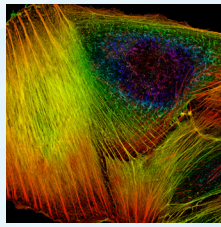
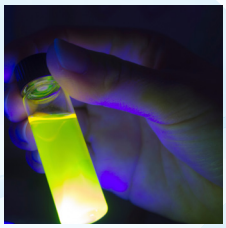
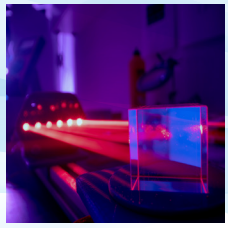
HORIBA
Scientific

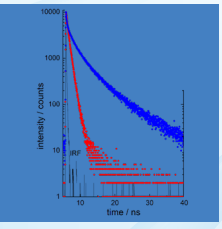
DeltaFlex™

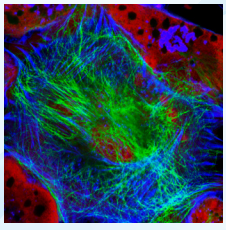
TCSPC/MCS Fluorescence Lifetime System











Ultimate performance
and flexibility for lifetimes
from 5 ps to seconds

fluorescence.com

JOBIN YVON
Technology

DeltaFlex™

Ultimate TCSPC/MCS Performance and Flexibility for Lifetimes From 5 Picoseconds to Seconds

The HORIBA DeltaFlex system is the Time-Correlated Single Photon Counting (TCSPC) system of choice for the measurement of fluorescence lifetimes from picoseconds to seconds. Taking advantage of more than 45 years of TCSPC innovation, it is a complete fluorescence/phosphorescence system designed and optimized with innovative pulsed lasers and LEDs, timing electronics, detectors and sample handling components, all powered by HORIBA's highly intuitive and extremely powerful EzTime™ touchscreen software interface.

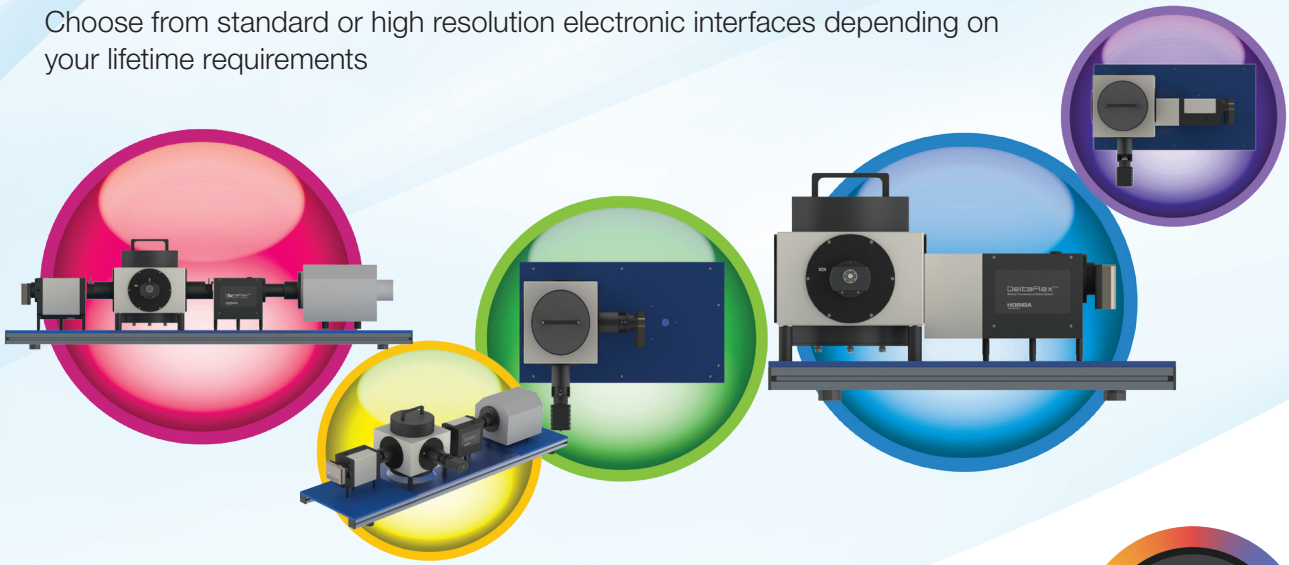
Unique Benefits from a Lifetime in Fluorescence

- Flexibility to meet any requirement
- Better user experience with automated component recognition and control
- Extensive choice of sources and detectors to meet all wavelength and lifetime requirements
- EzTime intuitive, automated, touchscreen software

DeltaFlex: Flexibility is in the name, and flexibility is in the design

The modular DeltaFlex system is comprised of a choice of the following main components:

- Optical configuration
  Choose from filters or monochromators and single detector (L format) or simultaneous dual detector (T Format)
- Excitation sources
  Choose from a plethora of pulsed lasers and LED sources
- Detection modules
  Choose from a wide range of dedicated TCSPC detectors depending on your emission wavelength range, lifetime requirements and budget
- Timing electronics
  Choose from standard or high resolution electronic interfaces depending on your lifetime requirements

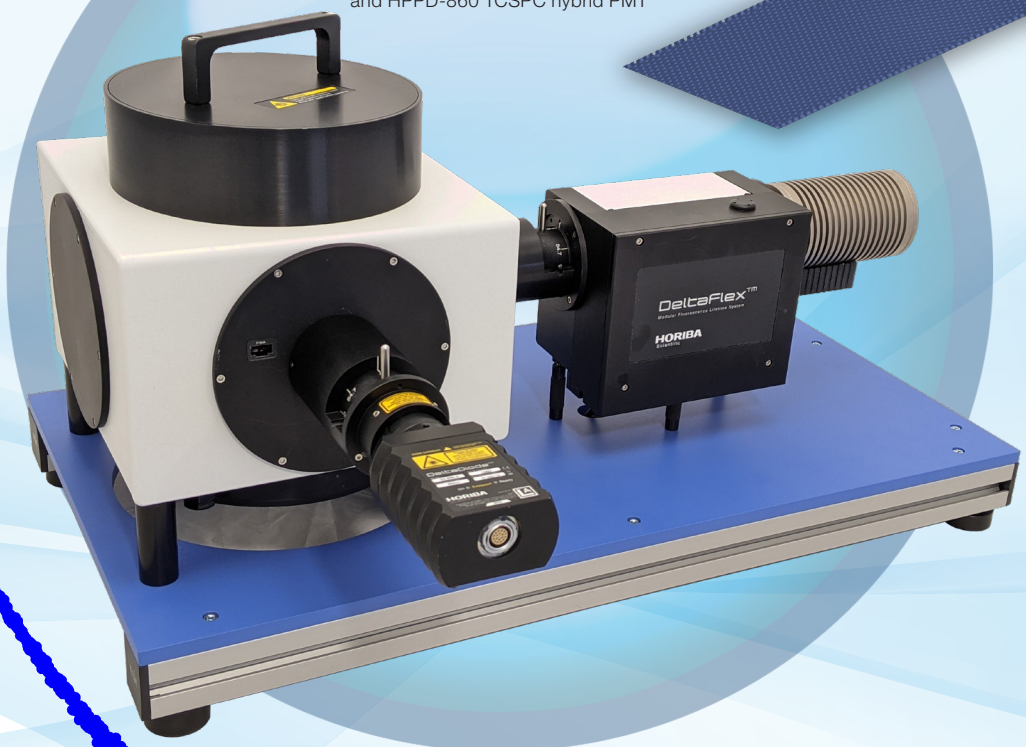


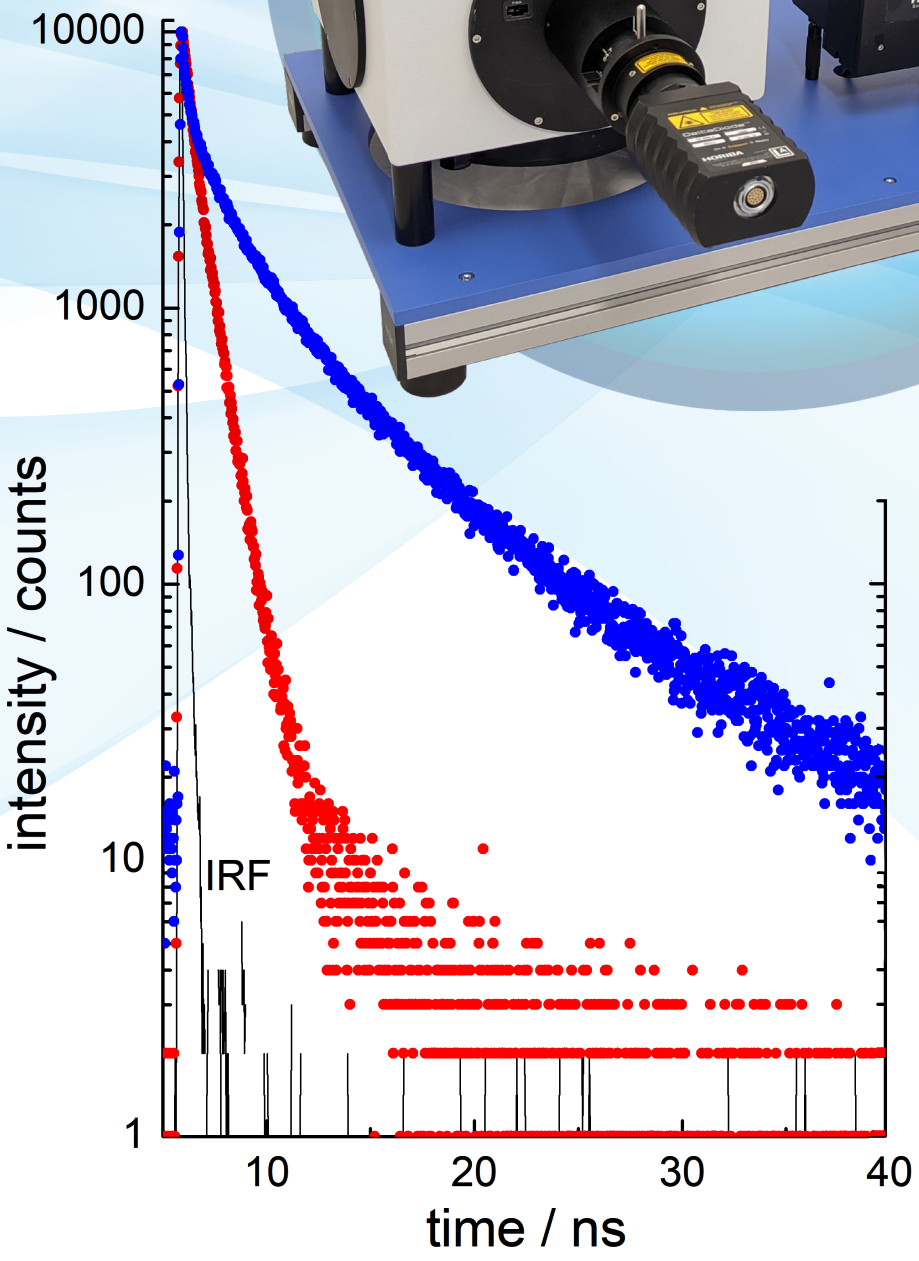
All DeltaFlex systems are controlled using EzTime software which provides for full instrumentation control and acquisition, as well as a comprehensive suite of data analysis modules for fluorescence and phosphorescence lifetime determination, decay associated spectra (DAS), time-resolved anisotropy and uncorrected steady state emission spectra (if equipped with a scanning emission monochromator).

A Lifetime in Fluorescence

More than 45 Years of TCSPC Innovation

DeltaFlex-01
High perfomance TCSPC platform
with 100 MHz DeltaDiode laser,
TDM-850 emission monochromator,
and HPPD-860 TCSPC hybrid PMT





Fluorescence in Industry, Chapter 3; ***Instrumentation for Fluorescence Lifetime Measurement Using Photon Counting.*** **Part of the Springer Series on Fluorescence book series (SS FLUOR, volume 18)**

DeltaFlex TCSPC/MCS Applications

The DeltaFlex Covers the Broadest Range of Luminescence Research

Materials Research • Earth Sciences • Chemistry • Food Science • Life Sciences

DeltaFlex Modularity

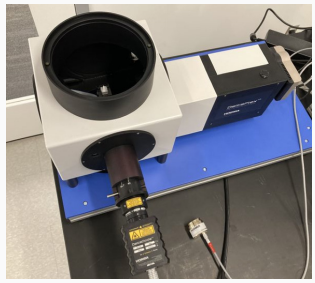
Flexible Optical Design to Create the Perfect System for You

Choose these:

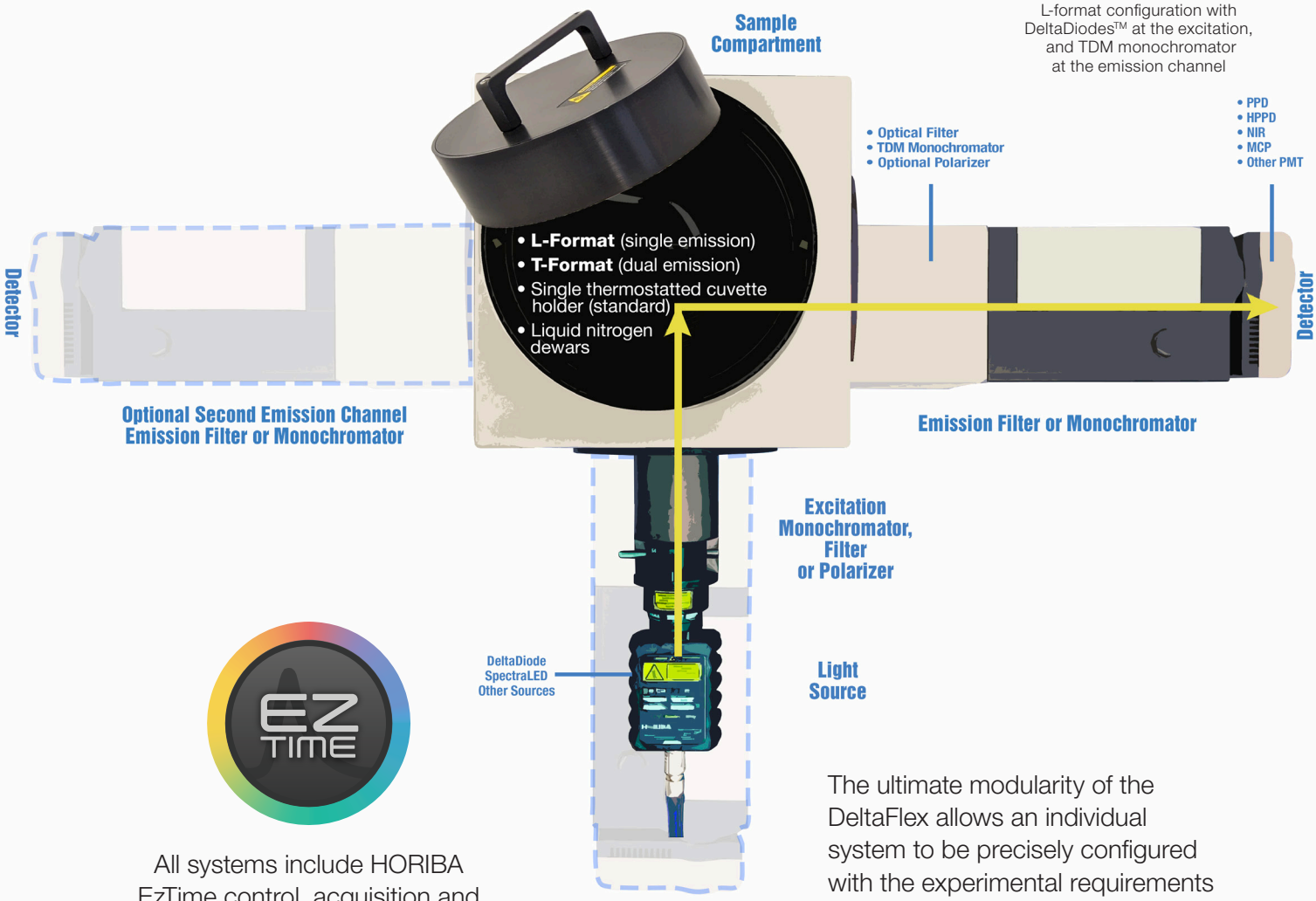
- Sample Compartment
- Light Source
- Detectors
- Emission Filter or Monochromators

Then configure to your needs with these options:

- 4 position thermostatted cuvette holder
- Solid sample holders
- Thermo-electric cuvette holders
- Cryostats
- Liquid nitrogen dewars



Example: DeltaFlex-01 in L-format configuration with DeltaDiodes™ at the excitation, and TDM monochromator at the emission channel



All systems include HORIBA EzTime control, acquisition and analysis software.

The ultimate modularity of the DeltaFlex allows an individual system to be precisely configured with the experimental requirements of any particular research lab.

The measurable lifetime range, as well as the excitation and emission wavelengths of any DeltaFlex configuration, depends on the specific light sources, detector and timing electronics selected.

DeltaFlex TCSPC Excitation Sources

Choose from a Variety of Excitation Light Sources to Suit your Experimental Requirements

Pulsed Light Sources

DeltaDiode Lasers (denoted with L): 35 to 100 ps, 10 kHz to 100 MHz
DeltaDiode Lasers (denoted with LB): 35 to 100 ps, 10 kHz to 25 MHz
DeltaDiode LEDs: 750 to 950 ps, 10 kHz to 25 MHz

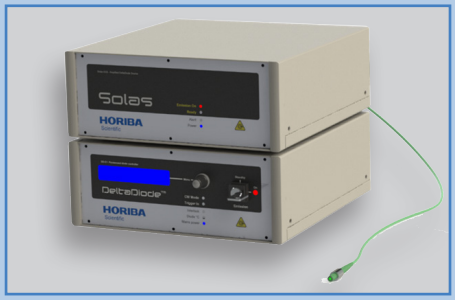
Over 50 DeltaDiodes emitting from UV to Near IR

- DeltaDiode-265, 285, 310, 325, 340, 360, 370, 455, 375L, 375LB, 390, 395L, 395LB, 405L, 405LB, 415L, 420LB, 425L, 440L, 440LB, 450L, 450LB, 470L, 470LB, 485L, 485LB, 495L, 510L, 510LB, 532LN, 560LN, 595LN, 635L, 635LB, 650L, 650LB, 670L, 670LB, 730L, 730LB, 785L, 785LB, 830L, 830LB, 980L, 980LB, 1060L, 1060LB, 1310L, 1310LB

SpectraLED LED sources for Phosphorescence Lifetimes (adjustable pulse duration)

SpectraLEDs emitting from UV to Near IR

- SpectraLED-265, 285, 310, 325, 340, 355, 370, 390, 415, 460, 495, 525, 560, 590, 605, 625, 740, 830, 970, 1200, 1275



High power Solas fiber laser (80 to 100 ps, on demand to 100 MHz)

- Solas-355L or 532L or 1064L

Other Lasers

- Super-continuum laser (requires excitation monochromator)
- Ti-sapphire laser
- Customer supplied laser

Excitation Source: DeltaDiode™

Ultimate Short-pulsed, Picosecond Lasers and LEDs from 265 to 1310 nm

DeltaDiode laser and LED sources offer plug and play ease of use while delivering excellent performance and reliability for the most demanding TCSPC experiments. With available wavelengths from the UV to the NIR, these picosecond sources can operate at rates up to 100 MHz. Each DeltaDiode laser has thermoelectric temperature control for individual optimization, and they are all controlled by a common DeltaDiode-C1 control module that is interfaced to EzTime software.

DeltaDiode laser connected to DeltaDiode controller

True Plug and Play Diodes

These plug and play lasers feature smart technology that fully communicates with EzTime software, allowing you to seamlessly and instantaneously switch from one diode to another. All calibration settings for each DeltaDiode head are stored in that head during factory calibration, and are subsequently read back by the DeltaDiode controller when connected. These settings are then used by EzTime software (via USB) to optimize the brightness and pulse profile of the DeltaDiode for any repetition rate requested by the operator. Once you connect the DeltaDiode to the diode controller, HORIBA's TCSPC software 'knows' how to drive that particular source, at any repetition rate. You only need one controller for all of your DeltaDiodes, and there is absolutely no operator intervention, such as a registration process, to optimize performance when switching from one source to another. The repetition rate is automatically optimized to suit the sample.

DeltaDiode Benefits

- Up to 100 MHz repetition rate for faster acquisitions
- Measure lifetimes down to 5 ps (depending on detector and electronics selected)
- True interchangeable plug and play switch from wavelength to wavelength
- One DeltaDiode-C1 controller works with all DeltaDiode sources
- Burst mode allows for measurement of long-lived phosphorescence lifetimes
- Over 30 wavelengths to choose from, between 265 and 1,310 nm
- DeltaDiode "LB" models are more affordable than their "L" counterparts and operate at repetition rates up to 25 MHz
- Continuous mode available for some models

DeltaDiode Specifications

DeltaDiode heads are manufactured with either laser diodes, or LEDs as their primary sources. Laser diodes offer shorter pulse durations, brighter intensities and operate at faster repetition rates than the LED versions. DeltaDiodes with a laser diode source are denoted with an L, or LB, in the part number, such as the DeltaDiode-370L.

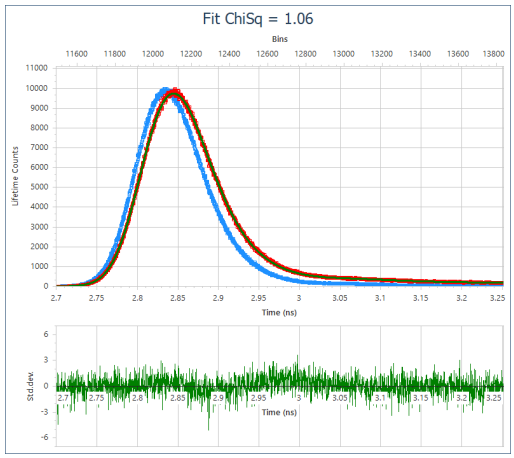
DeltaDiode General Specifications

DeltaDiode Type	Pulse Duration	Repetition Rate	Available Wavelengths
DeltaDiode Laser (Denoted with an "L" on part number)	35 to 200 ps	10 kHz to 100 MHz	375 to 1,310 nm
DeltaDiode LED (No "L" on part number)	750 to 950 ps	10 kHz to 25 MHz	265 to 455 nm

HORIBA Scientific has a policy of continuous product development, and reserves the right to amend part numbers, descriptions and specifications without prior notice.

DeltaFlex with DeltaDiode Lasers for Short Picosecond Lifetimes (> 5 ps)

DeltaDiode lasers are an excellent choice for short picosecond lifetimes, with pulse durations as short as 35 picoseconds. These sources have the possibility of measuring fluorescence lifetimes down to 5 ps (1/10th of the instrument response function), with a fast HPPD detector and the high resolution FiPho-HR electronics selected.



Beetroot extract average lifetime less than 20 ps excited using a Solas-532L with emission at 602 nm.

DeltaDiode Controller Specifications

	Function	Specification
DD-C1 Controller	Repetition Rates	10 kHz, 20 kHz, 50 kHz, 100 kHz, 250 kHz, 500 kHz, 1 MHz, 2 MHz, 4 MHz, 5 MHz, 8 MHz, 10 MHz, 16 MHz, 20 MHz, 25 MHz, 50 MHz, 80 MHz, 100 MHz, or Trigger Input (single-shot to 50 MHz). Subject to attached head
	Trigger Input	Pulse amplitude +0.5 V to +5 V, trigger threshold software programmable from +0.2 V to +2 V, 50 Ω, 20 ns minimum spacing
	Sync Outputs	Simultaneous output of NIM-compatible (-0.8 Vpp 50 Ω) and TTL-compatible (+2 Vpp 50 Ω), automatic width selection 4-15 ns nominal
	Sync Delay Control	Adjustment of sync output pulse timing in range -10 ns to +10 ns nominal in 1 ns steps, uncalibrated
	Fast Gate Input	Pulse amplitude +0.5 V to +5 V, trigger threshold software programmable from +0.2 V to +2 V, 50 Ω. Selectable Inhibit/Enable modes
	Slow Gate Input	Pulse amplitude +2 V to +5 V. 10 kΩ. Selectable Inhibit/enable modes. Operates in Pulsed and CW modes
	Interlock	2-pin connector (included). Contacts must be short-circuited to enable emission
	Connection to Head	1.5 m cable (included)
	User Interface	LCD display (stand-alone operation) or software (PC control)
	PC interface	USB 2.0 with integral hub for downstream connection to other USB peripherals (cable to host PC and software supplied)
	Power Requirement	90 V to 250 V AC, 50/60 Hz, 100 VA
	Operating Temperature	+15˚ C to +30˚ C (ambient)
	Weight & Dimensions	3.1 kg, 234 x 255 x 92 mm

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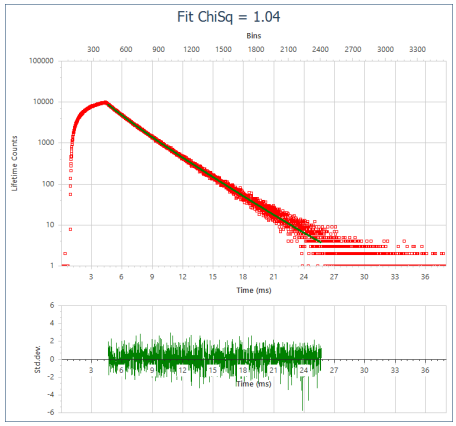
DeltaDiode Detailed Specifications

Refer to DeltaDiode Specifications Sheet for detailed wavelength and performance specifications of all currently available sources.

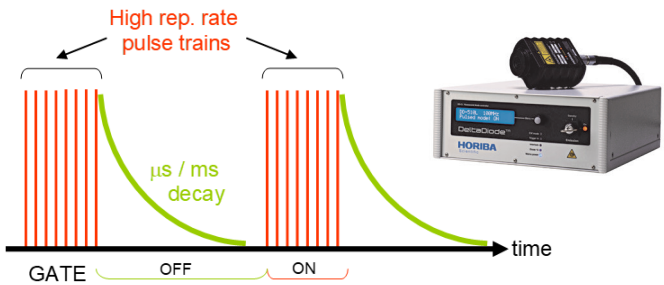
"Burst Mode" Allows a Single DeltaDiode Laser to Measure Lifetimes from Picoseconds to Seconds

Normally a picosecond pulsed laser is useless for long-lived phosphorescence lifetimes since the event is orders of magnitude longer than the laser's very short pulse duration. However, all DeltaFlex lasers can be operated in a burst mode under software control from EzTime software. This allows these very short-pulsed picosecond lasers to also be used for long phosphorescence lifetimes when using the MCS mode of the electronics module. In this way you do not have to purchase a different, longer duration pulsed light source, like SpectraLED or a pulsed xenon lamp for phosphorescence measurements.



Lanthanide (Terbium) in glass matrix fitted to a 2 exponential decay model average lifetime of 2.4 ms using DeltaDiode-375L in burst mode with emission at 545 nm, detected with HPPD-860.

Burst mode works by increasing the repetition rate of the laser to its maximum value of 100 MHz (or 25 MHz depending on the laser selected). This "train of pulses" can then be "gated" on and off. Since the lifetime emissions studied using this technique are long-lived, to the sample it will appear like a continuous excitation pulse. The duration of the gated pulse is software controlled allowing for optimization of sensitivity and lifetime range.



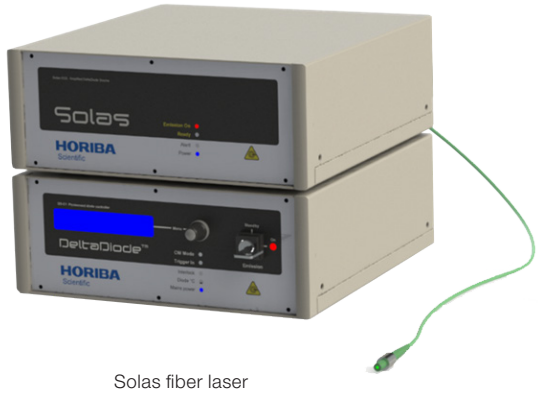
Train of DeltaDiode laser pulses can be adjusted to create a super pulse for long-lived lifetimes.

Excitation Source: DeltaDiode Solas™ MOFA Fiber Laser

Solas is a new high-power, picosecond, fiber laser from HORIBA based on a Master Oscillator Fiber Amplifier (MOFA) design.

With a master oscillator generating over 300 mW of power at 1064 nm at 100 MHz, Solas can be configured to deliver either 1064 nm, 532 nm or 355 nm laser pulses.

As with all DeltaDiodes, the Solas can be operated at up to 100 MHz, with pulse configurations including pulse on demand and burst mode. The Solas allows for software-controlled intensity adjustment from 100% to 10% of full output power (in 10% increments).



Solas fiber laser
with DeltaDiode-C1 controller

As with our entire DeltaDiode series sources, no tweaking is required when the software changes the repetition rate, and the same DeltaDiode-C1 controller can be used across the entire family of DeltaDiode sources, including the Solas.

Solas MOFA Fiber Laser Specifications

Parameter	Solas 355L	Solas 532L	Solas 1064L
Power	> 7 mW at 80 MHz	> 30 mW at 80 MHz	> 300 mW at 80 MHz
Power Stability	0.5% RMS over 10 min		
Pulse duration	80 to 100 ps (FWHM)		
Spectral Width	< 0.2 nm		< 0.4 nm
Resolution Rate	Pulse on demand to 100 MHz		
Pointing Stability	< 1 µrad		
Polarization Extinction Ratio	> 20 dB		
Beam Quality	Multi-mode fiber output	Circular TEM00 beam	

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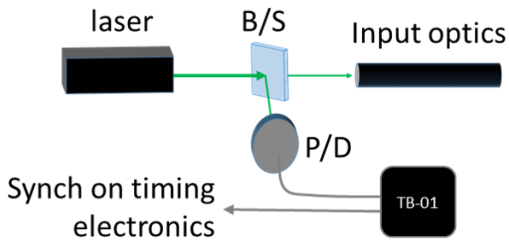
Excitation Source: 3rd Party Femtosecond and Super-continuum Lasers

The DeltaFlex system can be configured to work with customer supplied pulsed lasers such as Ti-sapphire lasers or broadband super-continuum lasers. Femtosecond lasers provide the ultimate in short lifetime detection when used with fast detectors (MCP or HPPD). Super-continuum lasers offer a continuum of wavelengths that can be selected when light is passed through an excitation monochromator. Optical coupling can be made via an excitation monochromator or sample chamber input optics.

Figure #: Use your pulsed laser as an excitation source for the DeltaFlex.

If your laser does not feature a synchronization output, it can be optically interfaced using a custom beam splitter (B/S) and a fast photodiode (P/D). A TB-01 module converts the P/D output for connection to the FiPho electronic interface. The TB-01 can also convert any non-NIM signal to NIM.



Electronic synchronization
direct from laser/pulse picker.

Please consult with HORIBA for compatibility requirements and expected performance of your laser with the DeltaFlex.

Excitation Source: SpectraLED™

Innovative and Affordable Pulsed Light Source for Phosphorescence Measurements from Deep UV to NIR

The SpectraLED is a novel light source designed specifically for the measurement of phosphorescence lifetimes. These phosphorescence sources are based on LED technology and there are many to choose from that emit at specific wavelengths from the deep UV to the NIR.

The SpectraLED is a modern approach to measuring longer lived luminescence decays, with software adjustable pulse duration and repetition rates to optimize long lived decay measurements.

SpectraLED sources are available at many discrete wavelengths and require no dedicated controller interface.

SpectraLED Benefits

- Software-controlled pulse duration from < 250 ns to > 10 s
- Wavelength selections from 265 to 1,275 nm
- Sharper and cleaner temporal pulse profile than pulsed Xe lamp
- Collect lifetimes up to 100x faster than a traditional pulsed Xe lamp

SpectraLED Specifications

	Pulse Duration	Repetition Rate	Available Wavelengths
SpectraLED	< 250 ns to > 10 s	0.1 to 100 kHz	265 to 1,275 nm

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Excitation Source: SpectraXE™

Broadband Pulsed Xenon Lamp for Phosphorescence Measurements from Deep UV to NIR

The SpectraXE is a pulsed xenon lamp source offering broadband and white light output from the UV to the NIR, with 2 watts of average power delivered in a 0.4 microsecond pulse duration. The SpectraXE requires either a filter or an excitation monochromator for wavelength selection.

SpectraLED sources require no dedicated controller interface.

SpectraXE Benefits

- Broadband white light source that requires a filter or excitation monochromator for wavelength selection.
- Computer control of repetition rate up to 80 Hz
- 0.4 microsecond pulse duration
- Connects directly to FiPho TCSPC Controller

SpectraXE Specifications

	Pulse Duration	Repetition Rate	Available Wavelengths
SpectraXE	0.4 µs	0.1 Hz to 80 Hz	185 to 2,000 nm

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Sample Compartment Options

Wide Range of Sample Accessories

The DeltaFlex comes standard with a single cuvette holder with integrated temperature sensor and stirrer, and motorized autofocusing optics for signal optimization, and there are a number of optional sample holders to choose from.

Sample holder options with DeltaFlex

Sample Accessories

- Four position cuvette holders
- Front surface sample holders
- Liquid nitrogen dewars
- Peltier cuvette holders
- Stopped-flow accessory
- Cryostats (liquid nitrogen, helium and closed loop)

Emission Wavelength Selection

Choice of Filters or Time-Domain Monochromators

Bandpass and long pass filters are often used for emission wavelength selection for TCSPC detection. For greater flexibility, the DeltaFlex offers purpose-built time-domain monochromators (TDM), allowing for the easy adjustment of wavelength and bandpass.

TDM-800 time-domain monochromator

Emission Filtering Options

TDM Monochromator

TDM-800, (200 to 800 nm)
TDM-850, (200 to 850 nm)
TDM-1200, (300 to 1,200 nm)
TDM-1600, (400 to 1,600 nm)

Optical Filters

Selection of bandpass or long pass filters placed in 2" square filter holders

Time Domain Monochromators (TDM)

Designed for the Most Demanding Short Lifetime Measurements

Providing excellent stray light rejection and a time-dispersion of just 0.13 ps/nm, HORIBA TDM monochromators are designed with a Seya-Namioka geometry and feature an integral safety shutter interlocked to the sample compartment, computer-controlled adjustable slits and wavelength drive.
The temporal dispersion of the HORIBA TDM monochromators are such that they can even be used for the shortest fluorescence lifetime detection down to 5 picoseconds when used with the appropriate laser, detector and electronics, as outlined below.

HORIBA TDM Monochromators can Measure Fluorescence Lifetimes Down to 5 Picoseconds!

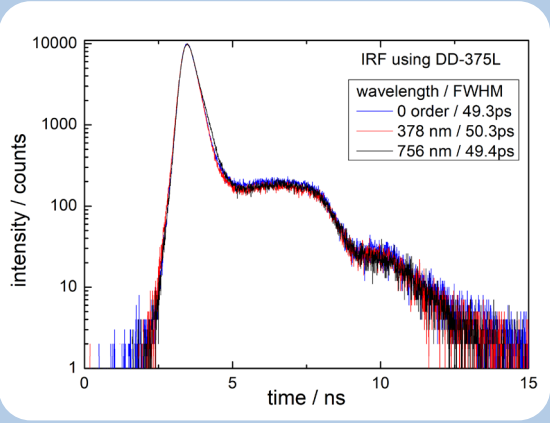
When measuring short-lived fluorescence decays, it is important to select components and electronics with the fastest time responses possible. Measuring the optical profile of a scattering sample will yield a system's temporal response. It is the full width at half maximum (FWHM) of the instrument response function (IRF) that will determine the shortest lifetime that can be measured with a particular TCSPC system. As a rule of thumb, fluorescence lifetimes can be determined down to ~ 10% of the IRF FWHM by using reconvolution.

The measured IRF width depends on factors such as (in approx. order of importance):

1. Optical pulse width of light source (FWHM)
2. Detector transit time spread (TTS)
3. Electronic jitter in the timing electronics (FWHM)
4. If used, the optical time-dispersion of a monochromator (ps/nm)

TDM achieves low time dispersion with one Jobin Yvon grating resulting in fewer optical losses compared to a double subtractive monochromator.

As you can see, the DeltaFlex has been designed for the most demanding short lifetime measurements.



Instrument response time of a DeltaFlex equipped with DeltaDiode-375 laser, MCP-PMT detector, timing electronics and TDM-800 monochromator. Note that due to the excellent optical characteristics of the TDM monochromator, there is virtually no difference in the IRF when measured at 0 order, 378 nm or 756 nm. This measured IRF of 50 ps corresponds to a minimum lifetime determination of 5 ps, using the 10% rule of thumb.

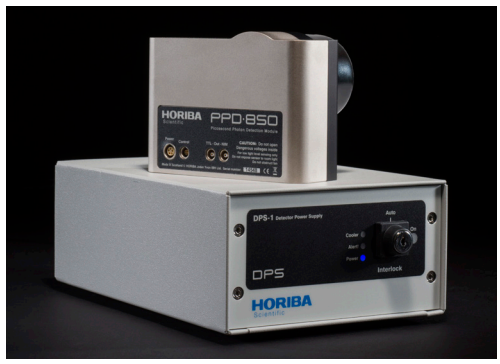
TCSPC Detectors

Single Photon Detection with Picosecond Accuracy from Deep UV to NIR

PPD™ Picosecond Photon Counting Detectors

The PPD Series is a range of miniaturized, cooled, single-photon counting detectors containing all the electronics necessary to detect single photons with picosecond accuracy. Each module contains a fast rise-time photomultiplier tube (PMT), a GHz pre-amplifier, a constant fraction discriminator (CFD), a regulated high voltage supply and a thermoelectric cooler. These detectors are compact, fully integrated, and factory optimized modules made of precision milled, nickel-plated casings to provide the highest level of electromagnetic shielding and stability.

The PPD series offers very high time-resolution at an affordable price. When used in time-resolved fluorescence applications, lifetimes as short as 20 ps can be resolved using reconvolution. This makes the PPD not only an ideal time resolved detector, but also suitable for phosphorescence and general spectroscopic applications.



PPD-850 detector shown with DPS-1 detector power supply.

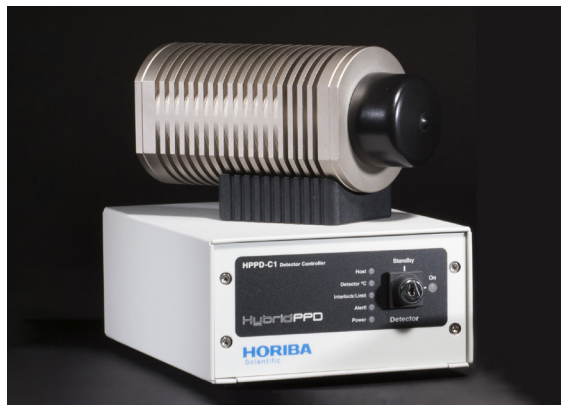
Available PPD Models

• PPD-650: 230 to 700 nm (uncooled) • PPD-850: 230 to 850 nm (cooled) • PPD-900: 230 to 920 nm (cooled)

HPPD™ Picosecond Photon Counting Detectors

The HPPD (Hybrid Picosecond Photon Counting) detectors are our latest development in TCSPC detector technology that combines the benefits of conventional PMT design (wide spectral response and large active area) with the advantages of solid state APD technology (exceptional temporal resolution, good detection efficiency and negligible after-pulsing).

Similar to the PPD, HORIBA HPPD detectors include pre-amplifier, a constant fraction discriminator, and temperature stabilization, all in a shielded detector housing.



HPPD-860 detector module shown with HPPD-C1 detector controller.

HPPD Benefits

- 5 ps lifetime resolution
- High quantum efficiency (QE)
- Reduced afterpulsing resulting in better decay residuals
- Peltier temperature controlled for stability
- Fully shielded design

HPPD Specifications

Model	Wavelength Range	Temporal Response (IRF FWHM)	Dark Count	Quantum Efficiency
HPPD-650	220 to 650 nm	50 ps	< 100 cps	28% (340 nm)
HPPD-720	300 to 720 nm	120 ps	< 1000 cps	47% (530 nm)
HPPD-860	220 to 860 nm	50 ps	< 200 cps	23% (280 nm)
HPPD-870	300 to 870 nm	130 ps	< 500 cps	26% (630 nm)
HPPD-890	380 to 890 nm	160 ps	< 1000 cps	16% (630 nm)

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We recommend the HPPD-860 for most fluorescence lifetimes research due to the excellent TTS of < 50 ps, enabling the determination of lifetimes to the limit of TCSPC (~5 ps). For FLIM applications, we would recommend the HPPD-720 because of its high QE, allowing for the efficient collection of photons.

For most applications, an HPPD detector is an excellent alternative detector to a Microchannel Plate PMT (MCP-PMT). HPPD detectors are, in particular, less fragile than the standard MCP PMT, which can be easily damaged by high level illumination.

MCP-PMT Detectors

Microchannel plate (MCP) photomultiplier tubes (PMT) have been extensively used in the past to measure the shortest possible fluorescence lifetimes.

With typical transit time spreads of 25 picoseconds, they represent the fastest detectors available for TCSPC detection, however the introduction of hybrid picosecond photon counting detectors (HPPDs) has replaced the need for the MCP-PMT.

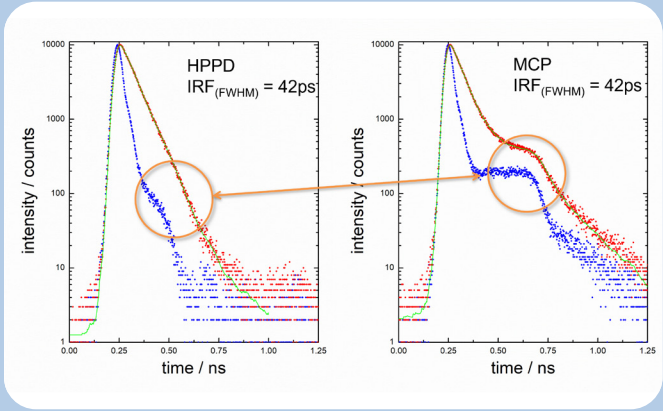
MCP-50S MCP-PMT detector with PHV-5 precision high voltage controller and CFD-2G amplifier and discriminator module.

HORIBA HPPD is an Excellent Alternative to Micro-Channel Plate PMT (MCP-PMT)

HPPD versus MCP-PMT

HPPD detectors offer a more affordable alternative to a traditional MCP-PMT for ultra-short fluorescence lifetime measurements.

Shown below is a comparison of DASPI (τ ~ 42ps lifetime) acquired on a DeltaFlex-01-DD equipped with DeltaDiode-405L, and FiPho-HR with an HPPD-860, versus an MCP-PMT. Although both detectors, HPPD and MCP, are able to measure the same fast Instrument Response Function (IRF) of 42 ps (FWHM), the response measured on the MCP has a more prominent afterpulse which can make it more difficult to measure shorter lifetimes.



Comparison of DASPI decay data with HORIBA HPPD (left) and MCP (right).

	HPPD-860	COOLED MCP-PMT (R3809-50)
Typical IRF FWHM at 400 nm	40-45 ps	40-45 ps
Shortest Measurable Lifetime	5 ps (lower afterpulse)	5 ps
Wavelength Response	220-860 nm	160-850 nm
Robust for Steady State Spectra	Yes	No
Amplifier + CFD	Integrated (no cable)	External
High Voltage Bias	Integrated (no cable)	External
Compatible with Phos and Steady State	Yes	No (requires second detector)
Temperature Control	Integrated TEC (air-cooled)	External (water-cooled)
Dark Count Rate (Cooled)	< 200 cps	< 20 cps
PC Interface	USB	N/A

HORIBA Scientific has a policy of continuous product development, and reserves the right to amend part numbers, descriptions and specifications without prior notice.

NIR TCSPC Detectors to 1,700 nm

There are a number of NIR photon counting PMT detectors and NIR SPAD detectors available for the DeltaFlex that allow for TCSPC lifetime detection in the NIR up to 1,700 nm.

Some options for extended NIR TCSPC detection for nanosecond or shorter fluorescence lifetimes are given below. Other options are available upon request.

NIR TCSPC Specifications

Model	Sensor	Wavelength Range	Temporal Response	Dark Count	Cooling
NIR-R4	R5509-43 PMT	300 to 1,400 nm	1.5 ns (TTS)	< 25,000 cps	Liquid nitrogen
NIR-R7	R5509-73 PMT	300 to 1,700 nm	1.5 ns (TTS)	< 250,000 cps	Liquid nitrogen
NIR-H2	H10330-25 PMT	950 to 1,200 nm	400 ps (TTS)	< 2,500 cps	Thermo-electric
NIR-H4	H10330-45 PMT	950 to 1,400 nm	400 ps (TTS)	< 25,000 cps	Thermo-electric
NIR-H7	H10330-75 PMT	950 to 1,700 nm	400 ps (TTS)	< 250,000 cps	Thermo-electric
NIR-S1	Count-100N SPAD	400 to 1,000 nm	< 3 ns (TTS)	100 cps	None

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FiPho Timing Electronics

High Performance TCSPC and MCS Electronics Interface

FiPho™

HORIBA's FiPho Photon-counting Platform combines up to three high-performance timing engines into a single module that seamlessly spans a time range over thirteen orders of magnitude. Combining the latest in SiGe ASIC technology with a cutting-edge FPGA core and USB 3 interface, FiPho is a photon-timing powerhouse that is uniquely simple to use and readily updated to any time-resolved measurement.

Short-lived decay (betacyanin, τ ~ 10 ps) using the HR module

FiPho TCSPC Electronics Specifications

Specifications	FiPho	FiPho-HR
Full Detectable TCSPC Lifetime Range	<20 ps to 30 sec	5 ps to 30 sec
TCSPC Converter Type	Digital TDC	Digital TDC and Analog TAC
TCSPC Bin Width	<15 ps	~ 250 fs
Phosphorescence Mode	MCS	MCS
Independent Stop Channels	1 to 4	1 to 4
Photon Streaming	Included	Included
FLIM Capable	Yes	Yes

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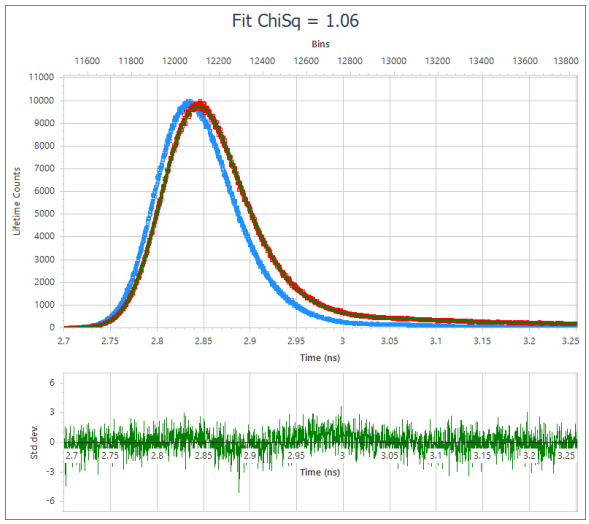
Modern Digital TDC Electronics in Every FiPho

FiPho's primary TCSPC engine is based around an ultralow deadtime quad-TDC (Time-to-Digital Converter). This TDC engine covers the time ranges most used for TCSPC fluorescence lifetime measurements. It combines high counting throughput with picosecond accuracy and a crystal-locked time-base for long-term operational stability. The Quad-TDC provides four independent timing channels that can be simultaneously used with multiple detectors for applications such as FRET, time-resolved anisotropy or multiwavelength kinetic studies.

High-Resolution TAC for Extremely Short Lifetimes

There may be "times" when you want to measure extremely short fluorescence lifetimes, and for these experiments you can configure a DeltaFlex TCSPC system with the FiPho-HR module. The FiPho-HR adds a high-resolution Time to Amplitude Converter engine (TAC) that offers class leading 0.25 picosecond resolution and the ability to measure fluorescence lifetimes down to ~ 5 picoseconds. The FiPho-HR combines the best of the analogue and digital domains by offering the high resolution TAC along with the speed and efficiency of a TDC. EzTime software seamlessly switches the engine based on the time range selected, so that there are no manual or electronic adjustments to change from a TDC to a TAC.



Beetroot extract, measured using DeltaDiode excitation with a time per bln of < 0.3 ps using FiPho HR

Advanced Photon Streaming in Every FiPho

Every FiPho provides advanced measurement modes including Photon Streaming (also known as Time-Tagging or FIFO mode), where every photon is registered and recorded individually. Photons can be sorted into histograms enabling kinetic measurements with 1,000 histograms per second to be recorded. All data is streamed to disk enabling full data analysis to be performed. This, when combined with high repetition rate lasers, such as our 100 MHz DeltaDiodes, ensures optimal collection efficiency (see Photon Streaming section below).

Multichannel Scaling for Seamless Long-lived Lifetime Measurements

All FiPho and FiPho-HR TCSPC platforms include a Multi-channel Scaler (MCS) engine that is capable of measuring longer-lived phosphorescence decay times up to thirty seconds. It has a resolution from 5 ns per bin, enabling decay times on the nanosecond range to be determined. The MCS engine is very flexible and can either accept or deliver trigger pulses allowing a variety of excitation sources to be used. For the greatest in versatility it can convert our picosecond DeltaDiode lasers into variable pulse width sources, ideal for phosphorescence measurements, by using them in “burst mode”. In this case, EzTime software seamlessly controls the switch from the TCSPC to MCS engine, with no manual adjustments, so that a single DeltaDiode laser can cover a time range of ~13 orders of magnitude.

Detailed FiPho Electronics Specifications

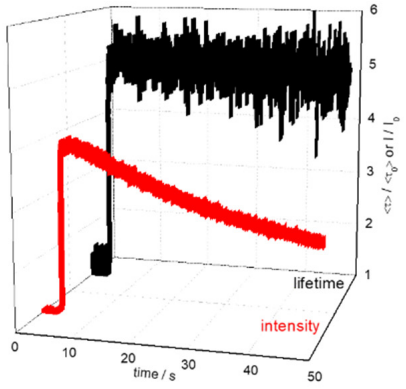
Specifications	FiPho (TDC, MCS)	FiPho-HR (TDC, TAC, MCS)
Full Detectable Lifetime Range	<20 ps to 30 sec	5 ps to 30 sec
TCSPC Time Range	<2 ns to 55 µs	<2 ns to 55 µs
Deadtime	5 ns	5 ns
TCSPC Bin Width	<15 ps	~ 250 fs
Electronics Jitter (FWHM)	30 ps	< 10 ps
TCSPC Histogram Size	Up to 16k	Up to 64k
Histogram Bin Depth	32 bit	32 bit
Independent Stops	1 to 4	1 to 4
Maximum Start Rate	100 MHz	100 MHz
Maximum Stop Rate	40 Mcps	40 Mcps
Operating Mode	Automatic Forward Timing	Automatic Forward or Reverse timing
Streaming Mode	Photon Streaming (Time-Tag)	Photon Streaming (Time-Tag)
MCS Bin Width	5 ns	5 ns
MCS Time Range	< 2.5 µs to 330 seconds	< 2.5 µs to 330 seconds
Maximum MCS Histogram Size	64k	64k
Acquisition and Analysis Macro Scripting	Yes	Yes
PC Interface	USB 3.0	USB 3.0
Software	EzTime, EzTime Image	EzTime, EzTime Image

Photon Streaming

The FiPho TDC engine, when combined with 100 MHz DeltaDiode sources and EzTime software, allows the DeltaFlex to acquire millisecond lifetime kinetics by Photon Streaming (measuring individual photon arrival times).

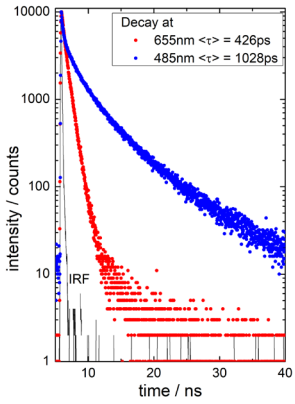
Photon streaming, also referred to as “time-tagging” or “FIFO mode”, labels each individual photon with its detection time. This is done both in terms of a macrotime (i.e. time after the start of the experiment) and microtime (i.e. position within the TCSPC histogram). Macrotime resolutions from ~ 10 ns are possible with the FiPho when using 100 MHz DeltaDiode sources and systems can be configured to collect data from multiple detectors simultaneously.

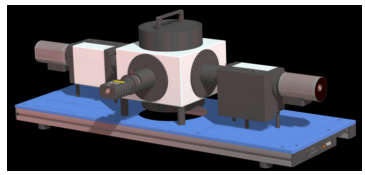
HORIBA TCSPC “streaming measurements” are well suited to following dynamic processes such as molecular binding, for example. Recording individual photon events allows a greater flexibility in analysis, where the number of histograms created from user selected time regions can be selected and saved as a new file. The use of lifetimes obtained from streaming measurements can be advantageous compared to solely intensity based measurements, since a change in lifetime is unaffected by factors such as photobleaching and changes in concentration.



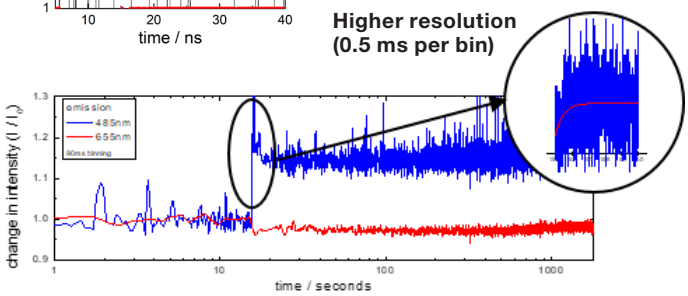
Effects on lifetime (black trace) and intensity (red trace) signal change upon binding of curuminoid to serum albumin. In spite of the continued photobleaching, the lifetime remains constant, allowing for a true picture of the kinetics process.

Study of butterfly pea extract binding to amylase

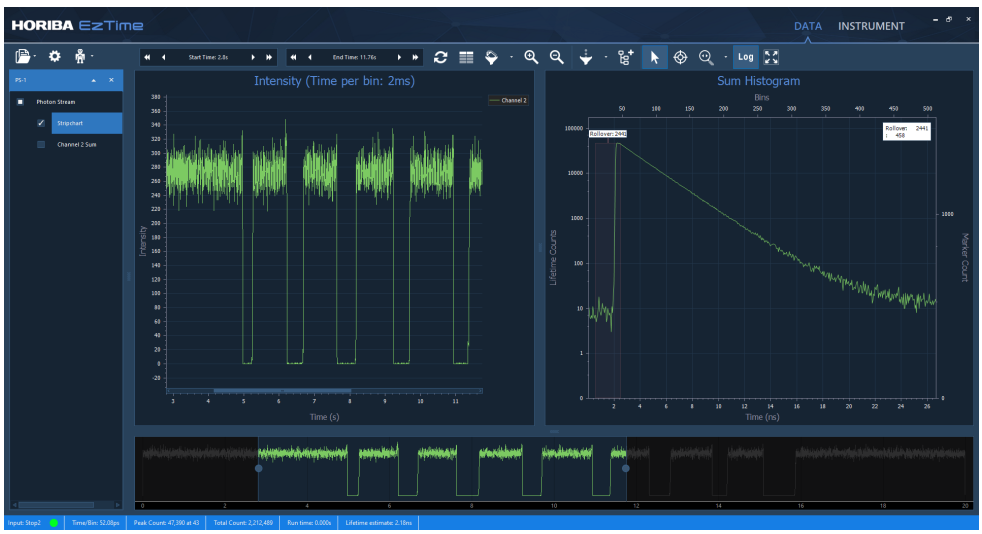




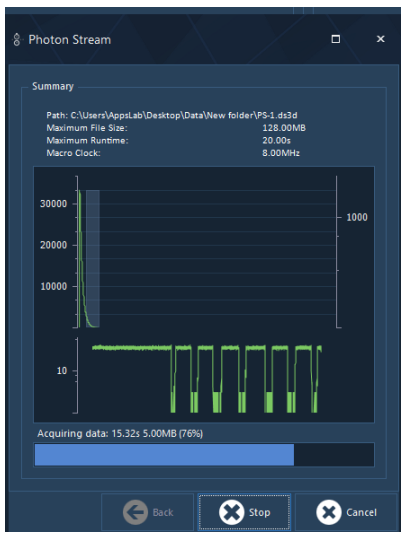
Photon streaming measurement monitoring change in lifetime and intensity upon binding to amylase



Binding to amylase observed simultaneously at two wavelengths - enables several components in the extract to be monitored at the same time
G. Hungerford *et al*, 2019. Spectrochim Acta A, 211, 108-113.



Interactive analysis of streamed data



Photon streaming (a.k.a. time tag) measurement in progress

Software

EzTime™

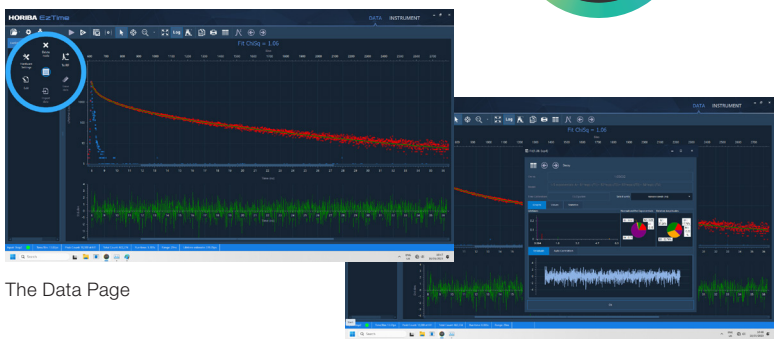
Intuitive, Automated, Touchscreen Software for Time-Resolved TCSPC and MCS Control, Acquisition and Data Analysis

EzTime is designed for use with the HORIBA DeltaFlex Fluorescence Lifetime Systems.

It is a complete application that handles the following:

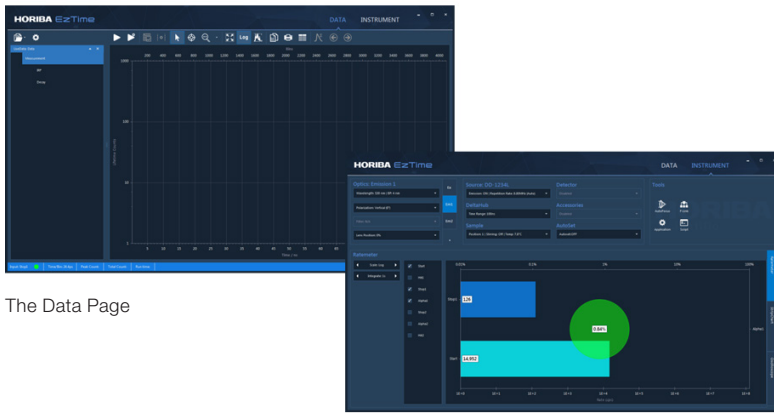
- Instrument recognition and control
- Data collection
- Data analysis

EzTime has been optimized for use with touch screen computers and can autofit data, requiring minimal operator interaction. It also enables the operator to define their specific data collection task using a simple, but potent, built-in scripting language.



The Data Page

The Instrument Page



The Data Page

EzTime Acquisition Modules

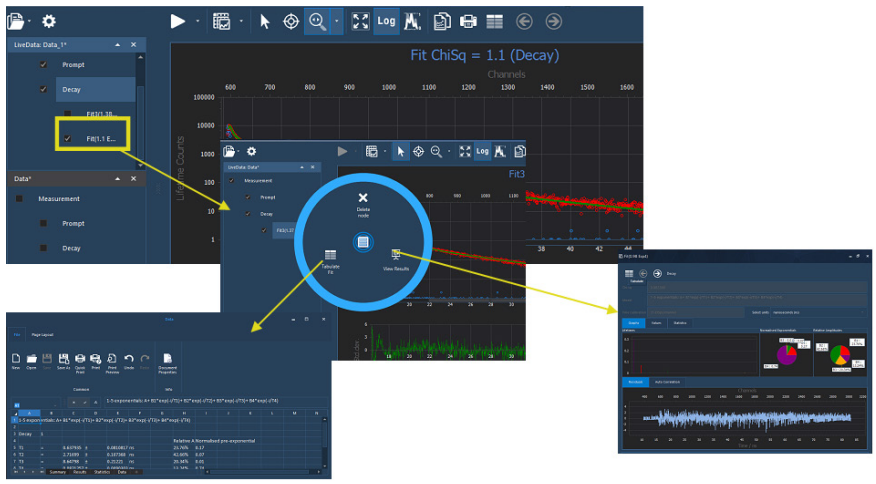
- One package for system control, data collection and analysis
- Multithreaded operation - analyze one dataset while acquiring the next
- Autofit feature – data automatically fitted with 1, 2 and 3 exponential models at end of acquisition
- Scripting – simple scripting commands to control data acquisition process and autofit
- Optimized for use with touch screen computers / monitors
- Tabulate function enables data and analysis to be saved in spreadsheet form (EzTime features a built-in spreadsheet editor and exported spreadsheets will open in MS® Excel®). Spreadsheets can be manipulated using the scripting feature to build custom reports
- Different time ranges can be displayed on the same graph
- Display of both time-resolved and spectral data on the same chart
- Autoset function (remembers hardware settings for decay and IRF measurements)
- Hardware settings recorded with IRFs and decays
- Automated scripts included for common measurements (TRES, anisotropy, turret scan)
- Script editor feature
- Support for photon streaming (aka time tag) modes (requires appropriate hardware)
- Automated instrument recognition and control

EzTime Radial expansions allow for selection of expanded functions. Within the Live Data panel, the Radial expansion allows a user to open many new nodes.

EzTime Data Analysis Modules

The fitting modules include the following models:

- 1 to 5 exponentials
- Exciplex
- Förster quenching 2D
- Förster quenching 3D
- Micellar quenching
- Stretched exponential
- Yokota-Tanimoto quenching
- Non-extensive decay (NED) distribution (up to five gamma distributions)
- Maximum entropy method (MEM)
- Global analysis for 1 to 5 exponentials
- Anisotropy analysis
- Batch analysis mode
- Time-resolved emission spectra (TRES)
- Time slicing TRES data
- Decay associated spectra



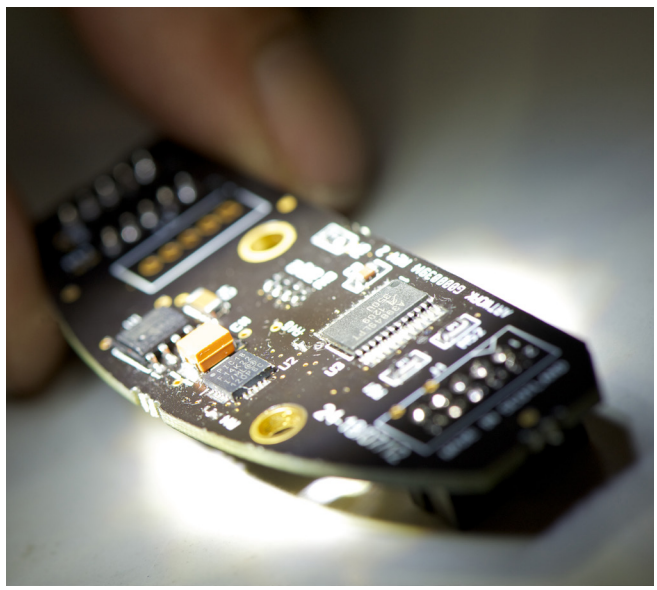
Radial expansions within EzTime allow you to view results or tabulated data.

Real time fitting features:

- Automated fitting of 1, 2 & 3 exponentials
- Automated selection of fit range
- Ability to simply export data and results
- Graphical and numeric representation

Have an EzTime of Your Experiments With F-link Communication Bus

With EzTime software and the F-link communication bus, it is easy for even the newest user to identify exactly what components are on the DeltaFlex at any time. F-link is an internal bus that is used in the DeltaFlex to link the various components together. For example, the sample compartment lid is interlocked via F-link to protect the detector and optionally switch off the laser. Other accessories, such as motorized polarizers and time-domain monochromators, also come with F-link. Since each F-link “node” is intelligent, whenever an F-link component is added to the system, it is auto-detected, and the configuration automatically updates without relying on troublesome registry settings.



Students, or multiple users at a core facility, will never be surprised with no sample signal due to the wrong LED or laser fiode is being used because the F-link communication allows EzTime to be “aware” of what the instrument set up and condition is. New F-link compatible components can be “sensed” by the software, enabling hardware additions to be simply added.

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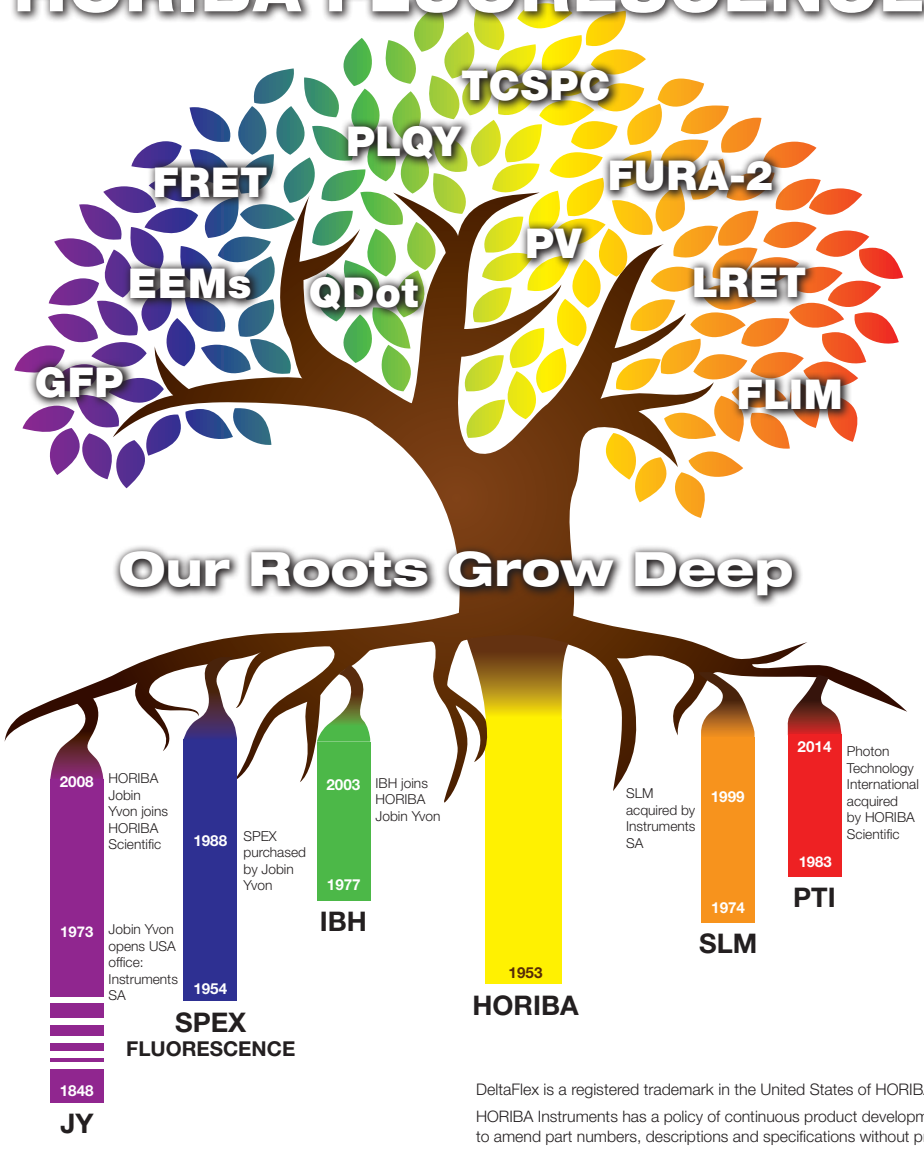

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