leaf areas, cuvette expandable to different volumes and shapes (small cylinder or cuboid) for measuring mosses, lichens or conifers. Sockets for cable connections with Control Unit 3100-C, LED Light Source 3040-L or one additional component (e.g. LED-Array/PAM-Fluorometer 3055FL)

Cuvette temp. (in each air exit of upper and lower cuvette half), ambient temp.: Pt 100 type A, range -10 to +50 °C, accuracy ±0.1 °C

Temperature control: Three modes of temperature control: Tracking ambient temperature (with or without offset), set value for cuvette temperature and set value for leaf temperature; cuvette temperature ranging from 10 degrees below ambient temperature (decreasing with light intensity) to +50 °C

Leaf temp. measurement: Thermocouple, range -10 to 50 °C, accuracy ±0.2 °C

External miniaturized quantum sensor: Mini Quantum Sensor MQS-B/GFS sits on top of the Standard Measuring Head 3010-S. Selective PAR measurement, range 0 to 2500 μmol m⁻² s⁻¹, accuracy ±5%, cosine corrected (measuring photosynthetic photon flux density PPFD)

Internal light sensor: Selective PAR measurement, range 0 to 2500 μmol m⁻² s⁻¹ PAR, accuracy ±10%, two sensors, one in the upper and one in the lower part of the cuvette

Cuvette ventilation system: Two frequency controlled impellers, one in the upper and one in the lower part of the cuvette, speed adjustable

Leaf area: 8 cm² standard, interchangeable adapter plates from 1 to 8 cm², flexible shape

Cuvette volume: 40 ml

Operating temperature: -5 to 45 °C

Dimensions: 31 cm x 7 cm x 13 cm (L x W x H)

Weight: 1.6 kg (incl. cable and tubes 2 m long)

LED LIGHT SOURCE 3040-L

Design: LED array with 24 red and 2 blue LEDs

Light intensity: Range 0 to 2000 μmol m⁻² s⁻¹ PAR max., typ. 90% red (640 nm) and 10% blue (470 nm)

Homogeneity of light distribution: ±20 % at leaf level

Leaf area: 8 cm²

Power consumption: 5 W max., power supply via Standard Measuring Head 3010-S

Operating temperature: -5 to 45 °C

Dimensions: 7.5 cm x 4.5 cm x 5.5 cm (L x W x H)

Weight: 160 g

BASIC COMPONENTS

AC POWER SUPPLY 3020-N

Design: DC power supply unit for laboratory use

Output voltage: 16 V DC

Max. output power: 135 W

Mains power supply: 100 to 240 V AC, 50/60 Hz

Operating temperature: 0 to 60 °C

Dimensions: 20 cm x 8 cm x 5 cm (L x W x H)

Weight: 1 kg

BATTERY CHARGER LC-03

Design: Mains operated automatic Li-ion or LiFePO4 battery charger (as indicated on the instrument housing) with two independent charge outputs, 2-line LC-display with backlight for each charge output.

Charging voltage: 16.4 V max.

Charging current: 0 to 3 A

Recharging time: 6 hours for one or two batteries 3025-A or 3035-A

Mains power supply: 100 to 240 V AC, 50/60 Hz

Operating temperature: -5 to 45 °C

Dimensions: 20.5 cm x 19 cm x 9 cm (L x W x H)

Weight: 1.7 kg

LIFEPO4 BATTERY UNIT 3035-A

Design: Mounting plate with GFS-3000 connector plug, containing two electronically separated LiFePO4 battery units placed in parallel, with protection circuit

Nominal voltage: 12.8 V

Typical capacity: 15 Ah (2 x 7.5 Ah)

Operating temperature: -30 to 60 °C

Standard operating time: 3 to 4.5 hours typ. with one LiFePO4 Battery Unit 3035-A, 6 to 9 hours typ. with two LiFePO4 Battery Units 3035-A

Dimensions: 28 cm x 16 cm x 7.5 cm (L x W x H)

Weight: 2.8 kg

FLUORESCENCE COMPONENTS

LED-ARRAY/PAM-FLUOROMETER 3055-FL

included in the system package GFS-3000FL instead of the LED Light Source 3040-L

Design: Combined PAM chlorophyll fluorometer and LED light source comprising an LED array with 24 red LEDs (for actinic illumination and saturation pulses), 2 blue LEDs (for measuring light and actinic illumination), 10 far-red LEDs and 6 photodiodes (for chlorophyll fluorescence detection)

Measuring light: Blue LEDs (470 nm), modulation frequency 5 to 60 Hz and 1.2 kHz (during saturation pulse)

Actinic light: Blue LEDs (470 nm) and red LEDs (640 nm), range 0 to 2000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PAR, typ. 90% red and 10% blue

Saturation light: Red LEDs (640 nm), typ. 4500 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PAR

Far-red light: Far-red LEDs (peak: 740 nm)

Signal detection: PIN-photodiode protected by long-pass filter (> 660 nm), selective window amplifier

Leaf area: 8 cm²

Measured and calculated parameters: see basic components

Power consumption: 15 W max. (during saturating light pulse), power supply via Standard Measuring Head 3010-S

Operating temperature: -5 to 45 °C

Dimensions: 7.5 cm x 6 cm x 6.5 cm (L x W x H)

Weight: 230 g

FIBEROPTICS PAM FLUOROMETER 3050-F

Design: PAM chlorophyll fluorometer enclosed in a metal tube, which can be connected to the Standard Measuring Head 3010-S. Measurement via an optical fiber, entering the leaf chamber of the Standard Measuring Head 3010-S through an air-tight connection

Measuring light: Blue LED (peak: 450 nm), modulation frequency: 10 and 500 Hz. PAR at 2 mm distance and ML-Ampl. 10: Ca. 0.3 $\mu\text{mol m}^{-2} \text{s}^{-1}$ with low frequency, 15 $\mu\text{mol m}^{-2} \text{s}^{-1}$ with high frequency

Saturating light: Blue LED (peak: 450 nm). At 1 mm distance: Typ. 11000 $\mu\text{mol m}^{-2} \text{s}^{-1}$. At 2 mm: Typ. 6000 $\mu\text{mol m}^{-2} \text{s}^{-1}$

Far-red light: LED (peak: 730 nm)

Signal detection: PIN-photodiode protected by a long pass filter (transmission=50% typ. at 645 nm), selective window amplifier

Measured and calculated parameters: The same as with the LED-Array/PAM-Fluorometer 3055-FL (see basic components)

Power consumption: 0.25 W continuously, 6.5 W (during saturating light pulse), supplied via Standard Measuring Head 3010-S

Operating temperature: -5 to 45 °C

Dimension of light guide: Length: 21 cm, diameter: 1.5 mm

Dimensions of housing: Length: 20 cm, diameter: 3 cm

Weight: 150 g

DARK LEAF CLIPS 3010-DLC

Design: For darkening leaf samples in the field, made from plastic material, with sliding shutters, positioning aid and stainless steel clips

Weight: 11g

ACCESSORIES

LICHENS/MOSSES CUVETTE 3010-V32 (SHOWN WITH ANIMAL)

Inner Volume: Diameter 3.2 cm, height: 4 cm

LICHENS/MOSSES CUVETTE 3010-V40

Inner Volume: ca. 40 ml, 3 cm x 5 cm x 2.7 cm (L x W x H)

CONIFER CUVETTE 3010-V80

Inner Volume: ca. 80 ml, 3 cm x 5 cm x 5.3 cm (L x W x H)

ARABIDOPSIS CHAMBER 3010-A

Design: Attachment to the Standard Measuring Head 3010-S for gas exchange measurements on above-ground plant material of small pot plants. Consisting of an aluminum attachment, two pot holders and a support for the horizontal bedding of the Standard Measuring Head 3010-S

Pot holder size (outside): Height: 7.5 cm, diameter: 10 cm

Above ground volume: Height: 2.5 cm, diameter: 4 cm

Usable pot size: Height: Max. 5.8 cm, diameter: 5.5 to 7 cm

LEAF AREA ADAPTER

Measuring area:

3010-1xA: 1 cm x 4 cm

3010-R3: 3 cm² round

3010-1.1x2.1: 1.1 cm x 2.1 cm

COMPACT TRIPOD ST-1010

Design: Stable tripod for mounting the Standard Measuring Head 3010-S, the tripod fits into the GFS-3000 transport box

OUTDOOR-SET 3000-CA/OS

Design: 2.5 m fiberglass antenna, antenna holder, 10 l air buffer volume with pneumatic connector air in and air out, luggage net, 27 cm and 3 m hose with pneumatic connectors, 66 cm x 30 cm heat protection sun screen

Weight: 1.2 kg



SYSTEM COMBINATIONS

DUAL-PAM GAS-EXCHANGE CUVETTE 3010-DUAL

Design: Cuvette is a sandwich of two 2 x 2 cm aluminum frames, each holding the end part of a Walz standard Perspex rod to connect various measuring heads of the DUAL-PAM-100. Distance between Perspex rod and leaf: ca. 1 mm on each leaf side. Pneumatically separated upper and lower cuvette halves. Controlled by a regulator unit with sockets for cable connections to the Control Unit 3100-C of the GFS-3000 and a trigger input line

Cuvette temperature: Pt 100 type A (located near the Peltier elements), range -10 to 50 °C, accuracy ±0.1 °C

Temperature control: Set point value for cuvette temperature. Cuvette temperature ranging from 10 degrees below ambient to max. +50 °C

Leaf temperature measurement: Thermocouple, range -10 to 50 °C, accuracy ±0.2 °C

External miniature quantum sensor: Mini Quantum Sensor MQS-B/GFS: Selective PAR measurement, range 0 to 2500 μmol m⁻² s⁻¹ PAR, accuracy ±5%, cosine corrected

Leaf area: 1.3 cm²

Trigger in: Triggers at 5V → 0V signal change

Operating temperature: -5 to 45 °C

Dimensions: Assembled cuvette: 10 cm x 4 cm x 12 cm (L x W x H), electronics box : 7 cm x 7 cm x 15 cm (L x W x H)

Weight: Cuvette, electronics box, cables, and mounting frame: 1.7 kg; Mounting Stand ST-101: 2 kg

IMAG-MIN/GFS

Design: adapter plate with snap-on-mount for connecting IMAG-Mini Head to Standard Measuring Head 3010-S; 9.5 cm x 6 cm x 1.4 cm (L x W x H)

Weight: 30 g

IMAG-MAX/GWK1

Design: Adapter plate with legs for placing IMAG-Maxi Head on 3010-GWK1 18.5 cm x 20 cm x 17 cm (L x W x H)

Weight: 390 g

GAS-EXCHANGE CHAMBER 3010-GWK1

Design: Chamber consisting of an aluminum cooling block with two pneumatic connectors and transversal fan, flat polymer lid or user-designed cuvette; micro-processor controlled electronics with connectors for temperature sensors, humidity sensor, PAR-sensors, GFS-3000 or 3010-I/GWK connection, power-input; cooled with Peltier-cooling units and ventilator

Measurement of chamber and ambient temperatures: Pt 100 type A, range -10 to 60 °C, accuracy ±0.1 °C, on customer request the range can be extended to 75 °C

Leaf temp. measurement: Thermocouple, range: -10 to 50 °C, accuracy ±0.2 °C

Temperature control: Three modes of temperature control: Constant cuvette temperature, constant leaf temperature, follow ambient temperature with an offset

Temperature control range: -10 °C to 60 °C depending on ambient temperature and radiative heat intake. With 4l volume, dark: 10 K below ambient temperature and 25 K above ambient temperature. With flat lid, dark: 20 K below ambient temperature and 35 K above ambient temperature

Relative humidity sensor: Range: 0 to 100% r.h., accuracy: ±1.5% (5 to 95% r.h.), T90 response time (11 to 75% r.h.): <10 s

External miniature quantum sensor: Mini Quantum Sensor MQS-B/GWK1 outside of chamber. Selective PAR measurement, range 0 to 2500 μmol m⁻² s⁻¹, accuracy ±5%, cosine corrected (measuring photosynthetic photon flux density PPFD)

Internal light sensor: Selective PAR measurement, range 0 to 2500 μmol m⁻² s⁻¹ PAR, accuracy ±10%, two sensors, one in the upper and one in the lower part of the cuvette

Cuvette ventilation system: Transversal fan

Maximum sample area: 14 cm x 10 cm

Pneumatic connectors: Hose fittings for 10/8 mm (OD/ID) tubing

Inner volume of the cooling unit alone: 840 ml (up to edge of aluminum frame)

Power supply: AC Power Supply 3020-N for laboratory operation

Power consumption: Max. 45 W

Operating temperature: -5 to 45 °C

Dimension of cooling unit: 26 cm x 25 cm x 19.5 cm (L x W x H)

Weight: 6.9 kg including cables and tubes

Cuvette Standard: Flat lid (inside: 16 cm x 14.5 cm, outside: 18.5 cm x 17 cm, volume: 320 ml); other design available on customer request

Optional glas lid: 3010-GWK1/G, aluminium frame 18.4 cm x 17 cm x 2 cm with glass surface 0.4 cm and opening for petiolus

Optional interface: 3010-GWK1/I for stand-alone operation of the GWK1

LED-PANEL RGBW-L084

Design: LED-Panel fitting to the gas exchange chamber 3010-GWK1: illuminated area 14 cm x 12 cm. LED Colors: red, green, blue and white maximum output (all colors together): 2000 μmol m⁻² s⁻¹ or better. Air cooled; with separate power supply. Colors can be mixed with red, green, blue, and white in steps of intensity 0 to 100 or more; total intensity can be chosen in steps of 0.1%; operation with GFS-Win software via RS485 connector

RGBW High Power LEDs: Blue: 455 ±10 nm, HBW (half bandwidth) 440 - 460 nm Green: 525 ±10 nm, HBW 500 - 545 nm Red: 625 ±5 nm, HBW 620 - 640 nm White: 450 ±10 nm, HBW 435 - 460 nm; second peak at 590 ±25 nm, HBW 510 - 640 nm with tail up to 800 nm

Homogeneity of light distribution: ±10% within the 14 x 12 cm area or ± 3 μmol m⁻² s⁻¹ (whatever is bigger)

PAR measurement: PAR sensors with multiplier between -50 and -800 μmol m⁻² s⁻¹ per μA result in a range of 0 to 6400 μmol m⁻² s⁻¹, resolution: 1 μmol m⁻² s⁻¹

Fuse: 10 A slow-blow fuse, 5 x 20 mm

Input voltage: 16 V, 8 A

Voltage inside: up to 36 V

Power supply: AC Power Supply 3020-N for laboratory operation

Operating temperature: -5 to 45 °C

Dimension: 27 cm x 19 cm x 13 cm (L x W x H)

Weight: 2.8 kg



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