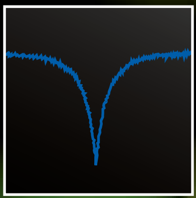
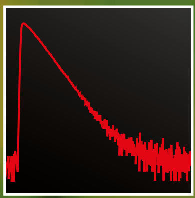
PicoQuant

Photon Counting and Timing

Reliable and easy to use modules with high-end performance





Your Benefits

World class solutions for photon counting and timing

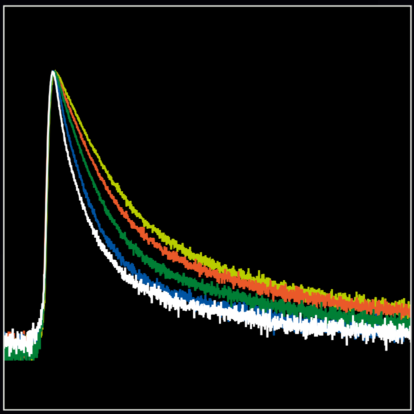
Since 1996 PicoQuant develops and manufactures hardware and software solutions optimized for detecting and analyzing single quanta of light. Our continuously evolving portfolio is ideally suited for many applications and research fields ranging from lifetime imaging, single molecule detection, time-of-flight / LiDAR to quantum correlation. All our products are designed to be versatile, reliable and intuitive to use.

- **World class precision and reliability**
  Electronics designed and manufactured by PicoQuant according to highest quality standards
- **Powerful tools for scientists**
  Mature instruments that have been developed in close collaboration with scientists to meet their needs
- **Custom-made Time-to-Digital Converters**
  PicoQuant's electronics feature purpose-tailored, high performance Time-to-Digital Converters (TDC)
- **Ready to use single photon detectors**
  Covering the UV / VIS / NIR range and featuring full RF and magnetic shielding
- **Accessible software**
  Enables users of all skill levels to perform a wide variety of data acquisition and analysis procedures

Applications

Your key to the world of photon counting and timing

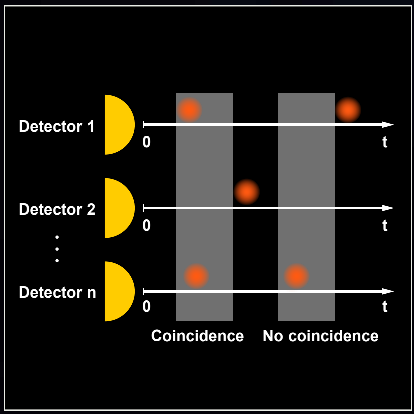
Time-Correlated Single Photon Counting (TCSPC) / time tagging or event timing in general has become a well established measurement technique. As such applications only use single light quanta, they are highly versatile and ideally suited for many applications where weak light intensities have to be detected.



Time-resolved luminescence

Gain insights into the excited state dynamics of your samples

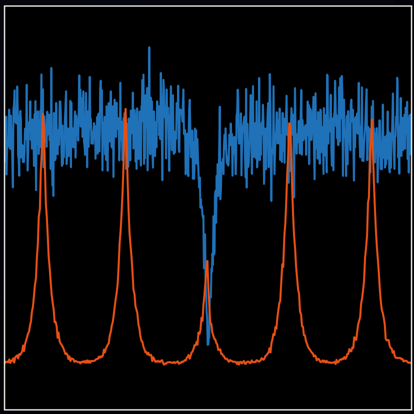
- Charge carrier dynamics in semiconductors
- Electron-hole diffusion lengths in solar cells
- Fluorescence lifetime of dyes, quantum dots, etc.



Coincidence counting

Study and understand an integral part of quantum experiments revealed by particle correlations, characterize quantum emitters

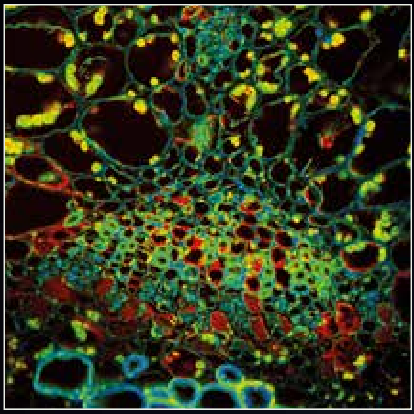
- Photonic quantum computation and quantum simulation
- Experimental tests of Bell-type inequalities / entanglement
- HOM-type measurements to determine the indistinguishability of non-classical photon sources



Temporal correlations

Determine and utilize the photon statistics of light fields

- Photon antibunching / $g^{(2)}$ - measurements to characterize single photon emitters
- $g^{(2)}$ measurements for quantum-super-resolved imaging



Fluorescence lifetime imaging

Record images based on differences in the excited state decay rates

- Sensing local environment
- Detecting molecular interactions and conformational changes
- Tissue characterization by autofluorescence

Time-of-Flight LiDAR / Ranging

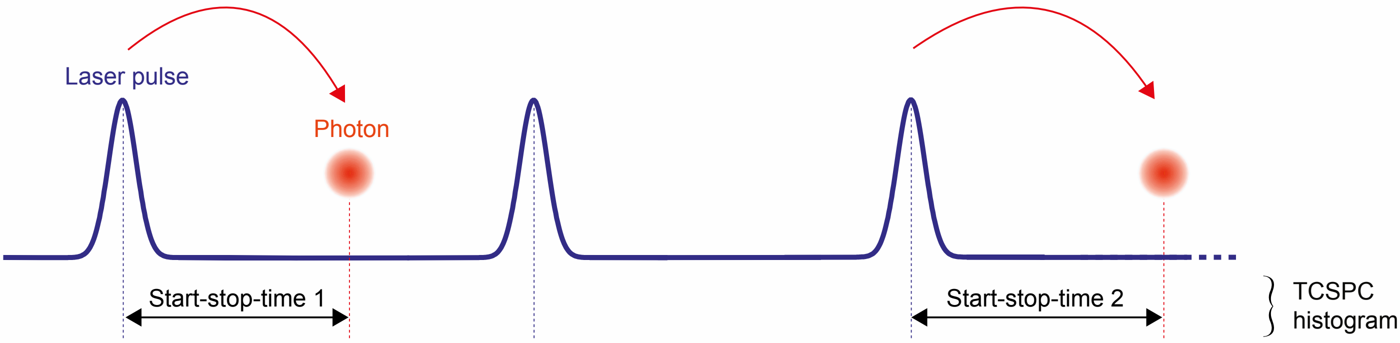
Measure distances based on time-resolved data acquisition

- Vehicular automation / autonomous driving
- Micro-topography
- Surveying and mapping

TCSPC

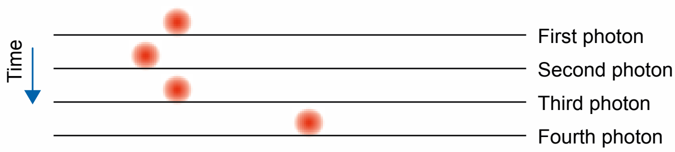
Accurate measurement of photon arrival times

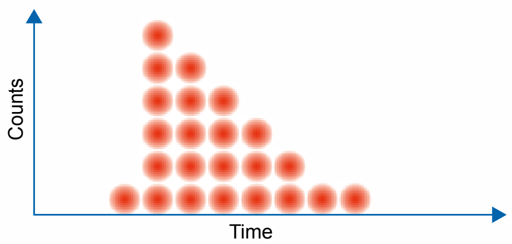
Time-Correlated Single Photon Counting (TCSPC) is a highly sensitive method with picosecond precision to study the temporal behavior of weak optical signals. This technique was originally used to measure fluorescence lifetimes, but has now been expanded to a wide range of applications.



Classic TCSPC measures the time difference between two signals, usually from a single photon sensitive detector and a reference signal from a pulsed laser.

A classic use case for TCSPC is to study the exponential intensity decay of fluorescent materials after pulsed excitation. In this case, the decay can be investigated by recording emitted photons with their exact arrival time relative to the excitation pulse. The „start" is triggered by the excitation pulse, and the arrival of a photon at the detector causes the „stop" signal.





In classic TCSPC, all measured time differences can be displayed as histogram from which the fluorescence lifetime is extracted by mathematical means.

After repeating these „start-stop" measurements over many excitation cycles, the recorded time differences can be displayed as a histogram. From this histogram, the fluorescence lifetime can be extracted by mathematical means (i.e. fitting).
TCSPC is not limited to fluorescence lifetime measurements. The technique can be applied to any experiment where the temporal evolution of light intensities with respect to a reference event is of interest (e.g., Time-of-Flight / LiDAR).

Custom high quality Time-to-Digital Converters

All PicoQuant timing modules are based on digital timing circuits, called Time-to-Digital Converters (TDC), which facilitate TCSPC measurements in forward start-stop operation. A cumbersome adjustment of signal cable lengths is not necessary, as signal delays in cables can easily be corrected via programmable timing offsets in each detector channel. PicoQuant's TDCs are designed for picosecond time resolution, short dead times, and outstandingly low differential nonlinearity.

"Over the years, the HydraHarp 400 has proven to be a reliable and excellent TCSPC unit for our single molecule spectroscopy and superresolution microscopy research."

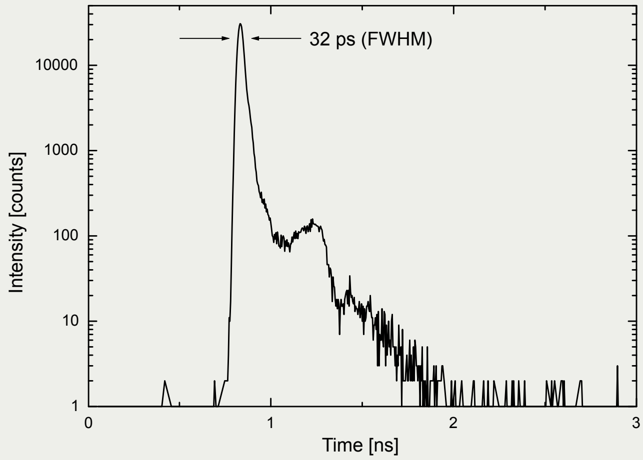
Jörg Enderlein, University of Göttingen, Germany

The multi-stop capability of PicoQuant's timing modules allows detecting more than one photon between two „start" signals, especially when timing electronics with ultra short dead times are combined with fast detectors. This can be used for fast data acquisition, phosphorescence lifetime measurements, or multichannel scaling.

Feature

Instruments Response Function

The IRF is an indication of the overall timing precision of a complete TCSPC system, including the excitation source, full optical path, detector and all electronics involved in signal processing. An ideal system with infinitely sharp excitation pulse as well as infinitely accurate detector and electronics would have an infinitely narrow IRF.



Example of an instrument response function (IRF) of 32 ps (FWHM), obtained with TCSPC in combination with a microchannel plate photomultiplier (MCP-PMT) and a fs laser.

This combination allows studying dynamics down to a few picoseconds. The small peak around 1.2 ns is a typical feature of MCP-PMT detectors.

Time Tagging Modes

Timing of individual photons or other events

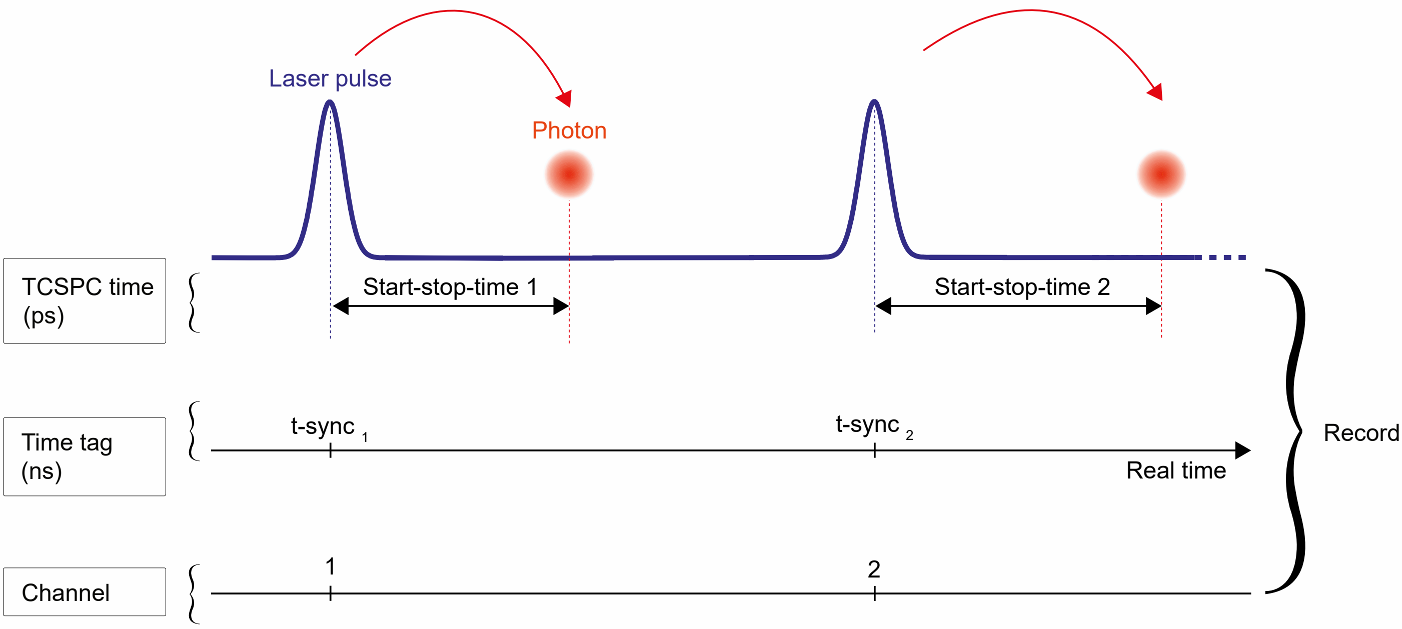
Time-Tagged Time-Resolved (TTTR) data acquisition, sometimes just called time tagging, allows recording individual events with precise information on their arrival time. This mode is particularly interesting when dynamic processes or correlations are to be investigated in depth.

In contrast to classic TCSPC (histogramming mode), the TTTR mode allows accessing the arrival time of each single event with respect to the overall experiment time. All PicoQuant TCSPC modules provide two different TTTR measurement modes: T2 and T3. These modes are ideally suited for advanced correlation measurements or applications where data acquisition needs to be synchronized with other devices (e.g., with a scanning system). TTTR mode data files store the full photon dynamics information, making it also possible to theoretically cover infinite time spans.

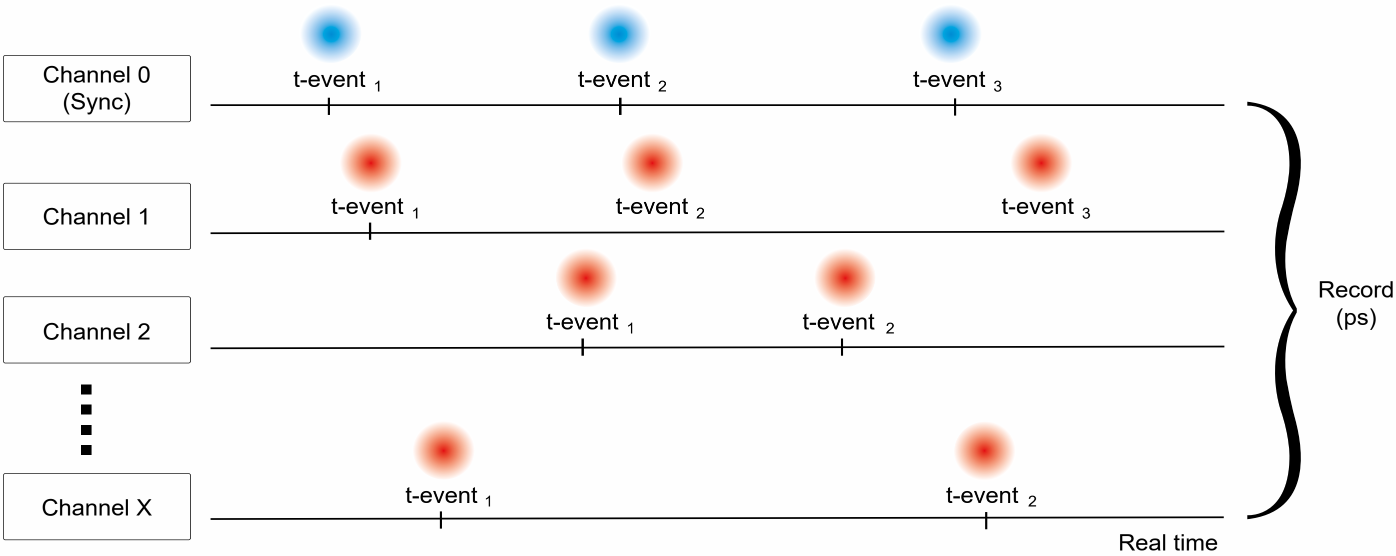
T3 mode

The T3 mode is an elegant solution for performing measurements at very high synchronization rates and can provide more effective data encoding for many applications. This mode is ideally suited for luminescence lifetime imaging and fluorescence correlation spectroscopy. Three different pieces of information are recorded for each detected event:

- The start-stop time difference (similar to classic TCSPC)
- The number of elapsed sync pulses since measurement start
- The channel at which the event has been detected



In T3 mode, the time difference between photon and synchronization signal is measured and stored along with detection channel number and corresponding number of the synchronization signal. With the latter information, one can reconstruct the arrival time of a photon on an absolute scale.



In T2 mode, all signal inputs are functionally identical and measure the arrival time of signals on an absolute time scale.

T2 mode

The T2 mode is PicoQuant's time-tagging mode. In T2 mode, no periodic sync signal is required. The sync input can therefore be used to connect an additional photon detector. T2 mode is often used for any kind of coincidence detection, such as coincidence counting and correlation for, e.g., antibunching in a HBT set-up.

Two pieces of information are collected for each event:

- The elapsed time since the start of the measurement
- The channel at which the event has been detected

External event markers

Both TTTR modes support capturing up to four external marker events that can be fed to the instrument as TTL signals. These events are recorded as part of the data stream with their arrival time since measurement start. This allows synchronizing the TTTR measurement with high precision to almost any other device, such as scanners for time-resolved imaging applications.

"The different measurement modes of PicoQuant TCSPC modules allow us to perform a wide range of applications with just a single device."

W.E. Moerner, Stanford University, USA, Nobel Prize Laureate

Picosecond Event Timers

High quality devices for a wide range of applications

PicoQuant offers highly reliable modules for TCSPC, time tagging, Multi-Channel Scaling (MCS), coincidence correlation, or event timing that cover the requirements for many applications. Each module features identical but independent detection channels as well as a common synchronization channel.

	TimeHarp 260	PicoHarp 300	MultiHarp 150
Detection channels*	1 or 2	1	4, 8, or 16
Temporal resolution	25 ps (PICO) 250 ps (NANO)	4 ps	80 ps
Dead time	< 25 ns (PICO) < 2 ns (NANO)	< 95 ns	< 0.65 ns
Interface	PCIe Gen2	USB 2.0	USB 3.0
Outstanding features	Short dead time. Compact form factor ideal for OEM integration.	High timing precision. Optional time tagging mode.	Combines high through-put with ultra short dead time. White Rabbit ready.

The synchronization channel can be used as an additional detector input when operating in T2 mode.

Compact cards

Stand-alon

	HydraHarp 400
	2, 4, 6, or 8
	1 ps
	< 80 ns
	USB 3.0
	Best time resolution and scalability. Outstanding versatility.

e modules

Top-of-the-line

HydraHarp 400

Multichannel picosecond event timer

The HydraHarp 400 is a modular, highly versatile top-of-the-line multichannel picosecond event timer and TCSPC system with USB 3.0 interface. It can accommodate up to 8 independent detection channels all with outstanding timing precision.

- *Scalable up to 8 independent detection channels and common sync channel*
- *65536 histogram bins per channel, minimum width 1 ps*
- *Time tagging with sustained throughput of up to 40 million events per second*
- *External clock synchronization input and output*

Example

Time-of-Flight / Ranging / LiDAR

Time-of-Flight (ToF) refers to a variety of methods that measure the time it takes for an object (e.g., photon) to travel a distance through a medium. Such methods are relevant for a broad range of applications like mass spectrometry, bunch purity analysis in synchrotron rings, or Light Detection and Ranging (LiDAR). In combination with appropriate scanning systems, ToF measurements can even be used to build three-dimensional depth images of remote targets or for transient imaging.

The example shows depth imaging using single-photon time-of-flight approach with picosecond resolution. Shown here are the photograph of a mannequin (A) and its corresponding depth image (B) with a cm-resolution (image measured at a distance of 325 m under daylight conditions). Data courtesy of G. Buller, Heriot-Watt University, Edinburgh, UK (Opt.Exp. 21, 8907, 2013)

MultiHarp 150

High-throughput multichannel event timer

The MultiHarp 150 is a multichannel event timer and TCSPC system combining outstanding data throughput with record breaking short dead times. It features a USB 3.0 interface for high bandwidth data transfer.

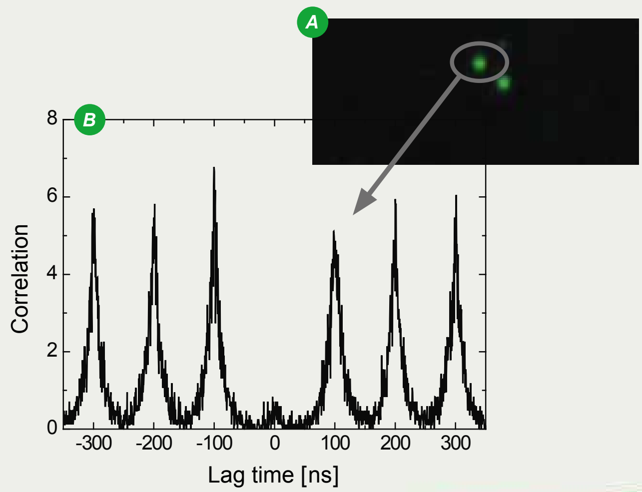
- *80 ps time resolution with 650 ps dead time*
- *4, 8 or 16 independent detection channels and common sync channel*
- *White Rabbit remote synchronization interface*
- *High sustained data throughput (180 million events per second in histogramming mode, 80 million events per second in time tagging mode)*

Example

Coincidence correlation / photon antibunching

Measuring coincidence correlations on a picosecond timing scale is a very useful tool for a wide range of research fields including life sciences and quantum optics. In quantum optics, coincidence correlations between several detector signals are used to study phenomena such as quantum entanglement or for quantum cryptography schemes. This technique also allows determining whether the observed source (e.g., single molecule, quantum dot, carbon nanotube, or defect centers in nanocrystals) behaves as a single photon emitter.

The example shows antibunching measurement of Nitrogen Vacancy (NV) centers in nano-diamonds. The NV centers were located via the FLIM image. (A) The missing peak at lag time zero in the anti-bunching trace (B) proves that there is only a single emitter in the nanocrystal under investigation. Image size approx. 13 µm x 13 µm. Sample courtesy of J. Wrachtrup, University of Stuttgart, Germany



PicoHarp 300

Stand-alone TCSPC module with USB interface

The PicoHarp 300 features two input channels, an USB 2.0 interface and provides high timing precision. It is ideally suited for determining fluorescence lifetimes and performing time-resolved photoluminescence measurements.

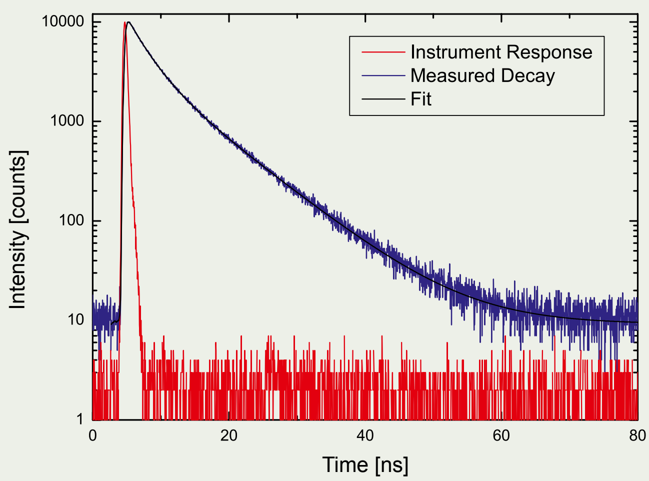
- *2 identical, synchronized but independent input channels*
- *65536 histogram time bins, minimum width 4 ps*
- *Optional time tagging with sustained throughput up to 5 million events per second*
- *Optional router for up to 4 detectors*

Example

Fluorescence lifetime measurements

The fluorescence lifetime is an intrinsic characteristic of fluorescent molecules, which can be strongly influenced by their chemical environment. These changes can be used to gain insights into the interaction of the fluorescent molecule with its environment or into dynamic processes such as chemical reactions.

This example shows the fluorescence lifetime measurement of L-tryptophane in water, excited with a pulsed LED and recorded with the PicoHarp 300. As can be expected, the decay is best described by a tri-exponential decay function. The recovered lifetimes are 0.35, 2.65, and 7.93 ns.



TimeHarp 260

TCSPC and MCS board with PCIe interface

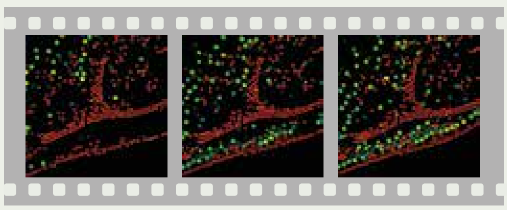
Available in four versions, the TimeHarp 260 is a compact TCSPC and Multi-Channel Scaling (MCS) board with PCIe interface and very short dead times. Thanks to its small form factor, the TimeHarp 260 is also an excellent choice for OEM integration.

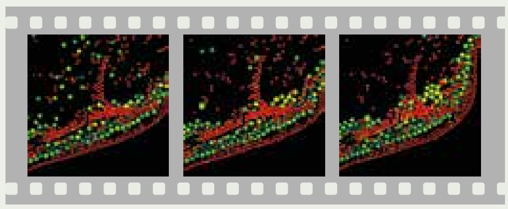
- *One or two independent input channels and common sync channel*
- *25 ps (PICO) or 250 ps (NANO) base time resolution*
- *Time tagging with sustained throughput of up to 40 million events per second*
- *Very short dead times < 25 ns (PICO) or < 2 ns (NANO)*

Example

Rapid Fluorescence Lifetime Imaging (rapidFLIM)

The pictures above show the diffusion behavior of two kinds of dye-labeled beads, monitored via rapidFLIM. The large beads with a size of 3.4 µm were labeled with Nile Red showing a fluorescence lifetime of 3.3 ns. The smaller beads (diameter of 2.7 µm) contained the dye Dragon Green, featuring a fluorescence lifetime of 4.0 ns.
The two species were distinguished based on their lifetime difference of about 700 ps. The beads formed a random structure at the edge of a water droplet, whose assembly was followed over time.
The movie was acquired with 8 µs pixel dwell time, corresponding to about 3 frames per second. FLIM image analysis was performed using the pattern matching FLIM approach.





PMA Series

Photomultiplier detector assemblies

Detectors from the PMA Series are single photon sensitive, fully integrated photon sensors with fast time response and low noise. They incorporate a fast photomultiplier tube, high voltage power supply, and preamplifier in a single package.

- *Timing resolution < 180 ps (FWHM)*
- *Quantum efficiencies up to 40% (cathode dependent)*
- *Spectral ranges from 185 to 920 nm*
- *Internal GHz pre-amplifier and shutter*
- *RF and magnetic shielding*
- *Optional thermoelectric cooler*

Spectral ranges between 185 and 920 nm

Various photocathodes can be incorporated into a detector from the PMA Series, covering different spectral ranges.

Timing resolution less than 180 ps

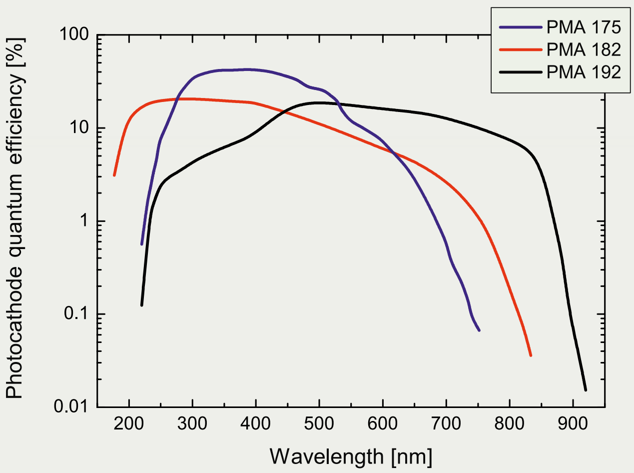
The PMA Series detectors feature a timing resolution better than 180 ps as well as a large active area (Ø = 8 mm), making them suitable for most photon counting set-ups, including time-resolved spectroscopy, diffuse optical imaging, or confocal scanning microscopy.

Robust design

The PMA Series detectors are encased in a refined iron or nickel coated housing to achieve high level of RF and magnetic shielding. They feature a safety shutter as well as optional thermoelectric cooling with safety protection.

Features

Photocathode quantum efficiencies for the PMA assemblies



By incorporating different photocathodes into a PMA assembly, the sensitivity and spectral range covered by the detector can be adjusted to the user's needs. The plot shows three variants here: one with peak quantum yield in the blue range, one covering the UV/VIS range, and a red sensitive one.

PMA Hybrid Series

Hybrid photomultiplier detector assemblies

The PMA Hybrid is a compact single photon sensitive detector based on a fast hybrid photomultiplier tube with peltier cooler to reduce the dark count rate.

- *Timing resolution < 50 ps (FWHM, cathode dependent)*
- *Detection efficiencies up to 45% (cathode dependent)*
- *Negligible afterpulsing*
- *Internal HV power supply, pre-amplifier, shutter, and overload protection*
- *Large sensor area: 3, 5, or 6 mm (cathode dependent)*
- *Active temperature stabilization*

Excellent timing, no afterpulsing

In addition to their excellent timing resolution (less than 50 ps in selected cases), all PMA Hybrid detectors have no measurable afterpulsing. This makes them ideal for many photon counting and timing experiments, such as time-resolved spectroscopy, lifetime imaging, or fluorescence correlation spectroscopy.

Housing with dedicated RF shielding

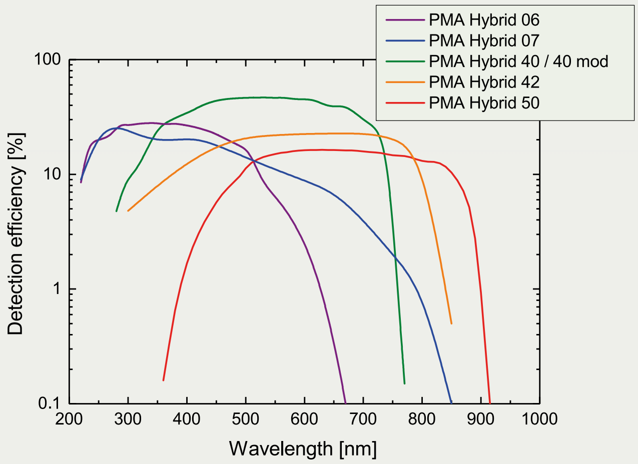
The PMA Hybrid's nickel coated aluminum housing achieves high level of RF shielding and protection against interference. The built-in pre-amplifier is specially aimed at timing sensitive applications.

Hybrid technology

The PMA Hybrid uses a combination of photocathode and silicon avalanche diode to provide a large active area with outstanding timing resolution.

Features

Detection efficiency curves of our PMA Hybrid assemblies



The plot shows five different photocathodes that can be incorporated into a PMA Hybrid assembly. These cover various spectral ranges with peak efficiencies in the UV/blue, the visible and up to the NIR spectral range.

EasyTau 2

Fluorescence decay analysis software

The EasyTau 2 is a versatile and powerful tool for interactive TCSPC decay data analysis and fitting that supports a broad range of time-resolved spectroscopy applications.

- *Decay fitting / analysis software for PicoQuant electronics*
- *Advanced error treatment via bootstrap analysis*
- *Steady-state and global decay analysis*

Fast and reliable decay fitting

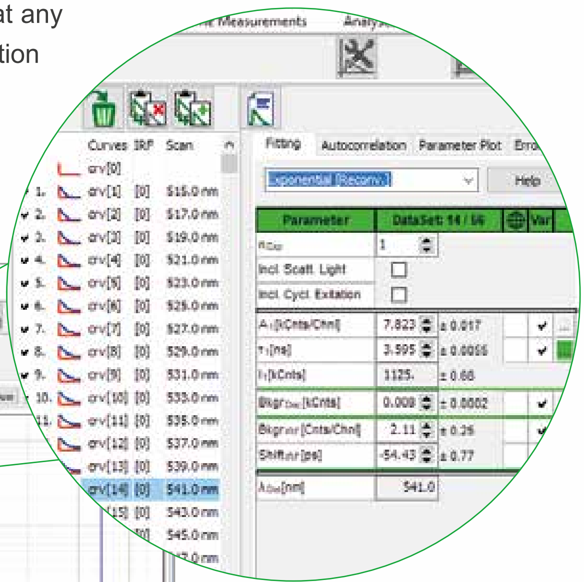
The analysis module supports both tail fitting and iterative reconvolution fitting to account for the Instrument Response Function (IRF). The software provides initial parameter guesses via automatic Monte Carlo search and quick fit convergence is ensured by reliable algorithms. Fitted parameters can then be plotted as a function of selected parameters from multiple data sets.

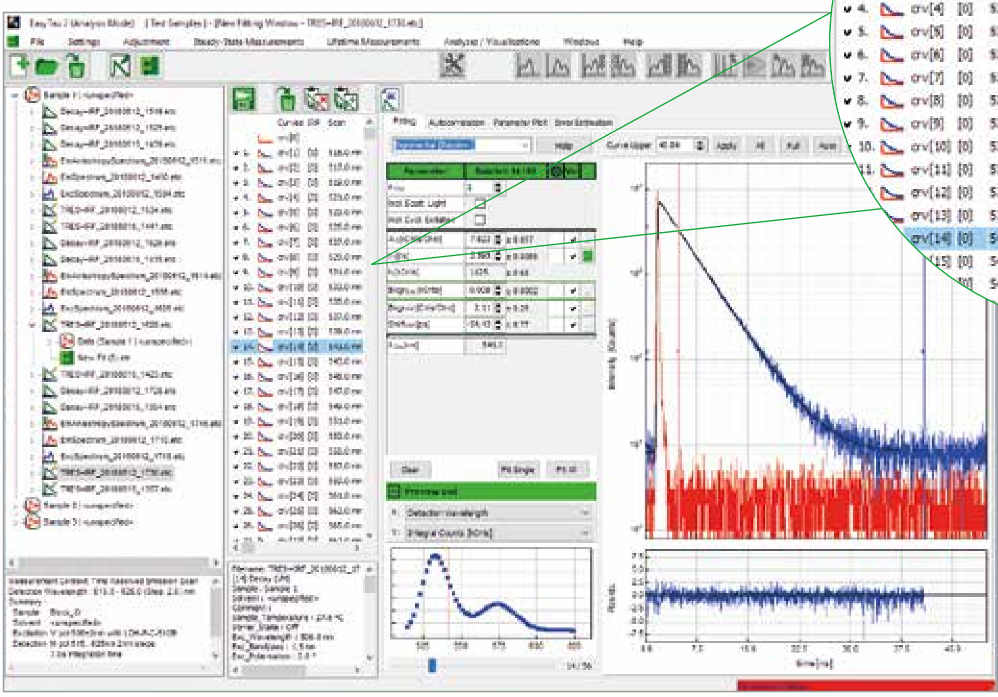
Exponential and lifetime distribution models

Exponential (up to 5th order) and stretched exponential models as well as Gaussian or Lorentzian lifetime distributions can be fitted to the recorded data. IRF and decay backgrounds, time shift, as well as other parameters can be included as fit parameters. Global fitting is available for all models.

Advanced anisotropy decay analysis

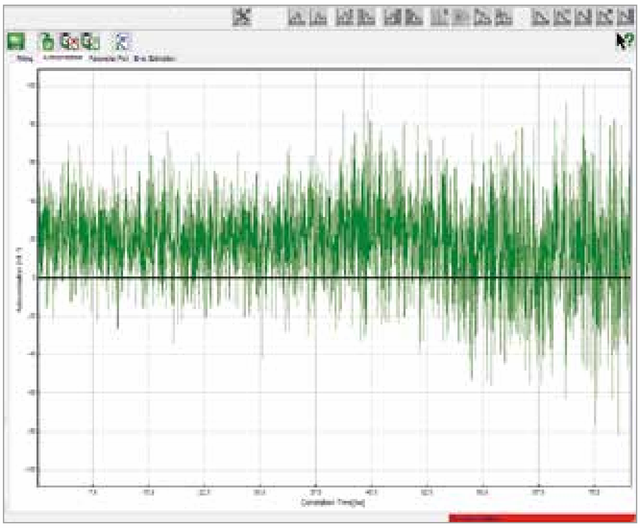
EasyTau 2 supports advanced analysis of fluorescence anisotropy via multiexponential reconvolution fits of the polarized decay curves at any polarization angle.





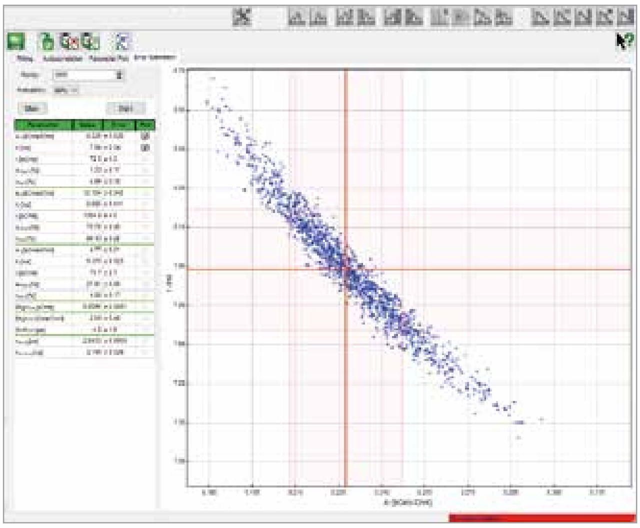
Advanced error treatment

EasyTau 2 provides calculation of a reduced chi-square value and a plot of the weighted residuals trace. Uncertainties in fit parameters and their correlations can be analyzed quickly via bootstrap analyses.



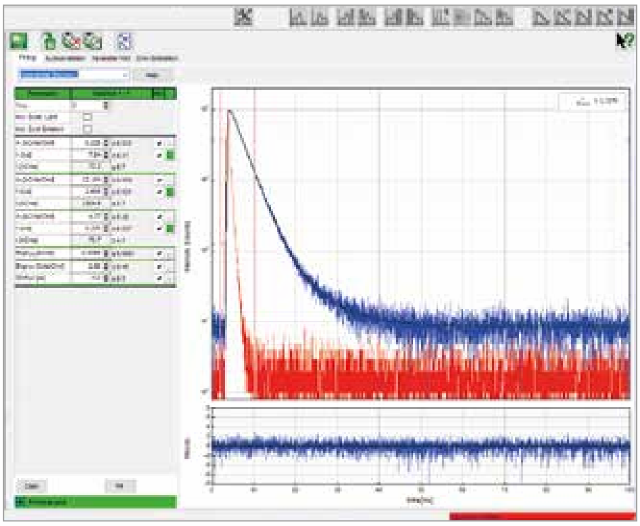
"The PicoHarp 300 provides us with flexibility and high reliability and we get data at a good level of throughput and in the right format for subsequent data processing."

Gerald S. Buller, Heriot-Watt University, Edinburgh, UK



Presentation ready results

EasyTau 2 can import data from all PicoQuant TCSPC devices and its modern, intuitive graphical user interface turns fitting and data analysis into an easy and enjoyable task. Presentation ready results can be saved and exported as customizable report files in HTML or PDF format.



SymPhoTime 64

Fluorescence lifetime imaging and correlation software

The SymPhoTime 64 is an integrated software solution with a focus on time-resolved microscopy techniques for data acquisition and analysis using PicoQuant TCSPC modules.

- *Powerful TTTR data acquisition and analysis software*
- *Ideally suited for 2D and 3D fluorescence imaging and point point measurements*
- *Supports fluorescence time trace and single molecule burst analysis*
- *TCSPC lifetime decay fitting with advanced error treatment*

Easy data acquisition

SymPhoTime 64 is the dedicated data acquisition software for PicoQuant's time-resolved confocal microscope MicroTime 200, LSM upgrade kits, or custom set-ups based on PicoQuant's TCSPC electronics.

Adapted interfaces for image analysis

The software interface is designed for intuitive analysis of a broad range of imaging methods, including Fluorescence Lifetime Imaging (FLIM), Förster Resonance Energy Transfer (FRET), and STimulated Emission Depletion (STED) super-resolution microscopy.

Ultrafast software correlator

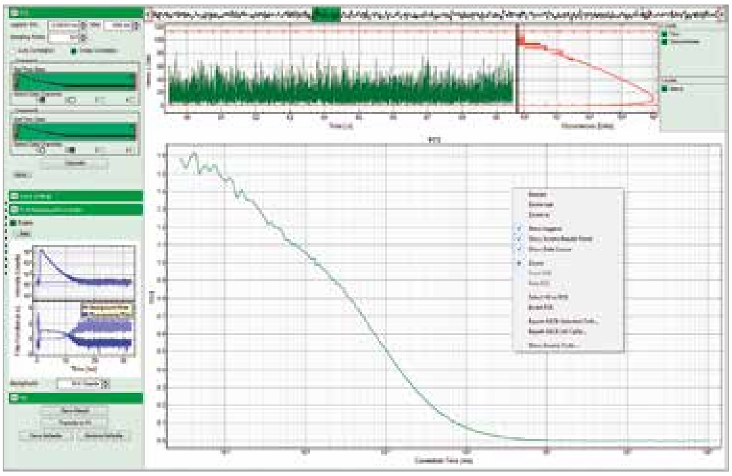
The SymPhoTime 64 features one of the fastest correlators currently on the market that is perfectly adapted to analysis procedures ranging from classic auto- (FCS) or cross-correlation (FCCS) to lifetime based correlation analysis (FLCS) and total correlation. The software includes fitting models that allow determining important parameters such as diffusion coefficients or molecular concentrations.

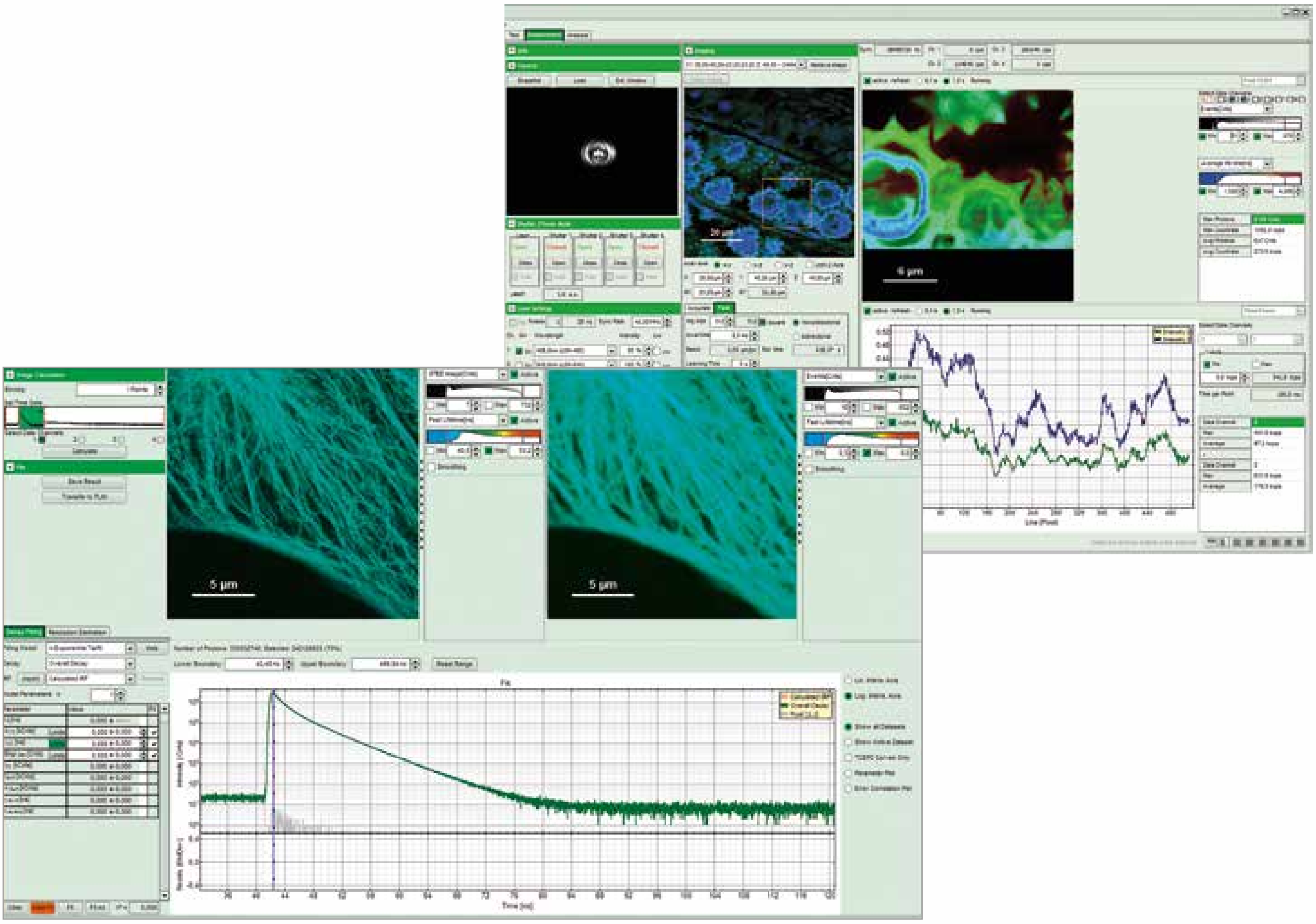
Intensity time trace analysis

SymPhoTime 64 provides a variety of methods to analyze fluorescence intensity time traces for applications such as FRET, Pulsed-Interleaved Excitation FRET (PIE-FRET), and anisotropy. Support for classic single molecule methods such as on/off histograms, burst size histograms, or fluorescence lifetime traces is also included.

“The HydraHarp 400 is the ideal device for multiplexed TCSPC applications such as single-molecule and ensemble fluorescence spectroscopy and imaging with multiparameter detection (MFD).”

Claus A. M. Seidel, University of Düsseldorf, Germany





QuCoa

Quantum correlation analysis software

QuCoa is an integrated solution for data acquisition and analysis using PicoQuant's TCSPC electronics with a focus on photon coincidences.

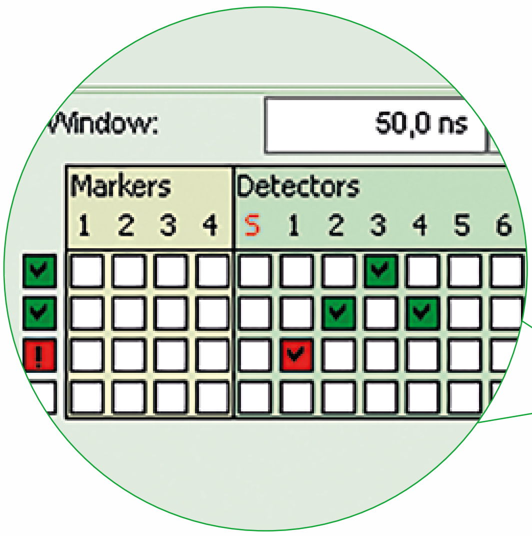
- *Antibunching ($g^{(2)}$) measurements including fitting of several models*
- *Coincidence counting / event filtering using AND, OR, NOT operators*
- *On-the-fly correlation and coincidence counting*

Easy data acquisition

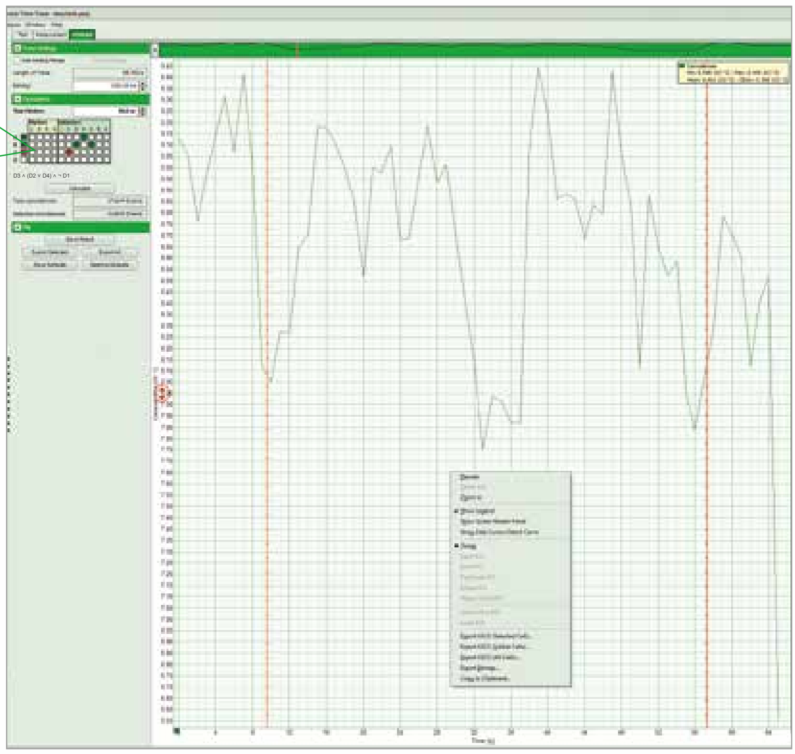
The QuCoa software makes full use of the unique T2 time tagging mode of PicoQuant's TCSPC electronics. Since all photon timing information is preserved with this mode, a broad range of data interpretation methods is supported, ranging from simple intensity time traces to complex correlation and coincidence counting applications.

Antibunching with cw or pulsed excitation

The QuCoa software package includes one of the fastest software correlators on the market, which permits correlating the absolute arrival times of photons in real time. The $g^{(2)}(0)$ value and count rates on all detectors are continuously displayed, regardless of excitation mode (cw or pulsed).



The activity pattern for a coincidence is defined by a logical combination of detector and / or marker signals. The patterns are defined by setting check marks in the table. In this example, a coincidence will be counted if a signal is registered on detector 3 and on detector 2 or 4 but not on detector 1.



"The MultiHarp 150 is an extremely flexible workhorse. It is the ideal device for performing antibunching experiments on NV centers in diamonds and coincidence counting with multiple detectors."

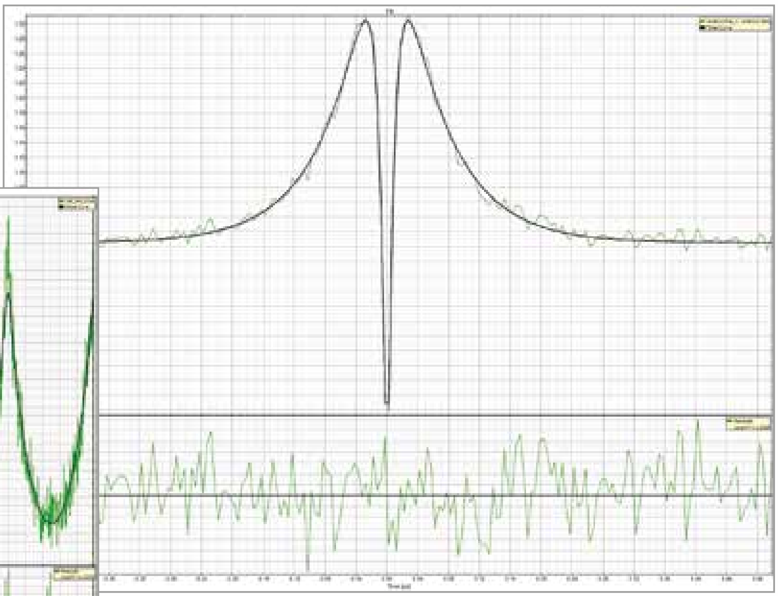
Oliver Benson, Humboldt University Berlin, Germany

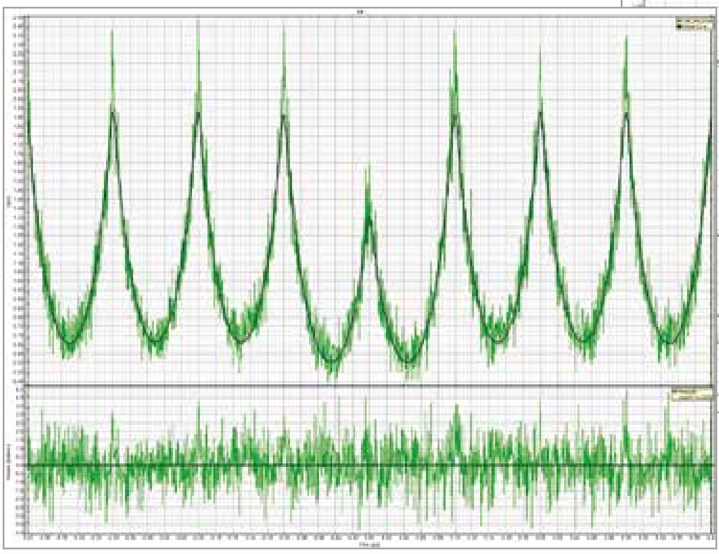
Included fitting models

Several established fitting models are included, such as single emitter models with or without shelved state or pulsed excitation based on exponential decays. All models take the timing uncertainty of the detectors into account.

Coincidence counting

The QuCoa software also includes event filters for coincidence counting applications. These filters allow combining detection channels and marker signals in a user-defined coincidence time window using logical operations (AND, OR, NOT) via an intuitive graphical user interface. The filters can be applied during data acquisition as well as offline.





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