Dual-Wavelength Emitter-Detector Unit

ED-P700DW

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1 Safety instructions

1. Read the safety instructions and the operating instructions first.
2. Pay attention to all the safety warnings.
3. Keep the device away from water or high moisture areas.
4. Keep the device away from dust, sand and dirt.
5. Always ensure there is sufficient ventilation.
6. Do not put the device anywhere near sources of heat.
7. Connect the device only to the power source indicated in the operating instructions or on the device.
8. Clean the device only according to the manufacturer's recommendations.
9. If the device is not in use, remove the mains plug from the socket.
10. Ensure that no liquids or other foreign bodies can find their way inside the device.
11. The device should only be repaired by qualified personnel.

2 Introduction

With the Dual-Wavelength Emitter-Detector Unit ED-P700DW a standard PAM-Fluorometer can be readily transformed into a very sensitive and selective device for measuring P700 absorbance changes. P700 is the reaction center chlorophyll of photosystem I (PS I). When P700 is oxidized during illumination or following chemical additions (like ferricyanide), the cation radical P700+ absorbs not only light around 700 nm (from which the name P700 is derived), but also near-infrared radiation around 810 nm. Detection of P700+ around 810 nm is advantageous for three major reasons:

1. Very powerful light emitting diodes (LED) are available in this wavelength range.
2. Very high intensities of this light can be applied without any actinic effect.
3. The signal is not disturbed by chlorophyll fluorescence.

P700 absorbance changes provide very detailed information on photosynthetic electron flow and on the quantum yield of photochemical energy conversion. This information is similar, although not identical to that provided by chlorophyll fluorescence. Actually, the two types of information are complementary. During rapid light induced transients, chlorophyll fluorescence primarily reflects the reactions at acceptor and donor sides of photosystem II (PS II), whereas **P700 reflects the reactions at acceptor and donor sides of PS I**. During steady state illumination, when electrons pass at the same rates via PS II and PS I reaction centers, the quantum yields of energy conversion detected via chlorophyll fluorescence and P700 should be identical, provided the absorbed energy is evenly distributed between the two photosystems. Observed differences provide valuable information on non-linear types of electron flow and differences in the optical cross sections of PS I and PS II. In

particular, P700 measurements may contribute to the elucidation of cyclic electron transport around PS I.

3 Special features of the ED-P700DW

The ED-P700DW features **a special dual wavelength measuring technique** which provides a number of outstanding advantages. In first place, the obtained difference signal **is relatively selective for P700 absorbance**, as it minimizes all non-specific signal changes which are identical or similar at the two measuring wavelengths. Hence, the absorbance changes due to plastocyanin and light scattering, which display relatively flat difference spectra in the 800-900 nm wavelength region, are largely suppressed. Furthermore, when dealing with suspensions, **the noise caused by stirring and chemical additions is mostly eliminated**. The same is true for signal drifts caused e.g. by sample settling in unstirred suspensions or changes of water status in leaves.

For measurements with the ED-P700DW the PAM-Fluorometer can be continuously operated at 100 KHz measuring pulse frequency and at the lowest DAMPING-setting. In this way, a **high time resolution** is obtained, which allows reliable assessment of sub-millisecond absorbance changes. As the original signals can be fully compensated (to zero) before being fed into the DETECTOR-input of the PAM-101, they can be much larger than the usual 2 V signal, resulting in a **high signal/noise ratio**. Also, as high GAIN-settings can be selected at the PAM-101 without risk of overload, **large difference signals** can be obtained at the analog output of the PAM-101 (0.1-1 V) which facilitates analog recording and A/D conversion. Using the ED-P700DW, measuring light intensity is independent of the LIGHT INT settings of the PAM-101. It is fixed at a maximal value in order to provide maximal difference signals. This is feasible, as even maximal measuring light intensity does not have any actinic effect. The current pulses at the Emitter-output of the

PAM-101 are just serving as trigger pulses for the actual LED-current pulses generated by the more powerful LED-drivers in the ED-P700DW. Triggering occurs at all LIGHT INT settings above 6.

4 Components of the ED-P700DW

The ED-P700DW consists of three major components, the actual **Emitter-Detector Unit (ED-P700DW-E)**, the **separate LED-Driver and Compensation Unit (ED-P700DW-T)** and **the AC/DC Adapter**. A special short-pass filter (Calflex X) is provided for protection of the fluorescence detector during simultaneous measurements of P700 and chlorophyll fluorescence (see section 7). The ED-P700DW-E features two optical ports (Emitter and Detector), with adaptors for the fiberoptics 101-F or 101-F5. Two cables connect the ED-P700DW-E with the ED-P700DW-T (Emitter-cable) and the PAM-101 (Detector-cable), respectively.

The **Emitter-Detector Unit** is connected via the fiberoptics with the sample. The measuring light is provided by **a Dual-Wavelength Emitter Cone** featuring a mixed array of near-infrared light emitting diodes peaking around 810 nm (sample) and 870 nm (reference). At the output of the cone, the measuring light is randomized by a scattering plastic foil before entering one arm of the fiberoptics. Another arm of the fiberoptics serves for guiding the remitted (scattered and reflected) part of the measuring light back from the sample to the detector (see Fig. 1, Remittance Mode). The detector properties as well as the fiber adapters are identical with those of the standard PAM Emitter-Detector Unit ED-101. In principle, also measurements in the transmittance mode are possible. In this case, additional fiberoptics are required for guiding the transmitted light to the Detector-port of the ED-P700DW-E (see Fig. 1, Transmittance mode). When two multibranched fiberoptics are available (101-F or 101-F5) a variety of light sources can be connected (see section 6) and the components for measuring chlorophyll fluorescence can be connected as well (see section 7). In principle, a second fiberoptics can be also connected in the remittance mode, replacing the reflector.

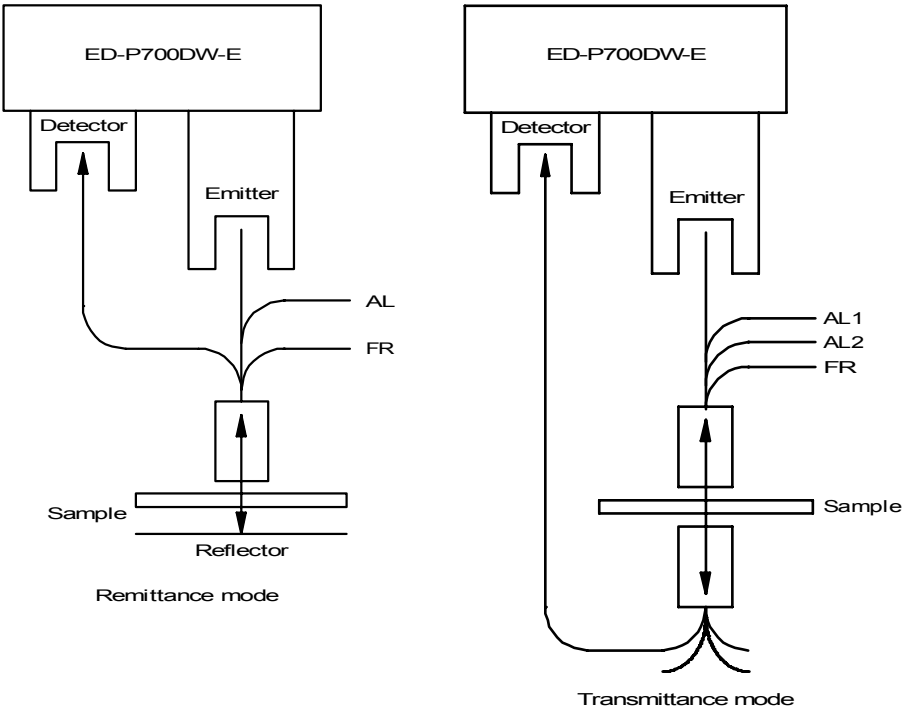

Fig. 1 Connection of fiberoptics to ED-P700DW-E in the remittance and transmittance modes. AL, actinic light source. FR, FR, light source. In addition, various flash light sources and the Emitter-Detector unit ED-101 for fluorescence measurements can be connected.

The **LED-Driver and Compensation Unit ED-P700DW-T** contains the two **LED-drivers**, the **compensation circuitry** (with coarse and fine adjustment) and a **calibration button**, with which an apparent $\Delta I/I$ of 10^{-3} units can be induced. For each trigger pulse derived from the PAM-101 EMITTER-output, the LED-Driver Unit produces two sequential measuring light pulses at 810 nm and 870 nm. Only the difference of the two pulse signals is amplified by the AC-coupled preamplifier and fed into the DETECTOR-input of the PAM-101.

Fig. 2: Front view of LED-Driver and Compensation Unit ED-P700DW-T

The difference signal, which can be adjusted to zero by using the compensation potentiometers (**Coarse** and **Fine**), is shown on the LCD-display of the PAM-101. After compensation, the GAIN of the PAM-101 can be turned up, in order to detect small difference signals induced by illumination or chemical additions.

The **AC/DC converter** provides the 18 V required for powering the ED-P700DW-T. It can remain permanently connected.

5 Setting up and calibration of the ED-P700DW

The ED-P700DW is readily connected with the PAM-101 and the fiberoptics to give a functional system for measuring P700 absorbance changes. Setting up the basic system involves the following steps:

5.1 Mounting of the optical system

In standard applications, the optical connection of the ED-P700DW-E is via the **fiberoptics 101-F or 101-F5**. The fiberoptics are preferably mounted on the **Stand with Base Plate ST-101**. Excessive tension on the fiber bundles has to be avoided. The joint end of the multibranched fiberoptics should be in close optical contact with the investigated sample. It is important to realize that only the remitted measuring light, which has optically interacted with the sample, can carry information on P700 absorbance. Therefore, if possible, reflecting surfaces between sample and fiberoptics should be avoided. Furthermore, a reflective surface (e.g. mirror or metal plate) should be mounted behind the sample, such that the transmitted measuring light is reflected back into the fiberoptics. This aspect is particularly important when dealing with suspensions (algae or chloroplasts). Good results are obtained with the **Suspension Cuvette KS-101**, which features a highly reflective bottom, and the **Optical Unit ED-101US/M**, using a one-side mirrored 10 x 10 mm cuvette (US-K1). Both cuvette systems allow stirring and temperature control of the sample. Signal quality depends strongly on chlorophyll concentration which should amount at least to 50 µg/ml. The signal is improved by the presence of scattering material which increases the optical path length of the measuring light within the sample.

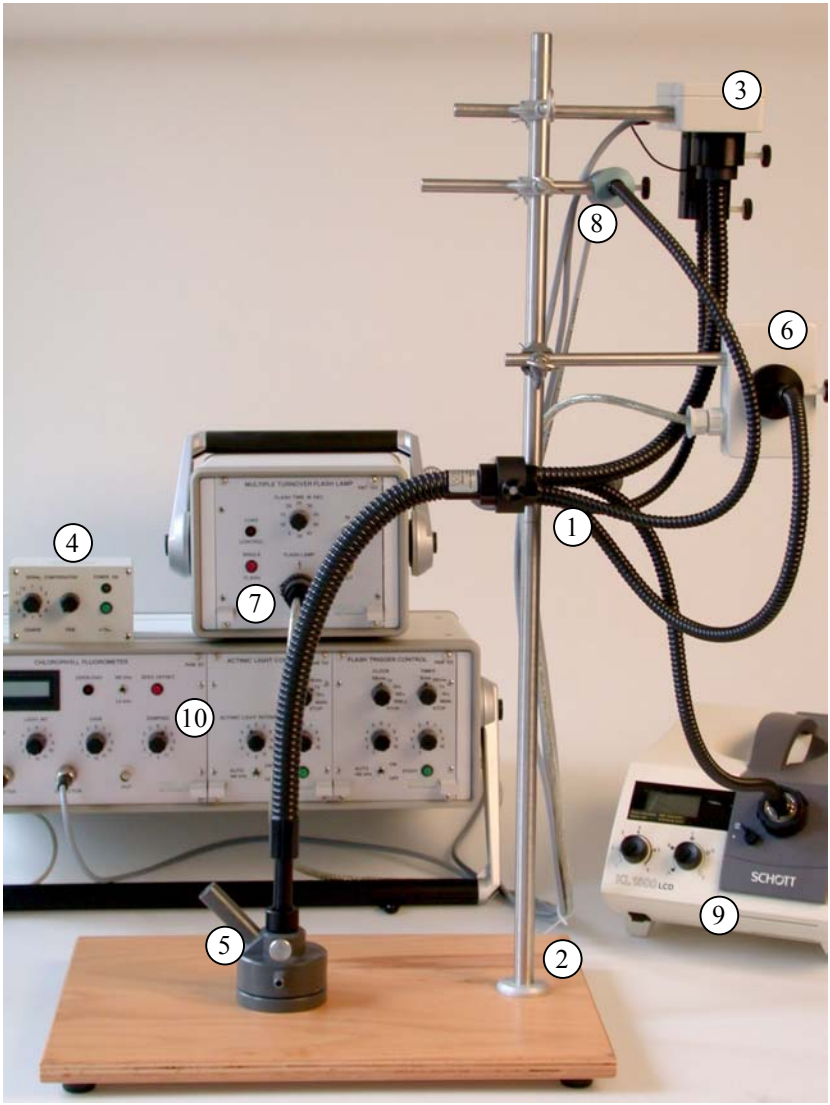

Fig. 3 Mounting of Fiberoptics 101-F5 and various optical components on the Stand ST-101. Example for build-up in conjunction with the Suspension Cuvette KS-101. The depicted components are: (1) Fiberoptics 101-F5; (2) Stand with Base

Plate ST-101; (3) Emitter-Detector Unit ED-P700DW-E; (4) LED Driver and Compensation Unit ED-P700DW-T; (5) Suspension Cuvette KS-101; (6) XF-103 Flash Lamp; (7) XMT-103 Flash Power-and-Control-Unit; (8) Far-Red LED Light Source 102-FR; (9) Fiber Illuminator FL-103/E; (10) PAM-101/102/103

5.2 Electrical connections with the PAM-101

The PAM-101 provides the triggering pulses for the LED-drivers of the ED-P700DW-T unit and the PAM-101 amplifies the difference signal generated in the detector part of the ED-P700DW-E. The following steps are required for connecting the ED-P700DW with the PAM-101:

1. Connect the cable end labelled EMITTER of the ED-P700DW-T to the socket labelled EMITTER of the PAM-101.
2. Connect the cable end labelled EMITTER of the ED-P700DW-E unit to the socket labelled EMITTER DETECTOR UNIT of the ED-P700DW-T box.
3. Connect the cable end labelled DETECTOR of the ED-P700DW-E unit to the socket labelled DETECTOR of the PAM-101.

5.3 Settings of the PAM-101

The standard settings of the PAM-101 for measurements in conjunction with the ED-P700DW differ from those used for fluorescence measurements. This is mainly due to the fact that even at its maximal intensity the near-infrared P700 measuring light does not have any actinic effect. Therefore, as the signal/noise ratio increases

with measuring light intensity, it makes sense to apply maximal measuring light intensity in all applications. Hence, a fixed maximal intensity of individual measuring light pulses is determined by the ED-P700DW-T unit and the LIGHT INT. settings of the PAM-101 have no influence on the intensity. However, the LIGHT INT. setting has to be >6 for triggering LED-current pulses by the ED-P700DW-T (see chapter 3). The following settings on the PAM-101 are recommended for standard applications:

100 kHz 100 kHz should be permanently switched on; when transiently switched off, there will be a signal drift, which depending on the applied GAIN may disturb measurements for several minutes

ZERO OFFSET After switching on the PAM-101 and before switching on the measuring light via PULSE ON, the ZERO OFFSET button should be pressed in order to zero the PAM-101 output signal.

PULSE ON After ZERO OFFSET the measuring light can be permanently switched on via PULSE ON; when transiently switched off, there will be a signal drift, which depending on the applied GAIN may disturb measurements for several minutes

LIGHT INT. LIGHT INT. can be permanently on setting 9 (any other setting between 7-12 would be alright as well)

GAIN After switching on the measuring light, GAIN initially should be at setting 1; after the unavoidable initial signal drift has ceased (ca. 15 min after PULSE ON) and the signal has been stably compensated (displayed difference signal close to zero), the GAIN can be increased up to 12 fold in

order to reach the required sensitivity; while it should be considered that the signal/noise ratio is independent of the GAIN, a high signal level can be advantageous for analog recording (e.g. chart recorder) as well as digital recording (via AD-converter).

DAMPING Normally setting 1 is appropriate; in most applications higher settings of DAMPING are not required due to the excellent signal/noise performance of the system; at high settings of GAIN and high sensitivity recordings the optimal setting of DAMPING depends on the required time resolution.

5.4 Signal compensation and initial signal drift

When (after installation of the optical system and proper connection of the ED-P700DW with the PAM-101) the measuring light is switched on (PULSE ON), the intensities of the 810 nm and 870 nm measuring light normally are not matching each other and a large difference signal is measured. Furthermore, due to the unavoidable warming up of the LEDs and LED-drivers, both light intensities initially display small drifts differing somewhat in slope, which result in a substantial drift of the highly amplified difference signal. Therefore, it is recommended to switch on the measuring light (PULSE ON) at least 10 min before adjustment of Signal Compensation and the actual start of measurements. After 10 min warm-up time the drift is equivalent to approximately 0.5×10^{-3} units of $\Delta I/I$. It further decreases with time.

For signal compensation 12 coarse settings and a fine adjustment are provided. The fine adjustment, which is controlled by a ten-turn

potentiometer, covers the range of approximately two coarse settings. Compensation is minimal at setting 1 with the fine adjustment potentiometer turned fully anti-clock wise. The appropriate setting depends on the individual instrument and the investigated sample. For proper compensation it is recommended to proceed as follows:

1. Be sure that you have applied ZERO OFFSET at the PAM-101 before switching PULSE-ON (LCD-display showing signal close to 0.00) and also that GAIN 1 is selected.
2. Make sure the investigated sample is reliably fixed with respect to the fiberoptics.
3. After PULSE-ON, allow at least 10 min for warm-up.
4. Select COARSE setting 1 and roughly middle position of the FINE potentiometer.
5. Turn the COARSE setting up until the difference signal displayed at the PAM-101 is minimal. For compensation of negative signals the Coarse setting has to be turned up.
6. Turn the FINE potentiometer such that the displayed signal is close to zero. For compensation of negative signals the potentiometer has to be turned clock wise.
7. If necessary, now the GAIN at the PAM-101 can be increased, by which any remaining offset will be correspondingly increased, which can be compensated again using the FINE-adjustment.
8. At high GAIN settings a slow signal drift may persist for approximately one hour, which can be gradually compensated by FINE-adjustment. As long as the absolute level of the difference signal does not saturate the PAM-amplifier (signals < 2 V), it does not affect any light or chemically induced P700 changes. Hence, while it is convenient to work at a low signal level (after appropriate compensation), in order to make optimal use of

amplification, the data collected at a higher signal level (large background signal) are valid as well.

5.5 Calibration of ΔI / I using the 1 °/oo push button

The output signal of the PAM-101 corresponds to a difference signal and, hence, does not contain information on the amplitudes of the original signals which depend on properties of the sample and the optical geometry, as well as on the GAIN. Using the 1 °/oo push button it is possible to simulate a **10^{-3} change of ΔI/I**. Actually, when this button is pressed, the intensity of the 810 nm measuring light is increased by 10^{-3} with respect to the 870 nm measuring light. Hence, the amplitudes of the two original signals are 1000 times larger than the difference signal induced by the 1 °/oo push button.

As the 810 nm signal is increased with respect to the 870 nm signal, this is equivalent to an absorbance decrease, thus simulating P700 reduction, which at the output of the PAM-101 is reflected by a negative signal change. Actually, signal polarity is arranged in this way in order to assure that standard light induced P700 absorbance changes give positive signals which most readily can be compared with the corresponding chlorophyll fluorescence induction curves.

6 Accessory light sources for P700 measurements

A number of accessory light sources are available which are useful in conjunction with P700 measurements. These include various actinic and far-red light sources, as well as single and multiple turnover flash lamps, which are briefly described in the following list:

102-FR Far-Red LED Light Source

The 102-FR may serve for **selective excitation of photosystem I**. It is connected to one of the fiber optics branches. It can be controlled by the PAM-102 module or in conjunction with the PDA-100 PAM-Data Acquisition System via the WinControl software. The far-red light causes oxidation of P700.

102-L LED Light Source

The 102-L may provide **moderate intensity actinic illumination**. It is connected to one of the fiber optics branches. It can be controlled by the PAM-102 module or in conjunction with the PDA-100 PAM-Data Acquisition System via the WinControl software. Even at maximal intensity setting the 102-L does not provide sufficient light to cause large induction phenomena in P700 absorbance.

XST-103 Single Turnover Flash System

In conjunction with the Flash Lamp XF-103, the XST-103 provides saturating flashes (half peak width 14 µs) which are single turnover with respect to PS II, whereas ca. two turnovers are possible at PS I. In conjunction with P700 measurements it is recommended to have the XF-103 equipped with a DT-Cyan short-pass filter (SP695, white light) instead of the standard blue glass filter (BG18) which is recommended for fluorescence measurements. The XF-103 is connected to one of the fiber optics branches. Flash triggering can be

controlled by the PAM-103 module. Saturating single turnover flashes are useful to study the **kinetics of P700 re-reduction** after preceding oxidation by far-red background light (see e.g. Schreiber et al. 1988). Furthermore, in presence of far-red background light, the **area integral of P700** reduction transiently induced by a saturating single turnover flash in comparison to the area integral of P700 reduction induced by a saturating multiple turnover flash allows to estimate the **size of the plastoquinone pool** (see Schreiber et al. 1988, Asada et al. 1992).

XMT-103 Multiple Turnover Flash System

In conjunction with the Flash Lamp XF-103, the XMT-103 **provides saturating pulses of light (pulse length 5-50 ms)** which at 50 ms length can induce complete reduction of the plastoquinone pool. In conjunction with P700 measurements it is recommended to have the XF-103 equipped with a DT-Cyan short-pass filter (SP695, white light) instead of the standard blue glass filter (BG18) which is recommended for fluorescence measurements. The XF-103 is connected to one of the fiber optics branches. Flash triggering can be controlled by the PAM-103 module. In the presence of far-red background light, the area integral of P700 reduction induced by a saturating multiple turnover flash in comparison to the **area integral of P700 reduction** induced by a saturating single turnover flash allows to estimate **the size of the plastoquinone pool** (see Schreiber et al. 1988, Asada et al. 1992). Furthermore, saturating multiple turnover flashes may serve to **saturate the PS I acceptor side**, thus allowing to estimate the effective quantum yield of PS I (Klughammer and Schreiber 1994).

XE-ST Single Turnover Flash Unit

The XE-ST Single Turnover Flash Unit provides sarurating 1 µs xenon-discharge flashes which are sufficiently short to be single

turnover not only for PS II but for PS I as well. At the exit of the flash unit the light is focused by a parabolic mirror, thus giving collimated light and high intensities even in conjunction with fiberoptics. Flash intensity can be attenuated via a ten-step selection switch.

FL-103/E or FL-101/E Fiber Illuminator

In conjunction with a variety of optical filters, the two types of Fiber Illuminator provide very strong continuous actinic light which can induce large amplitudes of **P700 dark-light induction phenomena** (see e.g. Schreiber et al.1988). In particular, in conjunction with the PAM-103 module, the FL-103/E is well-suited **for generation of saturation pulses** (300 ms to several s) causing full reduction of the plastoquinone pool and inducing maximal fluorescence yield. The Fiber Illuminators are connected to the fiberoptics using a bundle with a special adapter end piece. While the FL-103/E can be controlled by the PAM-103 Trigger Unit, the FL-101/E is manually controlled.

HPL-C High Power LED Lamp

A number of differently colored LED-Array Cones (standard versions red and blue) are available for strong continuous actinic light or saturation pulses. They are well suited for measuring dark-light induction kinetics and for assessment of the effective PS I quantum yield by saturation of the PS I acceptor side (Klughammer and Schreiber 1994). The HPL-C is particularly powerful when directly connected to one of the ports of the ED-101US/M Optical Unit. It can be also applied in conjunction with the fiberoptics using a special adapter. However, as only part of the light can be taken up by the fibers (maximally 5.5 mm ∅), the light intensity at the joint end of the fiberoptics is substantially lower than at the exit of the LED-Cone (14 mm ∅). The HPL-C can be controlled either manually or by the

PAM-103 module or in conjunction with the PDA-100 PAM Data Acquisition System by the WinControl software.

7 Parallel measurements of P700 and chlorophyll fluorescence

For parallel measurements of P700 and chlorophyll fluorescence two PAM-101 units are required. Furthermore, special steps are necessary in order to measure P700 and fluorescence simultaneously:

1. When dealing with intact leaves**, two fiberoptics (101-F or 101-F5)** can be used, with the leave being placed between the two endpieces and the fluorescence fiberoptics facing the upper surface of the leaf.
2. A major problem arises from the fact, that most of the near-infrared (NIR)-measuring light of the ED-P700DW is transmitted into the fluorescence fiberoptics and, hence, towards the fluorescence detector. As the standard version of the fluorescence detector is not protected against NIR, the P700 measuring light will disturb the fluorescence signal. Therefore, a **special short-pass filter (14 mm ∅ Calflex-X)**, which is delivered together with the ED-P700DW, should be placed between the fluorescence detector and the corresponding fiberoptics endpiece. The side with the interference layer should be facing the fiberoptics (distinguish layer at low angle of view). Unavoidably, this filter also cuts down the fluorescence signal appreciably, as due to strong reabsorption of shorter wavelength emission in leaves, a large part of the original signal is due to longer wavelength emission. Normally, the remaining fluorescence signal still is sufficiently large for satisfactory results. If, however, signal amplitude is a problem, use of **the special fluorescence Emitter-Detector-Unit ED-101BL** can be recommended, which features blue excitation light, such that shorter wavelength emission can be measured.

3. When dealing with suspensions, for parallel measurements of P700 and fluorescence the **Emitter-Detector-Cuvette Unit ED-101US** is recommended. In addition to special optical ports for the fluorescence measuring light source and fluorescence detector, this unit provides two other ports for fiberoptics and/or various lamps. It is recommended to place the fiberoptics endpiece of the P700 measuring system into the port opposite to the fluorescence measuring light source. On one hand, this minimizes disturbance of the fluorescence measurement by the P700 measuring light. And on the other hand, in this way the P700 signal is optimized, as the transmitted measuring light is effectively reflected by the short-pass filter in front of the fluorescence measuring light source, back through the sample into the fiberoptics and towards the P700 detector.

4. Even with the 90° geometry of the ED-101US some P700 measuring light will be scattered into the fluorescence detector pathway. The resulting disturbance can be prevented by placing the 14 mm ∅ Calflex X short-pass filter (delivered with ED-P700DW) between 10 mm quartz rod and fluorescence detector filter. The filter can be fixed in front of the opening in the detector filter. The side with the interference layer should be facing the quartz rod (distinguish layer at low angle of view). If signal amplitude is a problem, use of the blue LED Measuring Light Source US-L470 in conjunction with a RG 645 detector filter is recommended. In this case a much larger signal is observed, as the 685 nm emission peak, which is dominant in suspensions, is not cut off by the detector filter.

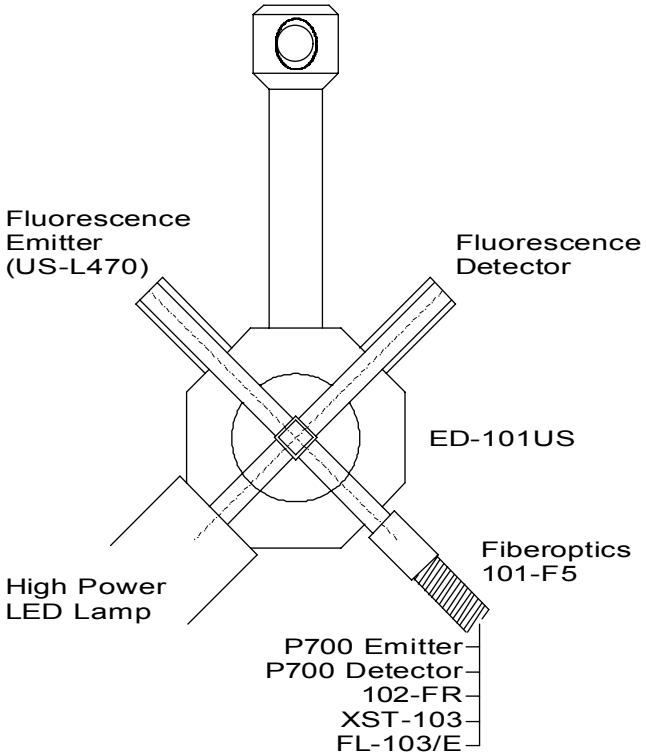

Fig. 4: Assembly of various optical components on the Emitter-Detector-Cuvette Unit ED-101US for simultaneous P700 and fluorescence measurements. Fluorescence Emitter (US-L470) and Detector are mounted at 90° angle to each other. The common endpiece of the Fiberoptics 101-F5 is mounted in the port opposite to the Fluorescence Emitter. The five bundles are connected to P700 Emitter and Detector, the Far-Red Lamp 102-FR, the Single Turnover Flash Lamp XST-103 and the Fiber Illuminator FL-103/E. Multiple turnover flashes can be given with the High Power LED Lamp.

8 Technical specifications

8.1 General environmental conditions

The general environmental conditions are valid for all instruments outlined in chapter 8.2. The values referring to the mains voltage apply only if the instrument features a mains connector.

Permissible environmental temperature

During operation: -5 °C to +45 °C

In resting state: -30 °C to +60 °C

Environmental humidity: up to 31 °C ≤ 80%, linearly decreasing to 50 % at 40 °C

Maximal altitude

During operation: 4000 m

In resting state: 15000 m

Mains voltage fluctuations: max. ±10 %

Overvoltage category: II

Contamination level: 1

8.2 Dual-Wavelength-P700-Unit ED-P700DW

Emitter-Detector Unit ED-P700DW-E

Design:	Metal housing with adapters for metal endpieces of Fiberoptics (101-F or 101-F5); cables connecting to LED-Driver Unit and Detector-input of PAM-101; featuring LED-Array Emitter (810 nm, 30 nm HBW, and 860 nm, 40 nm HBW), perspex cone with diffuser for focussing randomized measuring light on entrance of fiberoptics, PIN-photodiode detector with long-pass filter $\lambda > 760$ nm, and pulse-signal preamplifier.
Dimensions:	22.5 cm x 10 cm x 10 cm (L x W x H), including rod for mounting on stand
Weight:	720 g (incl. cables, 1.5 m long)

LED-Driver Unit ED-P700DW-T

Design:	Metal housing with cable connecting to Emitter-output of PAM-101 and connector for Emitter-Detector Unit ED-P700DW-E, circuitry for two synchronized LED-drivers; featuring controls for coarse and fine adjustment of signal compensation; calibration push-button for simulation of $\Delta I/I$ of 10-3 units.
Dimensions:	10.5 cm x 7 cm x 12.5 cm (W x H x D)
Weight:	480 g

AC/DC Adapter TEACH-L

Mains input:	100-240 V AC, 50/60 Hz

Output:	18 V DC
Dimensions:	approx. 11.5 cm x 6 cm x 3.5 cm (L x W x H)
Weight:	approx. 300 g

9 Literature on P700 measurements with the PAM

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10 Warranty conditions

All products supplied by the Heinz Walz GmbH, Germany, are warranted by Heinz Walz GmbH, Germany to be free from defects in material and workmanship for one (1) year from the shipping date (date on invoice).

The warranty is subject to the following conditions:

1. This warranty applies if the defects are called to the attention of Heinz Walz GmbH, Germany, in writing within one year (1) of the shipping date of the product.
2. This warranty shall not apply to any defects or damage directly or indirectly caused by or resulting from the use of unauthorized replacement parts and/or service performed by unauthorized personnel.
3. This warranty shall not apply to any product supplied by the Heinz Walz GmbH, Germany which has been subjected to misuse, abuse, abnormal use, negligence, alteration or accident.
4. This warranty does not apply to damage caused from improper packaging during shipment or any natural acts of God.
5. This warranty does not apply to underwater cables, batteries, fiberoptic cables, lamps, gas filters, thermocouples, fuses or calibrations.

To obtain warranty service, please follow the instructions below:

1. The Warranty Registration form must be completed and returned to Heinz Walz GmbH, Germany.
2. The product must be returned to Heinz Walz GmbH, Germany, within 30 days after Heinz Walz GmbH, Germany has received written notice of the defect. Postage, insurance, custom duties,

and/or shipping costs incurred in returning equipment for warranty service are at customer expense.

3. All products being returned for warranty service must be carefully packed and sent freight prepaid.

4. Heinz Walz GmbH, Germany is not responsible or liable, for missing components or damage to the unit caused by handling during shipping. All claims or damage should be directed to the shipping carrier.