FMS-300

Pulse-modulated chlorophyll fluorometer for teaching & research applications

Hansatech Instruments

Key features

> Versatile functionality:

Suitable for both teaching and research applications. FMS-300 can demonstrate complex concepts, conduct experiments, collect data, analyse results, and facilitate collaborative learning or research projects.

> Intuitive software with simplified control set:

Developed from the ground up with simplicity in mind. A user-friendly interface with minimal learning curve allows easy navigation of the different functions and options.

> Streamlined data capture:

FluoroControl software provides 6 pre-set experimental routines, which can be further configured, if required. This enables rapid learning and efficient, hassle-free data acquisition.

> Developed for high-performance:

A measuring pulse width of 400 ns from a dedicated LED allows greater intensities to be implemented yielding a strong, low-noise signal. Measuring pulse intensity can be defined between *0.001 - 0.1 µmol m^{-2} s^{-1}. Actinic and saturating pulse intensities of up to 3,000 and **20,000 µmol m^{-2} s^{-1} respectively can be delivered at the sample surface.

> Data visualisation & analysis:

The measuring LED performance means that 100% raw data is presented with no requirement to damp or average. Robust data visualisation, analysis and export tools allow users to interpret and present findings effectively. Valuable for both teaching complex concepts and conducting in-depth analysis in research applications.

> Fast & slow fluorescence data:

Presents fast and slow fluorescence data with equal emphasis. Fast fluorescence kinetics are captured during every saturating pulse for both dark and light-adapted sample states, believed to be a first for a commercially available chlorophyll fluorometer.

> Comprehensive parameter display:

Parameter sets relevant to the selected routine, are calculated for each saturating pulse. For dark-adapted samples, OJIP parameters in addition to parameters such as Fv/Fm are calculated. Light-adapted parameters including ETR, ΦPSII, Lake and Puddle models for non-photochemical quenching, and both a calculated Fo' and Fo' measured under far-red light are calculated where appropriate.

> Measuring light & actinic/saturating LED colours:

4 variants with different pairings of LED colour. Supplied with either blue/blue (455 nm), red/red (624 nm), blue/white or red/white measuring/actinic and saturating LEDs. All variants contain a far-red LED (730 nm) for determination of Fo' during the quenching analysis routine.

** Depending on optical accessory in use. Up to 0.1 µmol m^{-2} s^{-1} when using dark-adaptation of PTL-100 leafclips. Up to 0.41 µmol m^{-2} s^{-1} when using FMS/LG3 tapered light guide.*

*** Depending on optical accessory in use. Up to 60,000 µmol m^{-2} s^{-1} when using FMS/LG2 tapered light guide and up to 90,000 µmol m^{-2} s^{-1} when using FMS/LG3 tapered light guide.*

Welcome to the FMS-300

FMS-300 is an extremely user-friendly platform to introduce the fundamentals of chlorophyll *a* fluorescence measurements. Newcomers to the technique are quickly able to acquire and analyse data associated with both pulse-modulated (PAM) and fast-fluorescence (OJIP) types of fluorometry. Yet it is also a highly capable research instrument offering flexibility, functionality, and data acquisition of exceptional quality. Primarily a laboratory-based system, FMS-300 can extend to greenhouse and field applications when coupled with an appropriate portable power source.

FluoroControl software

FMS-300 is supplied with a state-of-the-art, sophisticated yet user-friendly, software package, FluoroControl, which features:

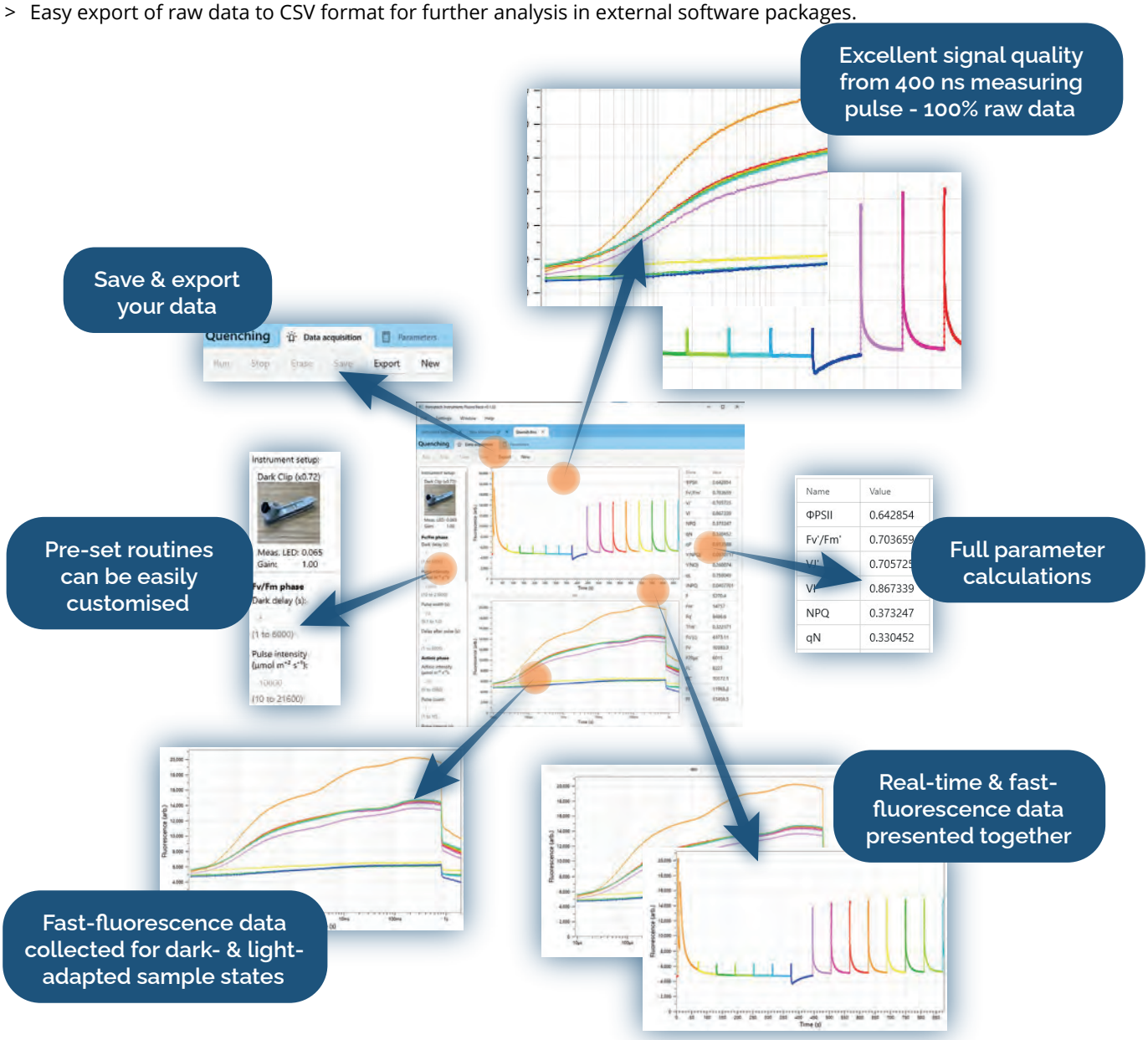
> Simple setup of optimum measuring LED intensity level. LED intensity settings are configured in calibrated µmol m^{-2} s^{-1}, allowing accurate documentation of methods.

> 6 pre-set typical experimental routines, configurable if required. Each routine consists of saturating pulse events with periods of measurement in the dark or under actinic or ambient light conditions. This allows fluorescence yield measurements to be made on all sample types under a wide ranges of environmental conditions.

> Calculation and display of parameters relevant to the selected experimental routine.

> Saving to files that will maintain all graphed displays and routine configuration.

> Easy export of raw data to CSV format for further analysis in external software packages.



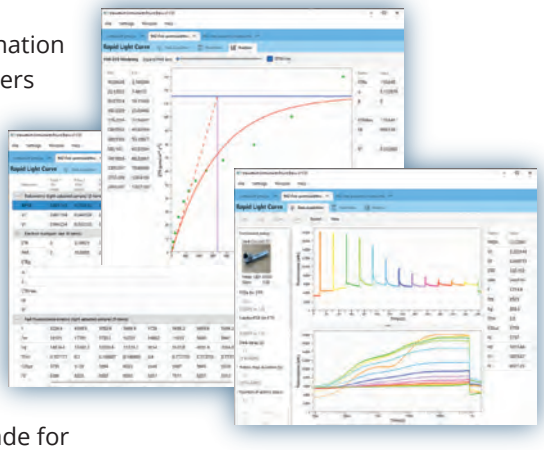
Experimental routines

Routine 1: Maximum QY
This routine provides a measurement of the Fv/Fm parameter; the maximum quantum yield of PSII photochemistry, and a full suite of OJIP (JIP-Test, Strasser et al., 2004) analysis parameters, performed on a dark-adapted sample.

Routine 2: Effective QY
Provides a measurement of the ΦPSII (or Y[II]) parameter from a light-adapted sample at steady-state photosynthetic activity. ΦPSII is an estimation of the effective quantum yield of PSII photochemistry.

Routine 3: Quenching
Performs a full quenching analysis according to the protocol defined in Baker (2008), with estimation of non-photochemical quenching. Parameters for both Puddle and Lake models (Kramer 2004, Hendrickson 2004) are presented along with other data relating to light- and dark-adapted sample states.

Routine 4: Light Response Curve
Analyses the electron transport rate (ETR) parameter for periods of actinic illumination with increasing intensity. The software plots ETR vs PPFD and calculates parameters including maximum ETR (ETRmax) and the minimum saturating irradiance (Ek). Actinic step durations can be lengthened to allow steady-state photosynthesis to be achieved for each light level.



Routine 5: Multi-Maximum QY
Allows successive measurements of dark-adapted Fv/Fm / JIP-Test measurements to be made. Allows comparison of several different samples, replication or screening of, for example, multiple phenotypes.

Routine 6: Multi-Effective QY
Allows successive measurements of light-adapted ΦPSII measurements to be made for comparison, replication or screening applications.

Leafclips and accessories

FMS-300 is optically linked to the sample via a 1 metre randomised fibre-optic cable. Also included is a convenient Manfrotto articulated friction arm to support the fibre-optic cable securely during measurement. The system is supplied with a set of 10 dark-adaptation leafclips and an open leafclip with PAR and leaf temperature sensors allowing samples to be measured under ambient light conditions.

Optional light guides and sample stand

3 light guides made from optical grade, highly polished borosilicate glass are available. These connect to the fibre-optic cable in place of a standard leafclip, to allow measurements in a wide range of specialised applications.

> FMS/LG1: An 8 x 100mm hexagonal light guide suited to e.g. cacti and succulents or insertion into water tanks for measurements on e.g. sea grass or coral.
> FMS/LG2: A 50 mm light guide which tapers to a 4 mm^2 optical area. This amplifies the saturating light intensity by x2 and allows pulses of up to 60,000 µmol m^{-2} s^{-1} for high-light applications. Facilitates measurement of smaller samples such as Arabidopsis. It can also be inserted into liquid samples such as algal or chloroplast suspensions held in vials or in oxygen electrode chambers.
> FMS/LG3: As FMS/LG2 above but tapers to a 2.5 mm^2 optical area which amplifies the saturating light intensity by x3, allowing pulses of up to 90,000 µmol m^{-2} s^{-1}.
> FMS-300/RS: This is a solid oak-base retort stand with laser-etched FMS-300 identity. Supports the articulated friction arm supplied with each FMS-300 system.

A choice of 4 LED colour options

The exceptional signal-to-noise qualities of the FMS-300-B variant make it a natural choice for most applications. More specialised situations, for example, where white light or measurement of cyanobacteria are intended, may benefit from one of the other options detailed below, depending on requirements and sample physiology. See below for details of the available configurations.

<table>
<tr><th>Variant</th><th>Measuring LED</th><th>Actinic & Saturating LED</th><th>Far-red LED</th><th>Fluorescence Detector</th></tr>
<tr><td>FMS-300-B</td><td colspan="2">Blue – 455 nm (FWHM 27 nm)</td><td rowspan="4">730 nm (FWHM 20 nm)</td><td>> 645 nm</td></tr>
<tr><td>FMS-300-R</td><td colspan="2">Red – 624 nm (FWHM 18 nm)</td><td rowspan="3">> 680 nm</td></tr>
<tr><td>FMS-300-BW</td><td>Blue – 455 nm (FWHM 27 nm)</td><td rowspan="2">Ultra-white</td></tr>
<tr><td>FMS-300-RW</td><td>Red – 624 nm (FWHM 18 nm)</td></tr>
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Table 1: LED configurations for each of the 4 FMS-300 variants.

The FMS-300-B is fitted with a different fluorescence detector filter to the other system variants, allowing fluorescence emission above 645 nm to be captured (Figure 2). This provides an extremely low-noise fluorescence signal since it transmits a significant proportion of the 685 nm emission peak. All other variants detect fluorescence above 680 nm (Figure 2).

Blue light is maximally absorbed at the upper surface and does not penetrate deeply into the leaf (Ramos & Lagorio, 2004). Red light penetrates deeper into the leaf inducing fluorescence over the entire cross section although a significant proportion of fluorescence is reabsorbed (Gitelson et al. 1999) resulting in an overall decrease in fluorescence intensity. Blue induced fluorescence is emitted from the surface of the leaf only with very little re-absorption resulting in a higher fluorescence intensity and a strong, low noise fluorometer signal (Ramos & Lagorio, 2004).

The use of blue excitation light wouldn't be suitable for some experiments. Cyanobacteria contain specialised antennae known as phycobilisosomes (PBSs) which are not thought to absorb blue light. Therefore, cyanobacteria have a reduced photosynthetic efficiency under blue light (Luimstra et al. 2018) and the use of a red excitation light would be applicable.

The emission characteristics of each LED relative to the absorption characteristics of chlorophyll *a* are shown in Figure 1. Figure 2 shows the fluorescence detection characteristics relative to the chlorophyll fluorescence emission spectrum for each variant of FMS-300.

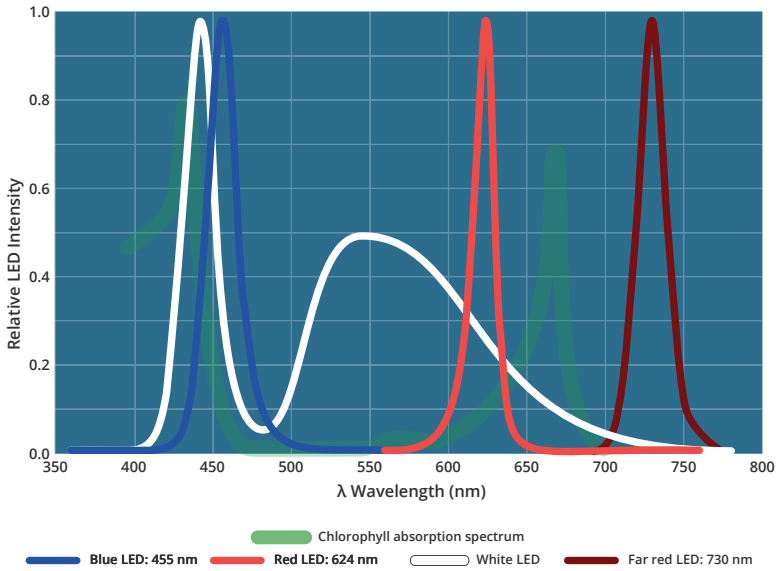

Figure 1: Emission characteristics of FMS-300 LEDs relative to the chlorophyll a absorbance spectrum.

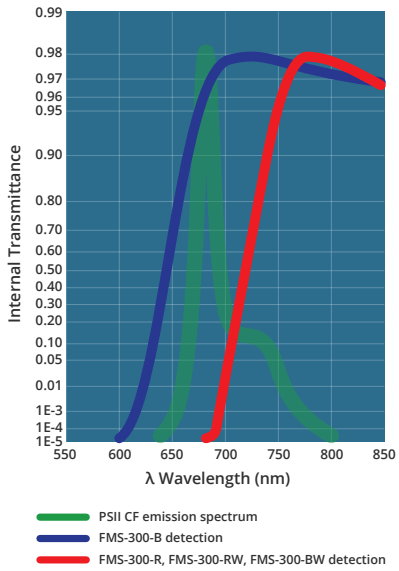

Figure 2: Detector characteristics of FMS-300 variants relative to the chlorophyll a emission spectrum.

Technical Specifications

All light intensity specifications refer to incident illumination at the sample surface.

Control Unit

Measuring LED:	Pulse width: 400 nanoseconds. Pulse frequency: Slow kinetics: 10 Hz. Fast kinetics: Semi-log frequencies from 10 Hz-100 kHz.
Pulse intensity:	Up to 0.1 µmol m^{-2} s^{-1}. Adjustable in 0.001 µmol m^{-2} s^{-1} increments. With light guide, FMS/LG2: >0.25 µmol m^{-2} s^{-1}. With light guide, FMS/LG3: >0.4 µmol m^{-2} s^{-1}.
Measuring LED colour:	FMS-300-B/BW: Blue 455 nm (FWHM 27 nm). FMS-300-R/RW: Red 624 nm (FWHM 18 nm).
Actinic intensity:	Up to 3,000 µmol m^{-2} s^{-1}. Adjustable in 1 µmol m^{-2} s^{-1} increments. With light guide, FMS/LG2: >8,000 µmol m^{-2} s^{-1}. With light guide, FMS/LG3: >12,000 µmol m^{-2} s^{-1}.
Actinic LED colour:	FMS-300-B: Blue 455 nm (FWHM 27 nm). FMS-300-R: Red 624 nm (FWHM 18 nm). FMS-300-BW/RW: Ultra-white.
Sat. pulse intensity:	>20,000 µmol m^{-2} s^{-1}. Adjustable in 1 µmol m^{-2} s^{-1} increments. With light guide, FMS/LG2: up to 60,000 µmol m^{-2} s^{-1}. With light guide, FMS/LG3: up to 90,000 µmol m^{-2} s^{-1}.
Saturating LED colour:	FMS-300-B: Blue 455 nm (FWHM 27 nm). FMS-300-R: Red 624 nm (FWHM 18 nm). FMS-300-BW/RW: Ultra-white.
Far-red LED:	730 nm (FWHM 20 nm). Intensity >20 µmol m^{-2} s^{-1}. With light guide, FMS/LG2: up to 60 µmol m^{-2} s^{-1}. With light guide, FMS/LG3: up to 90 µmol m^{-2} s^{-1}.
Detector:	PIN photodiode, rapid peak-pulse tracking.
Detection range:	FMS-300-B: >645 nm. FMS-300-R/BW/RW: >680 nm.
Electronics:	Dual processors: ARM 32-bit microcontroller running real-time operating system. PIC 8-bit microcontroller for dedicated measuring LED sampling.
Fibre-optic cable:	Length 1 m, statistically randomised fibre bundles, 7mm optical diameter at sample end.
Connections:	Optical connection for fibre-optic cable, 12 V DC socket, USB-C socket, MiniDIN socket for PTL-100.
Enclosure:	Shielded aluminium enclosure.
Dimensions:	150 (l) x 150 (w) x 85 mm (d). Weight 770g.
Communications:	USB 2.0. Cable type A - C.
Operating conditions:	0°C-40°C. Non-condensing humidity.
Power supply:	12 V DC mains power.
Power consumption:	5.6-7.2 W. Max. 50 W.
Display:	4 line x 20 character blue LCD display.

Options/Accessories

FMS/DLC: Additional pack of 10 dark-adaptation leafclips.
FMS-300/RS: Solid oak base retort stand with laser engraving.
FMS/LG1: 100 x 8mm hexagonal light guide.
FMS/LG2: 50mm x 8 - 4mm tapered light guide (x2 light intensities).
FMS/LG3: 50mm x 8 - 2.5mm tapered light guide (x3 light intensities).

Leafclips & Accessories

FMS/DLC:	Nylon 3D printed, 7 mm sample aperture, sliding shutter blade, 60° angle to between fibre-optic & sample.
PTL-100:	Nylon 3D printed, leaf temp. & PAR (400-700 nm) sensor. Electrical connection to FMS-300. Open faced, 60° angle to between fibre-optic & sample.
Manfrotto arm:	Mini Variable Friction Arm. 0.44kg, length: 12-24 cm, max. payload: 3 kg.
Manfrotto clamp:	Nano Clamp. 0.097 kg. clamp range 13-35mm, max. payload: 4 kg.
Transport case:	464 (l) x 366 (w) x 176 (d) mm. Weight: ~3 kg.

Software requirements

Operating System: Windows 10 or newer.

Supplied with

FMS-300 control unit.
Fibre optic cable.
PTL-100 PAR temperature leafclip.
FMS/DLC pack of 10 dark-adaptation leafclips.
Fibre optic cable support arm & clamp.
12 V DC Power supply.
USB A - C connection cable.
Transport case.

References

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Luimstra, Veerle M., et al. "Blue light reduces photosynthetic efficiency of cyanobacteria through an imbalance between photosystems I and II." Photosynthesis Research 138 (2018): 177-189.

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