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What is Time Correlated Single Photon Counting?

Introduction to

The Becker & Hickl SPC-series Module Family

PC Based Systems

intelligent measurement and control systems

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Time-Correlated Single Photon Counting

Time-Correlated Single Photon Counting (TCSPC) is a technique to record low level light signals with picosecond time resolution. Typical applications are

Ultra-Fast Recording of Optical Waveforms
Fluorescence Lifetime Measurements
Detection and Identification of Single Molecules
DNA Sequencing
Optical Tomography
Fluorescence Lifetime Imaging

The method has some striking benefits:

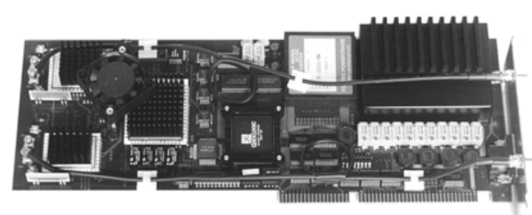
Ultra-High Time Resolution - 25 ps fwhm with the best detectors
Ultra-High Sensitivity - down to the Single Photon Level
Short Measurement Times
High Dynamic Range - Limited by Photon Statistics only
High Linearity
Excellent Signal-to-Noise Ratio
High Gain Stability
Suppression of Detector Leakage Currents

TCSPC works best for

High Repetition Rate Signals (MHz Range)
Wavelengths from 160 nm to 1000 nm

Measurement Principle

Time-Correlated Single Photon Counting is based on the detection of single photons of a periodical light signal, the measurement of the detection times of the individual photons and the reconstruction of the waveform from the individual time measurements. The method makes use of the fact that for low level, high repetition rate signals the light intensity is usually so low that the probability of detecting one photon in one signal period is much less than one. Therefore, the detection of several photons can be neglected and the principle shown in the figure below can be used:



Complete electronics on board - a TCSPC Module of Becker & Hickl

The detector signal consists of a train of randomly distributed pulses due to the detection of the individual photons. There are many signal periods without photons, other signal periods contain one photon pulse. Periods with more than one photons are very rare.
When a photon is detected, the time of the corresponding detector pulse is measured. The events are collected in memory by adding a '1' in a memory location with an address proportional to the detection time. After many photons the histogram of the detection times, i.e. the waveform of the optical pulse, builds up in the memory.
Although this principle looks complicated at the first glimpse, it is very efficient and accurate for the following reasons:
The accuracy of the time measurement is not limited by the width of the detector pulse. Thus, the time resolution is much better then with the same detector used in front of an oscilloscope or another linear signal acquisition device. Furthermore, all detected photons contribute to the result of the measurement. There is no loss due to 'gating' as in 'Boxcar' devices or gated image intensified CCDs.

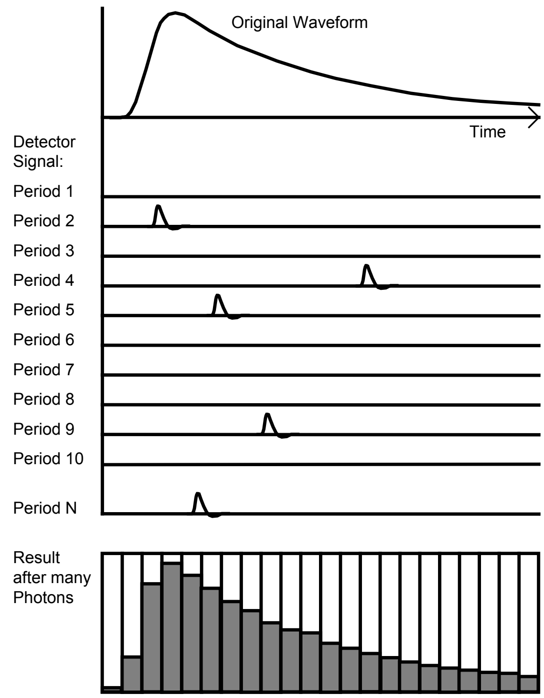


Fig. 1: TCSPC Measurement Principle

Sensitivity
The sensitivity of the SPC method is limited mainly by the dark count rate of the detector. Defining the sensitivity as the intensity at which the signal is equal to the noise of the dark signal the following equation applies:

$$S = \frac{(R_d * N/T)^{1/2}}{Q}$$

(R_d = dark count rate, N = number of time channels, Q = quantum efficiency of the detector, T = overall measurement time)
Typical values (uncooled PMT with multialkali cathode) are R_d=300s^{-1}, N=256, Q=0.1 and T=100s. This yields a sensitivity of S=280 photons/second. This value is by a factor of 10^{15} smaller than the intensity of a typical laser (10^{18} photons/second). Thus, when a sample is excited by the laser and the emitted light is measured, the emission is still detectable for a conversion efficiency of 10^{-15}.
Time resolution
The SPC method differs from methods with analog signal processing in that the time resolution is not limited by the width of the detector impulse response. For the SPC method only the timing accuracy in the detection channel is essential. This accuracy is determined by the transit time

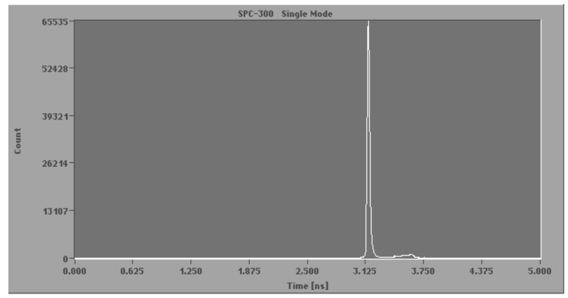
spread of the single photon pulses in the detector and the trigger accuracy in the electronic system. The timing accuracy can be up to 10 times better than the half width of the detector impulse response. Some typical values for different detector types are given below.

conventional photomultipliers
- standard types 0.6 ... 1 ns
- high speed (XP2020) 0.35 ns

Hamamatsu TO8 photomultipliers
- R5600, R5783 140 ... 220 ps

micro channel plate photomultipliers
- Hamamatsu R3809 25 ... 30 ps

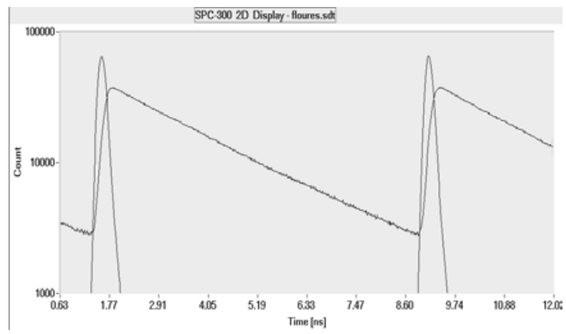
avalanche photodiodes 60 ... 500 ps



A laser pulse recorded with 30 ps fwhm

Accuracy

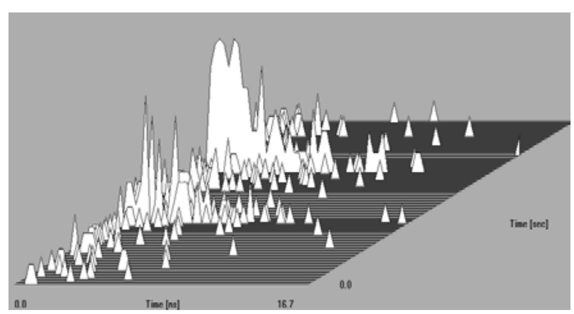
The accuracy of the measurement is given by the standard deviation of the number of collected photons in a particular time channel. For a given number of photons N the signal-to-noise ratio is $SNR = N^{-1/2}$. If the light intensity is not too high, nearly all detected photons contribute to the result. Therefore, the SPC yields a very good signal-to-noise ratio at a given intensity and measurement time. Furthermore, in the SPC method, noise due leakage currents, gain instabilities, and the stochastic gain mechanism of the detector does not appear in the result. This yields an additional SNR improvement compared to analog signal processing methods.



Fluorescence decay curves, excitation with Ar+ laser

Recording Speed

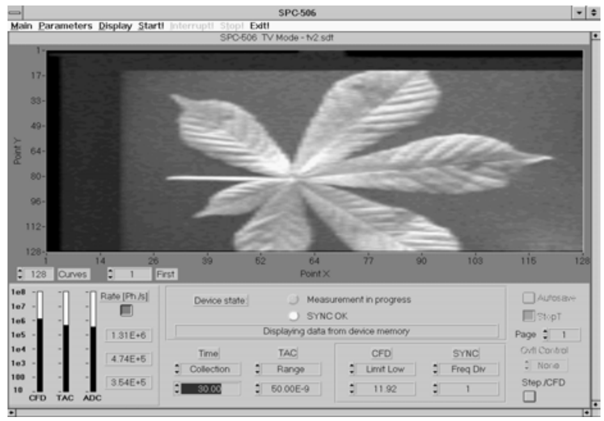
The TCSPC method is often thought to suffer from slow recording speed and long measurement times. This bad reputation comes from traditional TCSPC devices built up from nuclear instrumentation modules which had a maximum count rate of some 10^4 photons per second. State-of-the-art TCSPC devices from Becker & Hickl achieve count rates of some 10^6 photons per seconds. Thus, 1000 photons can be collected in less than 1 ms, and the devices can be used for such high speed applications as the detection of single molecules flowing through a capillary, for fast image scanning, for the investigation of unstable samples or simply as optical oscilloscopes.



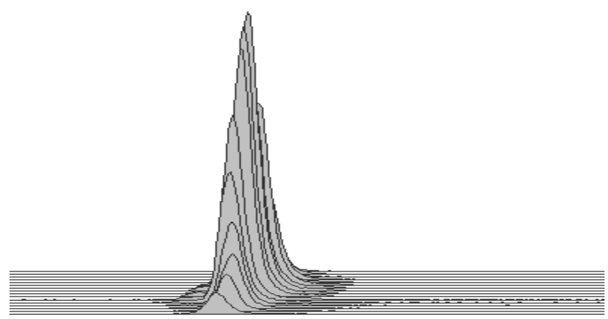
Fluorescence decay signals from single molecules running through a capillary. Collection time 1 ms per curve.

Multichannel and Multidetector Capability

Becker & Hickl has introduced multichannel and multidetector capabilities in their TCSPC modules. In the device memory space is provided for several waveforms, and the destination of each individual photon is controlled by an external signal. In conjunction with a fast scanning device, time resolved images are obtained with up to 128 x 128 pixels containing a complete waveform each. Furthermore, several detectors can be used with one TCSPC module. This technique makes use of the fact that the simultaneous detection of several photons in different detectors is very unlikely. Thus, the output pulses of several detectors are combined and an external 'Routing' device determines in which detector a particular photon was detected. This information is used to route the photons into different memory blocks containing the waveforms for the individual detectors.



A 128 x 128 pixel scan containing 16384 waveforms



16 signals measured simultaneously with a 16 channel PMT

PC Based Photon Counting Systems

Introduction

Based on a wide variety of photon counting modules Becker & Hickl delivers ready-to-use systems which contain one or more photon counting modules. Furthermore, combinations of different modules are available, and a step motor controller for experiment control can be added. Some examples for complex systems are described in this application note.
The following photon counting modules are available:

Time-Correlated Single Photon Counting Modules

- Recording of light pulses with a resolution down to 25 ps FWHM
- Time-Resolved Spectra with 25 ps Resolution
- Multi Detector Capability
- Short Measurement Times due to high Count Rates
- Optical Oscilloscope Capability
- Large Memory Versions for Image Scanning, Lifetime Imaging and Optical Tomography
- Versions for Fluorescence Lifetime Measurement of Single Molecules

Gated Photon Counting Counters and Multiscalers

- Up to 800 MHz Count Rate
- Multiscaling down to 250 ns / Channel
- Ultra-Low Background Count Rate by Gated Detection
- Steady State and Pulsed Emission Spectra
- Event Recording for Single Molecule Detection
- Bioluminescence Measurements

Multichannel Photon Counters

- Up to 32 Parallel Detector Channels with 100 MHz Count Rate

Fast Multiscalers down to 5 ns / Channel

- Luminescence Decay Measurements from ns to Seconds
- Ultra-Fast Acquisition, High Repetition Rates
- Time-of-Flight Measurements

Step Motor Controllers

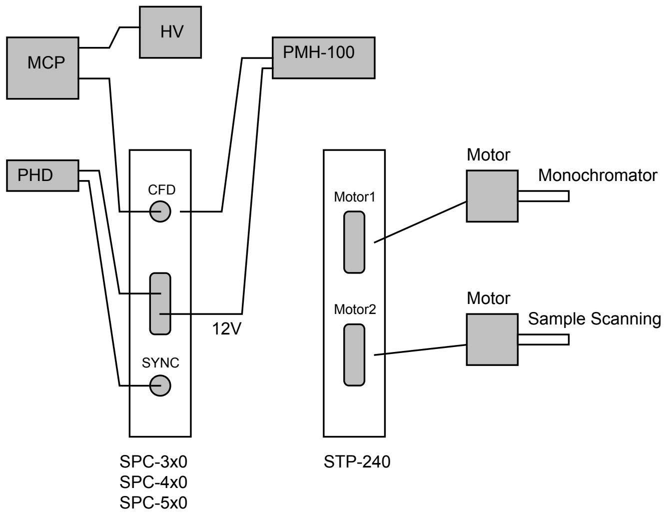
- Monochromator Control and Sample Scanning

Detectors and Preamplifiers

- PMT-Modules with internal HV Supply
- Ultra-Fast MCPs for TCSPC
- Preamlifiers with Detector Overload Detection
- Photodiode Modules for Gating and TCSPC Triggering

Time-Correlated Photon Counter with Step Motor Controller

A typical TCSPC (time-correlated single photon counting) system is shown in the figure below. It contains a time-correlated photon counting module (SPC-3, SPC-4 or SPC-5 module) and a step motor controller STP-240.



To achieve maximum time resolution, an MCP is used as detector. If maximum time resolution is not required, a PMH-100 detector is used. This is a rugged and easy-to use, but fast PMT module which is powered directly from the photon counting module. A fast photodiode modules is used to synchronise the SPC module with the light source. Both the PMH-100 and the photodiode module are powered directly from the SPC module.

Typical applications of the system shown above are:

Measurement of fluorescence decays or other optical waveforms down to 25 ps. Due to the high count rates (8 MHz for SPC-4-versions) extremely short measurement times are achieved.

Measurement of decay data of single Molecules (SPC-4-Versions). Fluorescence decay data are collected for single molecules running through a capillary. Depending on the SPC module version, the data is stored as a set of subsequent decay curves in time intervals down to 1 ms or as independent information for each individual photon.

Measurement of subsequent decay curves with wavelength stepping. The full time and wavelength dependence of the sample is recorded as a set of decay curves for subsequent wavelengths.

Measurement of decay curves with spatial scanning of the sample. The spatial dependence of the sample emission is recorded set of decay curves for subsequent sample points. With the SPC-5-versions up to 16384 decay curves can be recorded in one measurement.

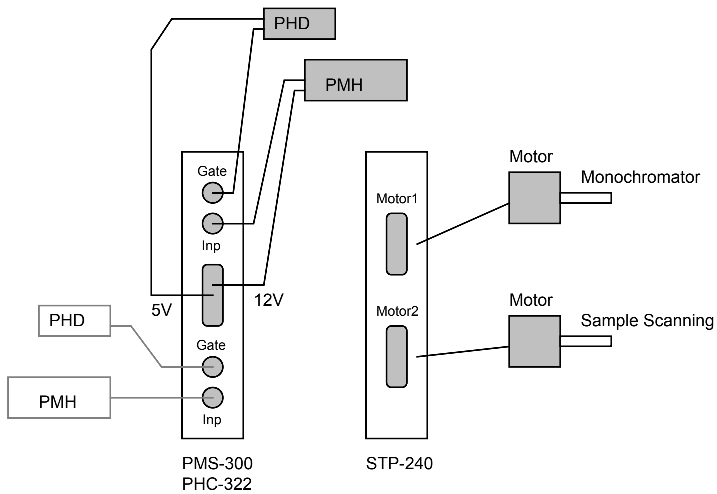
Measurement of subsequent decay curves in programmed time intervals. The variation of a sample with the time is recorded as a set of subsequent decay curves.

Recording of time-resolved spectra in time windows down to 25 ps. Up to eight spectra are recorded simultaneously for the same sample in different time windows.

Optical Oscilloscope Applications. All SPC modules provide an 'Oscilloscope Mode' which displays subsequently measured waveforms in intervals down to some 10 ms. Thus, optimising and adjusting your measurement setup is not longer a trial-and-error procedure.

Gated Photon Counter / Multiscaler with Step Motor Controller

A typical Gated Photon Counting system is shown in the figure below. It contains a gated photon counter (PHC-322) or a gated photon counter / multiscaler (PMS-300) and a step motor controller.



To detect the light signals, one or two PMH-100 detectors are used. These are rugged and easy-to use, but fast PMT module which are powered directly from the photon counting module. One or two fast photodiode modules are used to gate the PMS or PHC. As the PMH-100, the photodiode modules are powered from PMS or PHC module. Typical applications of the systems shown above are:

Steady state emission spectra. The high count rate of 800 MHz yields an exceptional high linearity up to extremely high peak intensities.

Sample scanning. The emission of the sample is recorded as a function of the position of the measured spot.

Steady state emission spectra with pulse excitation and gated detection. The gating reduces the detector background counts the extremely low values.

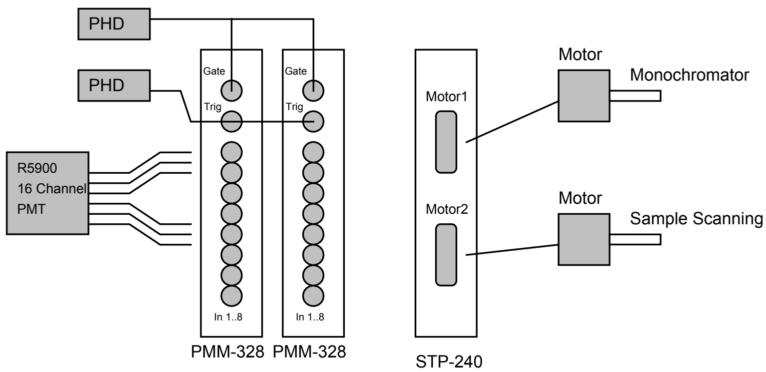
Luminescence decay curves in the us range (PMS-300). The high count rate of the PMS (800 MHz) allows to record more than 200 events for each channel in one sweep. Accumulation of several sweeps is free of dead time, therefore an extremely high repetition rate is achieved.

Time-of-flight measurements with a resolution down to 250 ns (PMS-300). The high count rate of the PMS (800 MHz) allows to record more than 200 events for each channel in one sweep. Accumulation of several sweeps is free of dead time, therefore an extremely high repetition rate is achieved.

Detection of single molecule or other particles (PMS-300). The 'Event Mode' of the PMS-300 allows the recording of events like the transition of a single molecule or another particle through a laser focus. The background counts are suppressed by an adjustable 'Event Threshold'.

16 Channel Photon Counter / Multiscaler with Step Motor Controller

For application which require a high number of detector channels the PMM-328 Eight-Channel Photon Counter has been designed. A system with this device is shown in the figure below.



As a detector for the PMM-328 usually the R5900 from Hamamatsu is used. This is a PMT with 16 independent channels delivering one output signal each. The R5900 is available in a 1x16 and in a 4x4 configuration. To record the photons detected by the 16 PMT channels two PMM-328s are required. Again, a step motor controller STP-240 is included for monochromator control and sample scanning.

The applications of the system shown above are similar to these of the PHC / PMS system. However, due to the high number of counter channels the system has some interesting features:

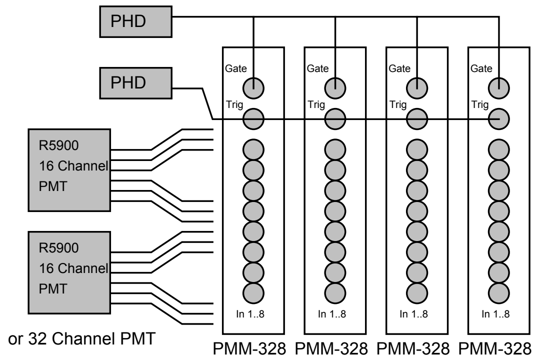
Simultaneous measurement of 16 waveforms. The PMM system records one waveform for each channel of the R5900. This can be used to investigate a sample at several wavelengths or at several points.

High efficiency sample scanning. 16 adjacent lines of a samples can be scanned simultaneously.

Multi-photon counting. A usual single channel photon counter can detect only one photon within its response time or within the response time of the detector. The system above can detect 16 photons at the same time - a stunning feature for a photon counter. To achieve multi-photon counting it is only required that the light is spread over all 16 channels of the R5900 and the results of the 16 counter channels are added.

32 Channel Photon Counter / Multiscaler

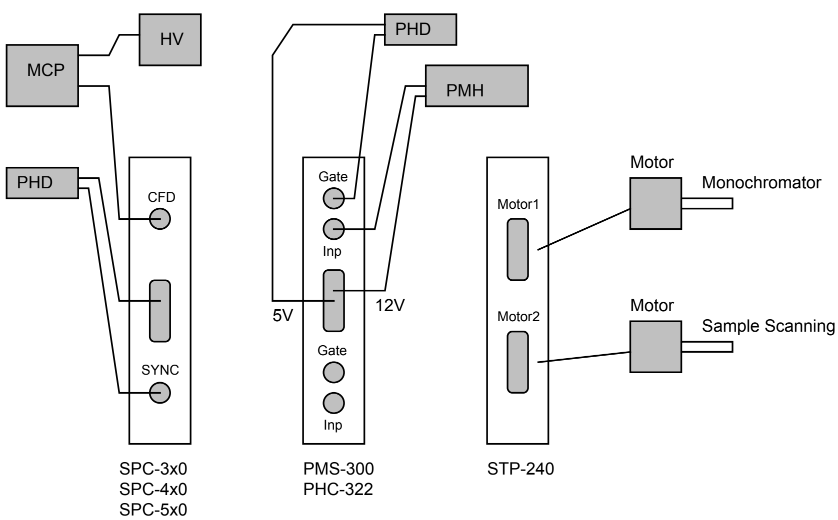
Up to four PMM-328 Eight-Channel Photon Counters can be combined in one system and operated with the same software.



With two R5900 PMTs or with a 32 channel PMT a 32 channel photon counting system can be built up. Systems of this type are used to simultaneously record up to 32 waveforms or to count several photons which appear simultaneously within the detector response time.

Combined Time-Correlated and Gated Photon Counter

An extremely versatile system is shown in the figure below. It contains a time-correlated photon counting module (SPC-3, SPC-4 or SPC-5 module), a gated photon counter (PHC-322) or gated photon counter / multiscaler (PMS-300) and a step motor controller. The step motor controller is used both by the SPC and by the PMS / PHC module software.



To achieve maximum time resolution with the TCSPC part, an MCP is used as detector. For the Gated Photon Counting and Multiscaling part a PMH-100 detector is used. This is a rugged and easy-to use, but fast PMT module which is powered directly from the photon counting module. Two fast photodiode modules are used for the synchronising of the SPC module and for gating

the PMS or PHC. As the PMH-100, the photodiode modules are powered from the SPC and PMS or PHC modules.
The system can be used for

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High Speed Optical Signal Recording Techniques
A Comparison

Time-Correlated Single Photon Counting
Modulation Techniques
Gated Image Intensifiers
Multi-Gate Photon Counting
Multiscaling

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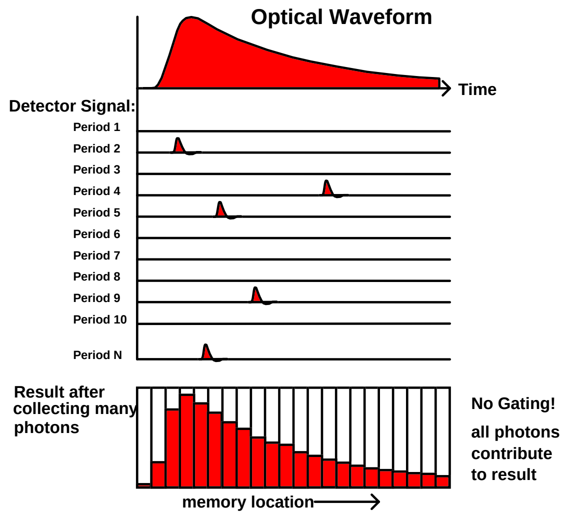
Time-Correlated Single Photon Counting



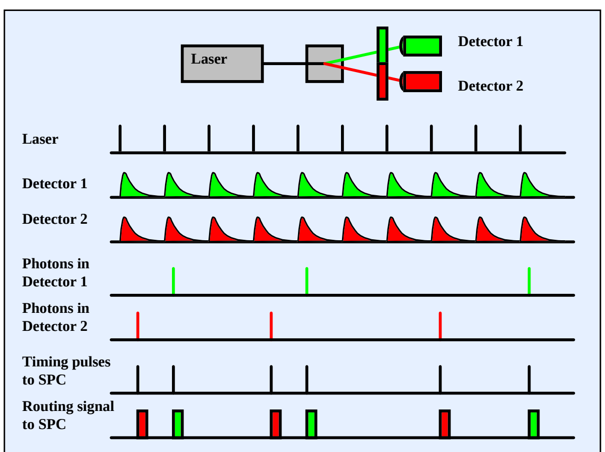
TCSPC works best for

High repetition rate signals (80 MHz)
Wavelength from 160 nm to 1000 nm

TCSPC yields

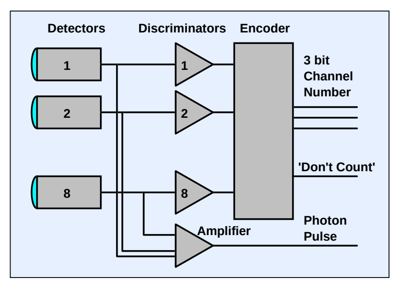
Ultra-high time resolution - 25 ps fwhm with the best detectors
Ultra-high sensitivity - down to the single photon level
High dynamic range - high linearity
Excellent Signal-to-Noise Ratio
Useful Count Rate > 5 MHz
Short measurement times

TCSPC Multi-Detector Operation

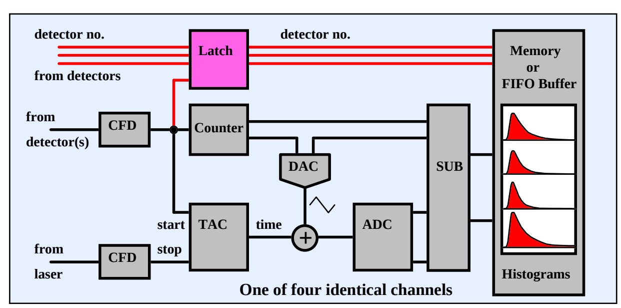


Principle of Multi Detector Operation

TCSPC Multi-Detector Operation



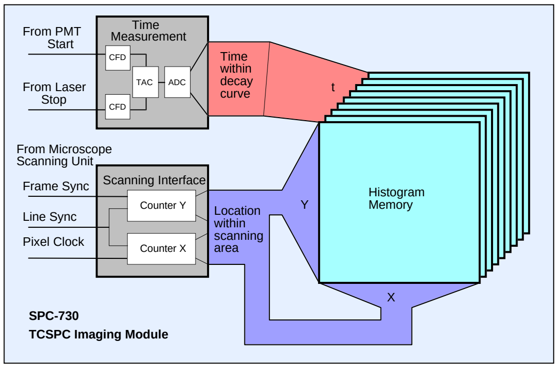
Detector interface for multi-detector operation



Multi-detector operation of the TCSPC module

- 8 detectors connected to one TCSPC channel
- All detectors work simultaneously
- 5 MHz useful overall count rate per TCSPC channel
- Counting efficiency same as for single detector at the overall channel count rate

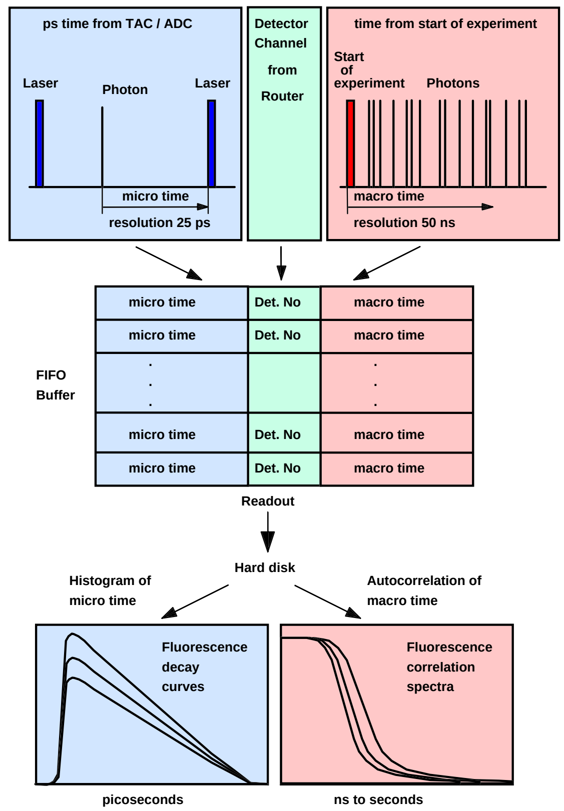
TCSPC Imaging



TCSPC Imaging yields:

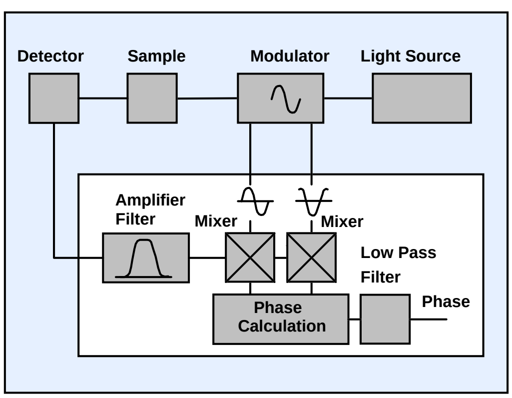
- Ultra-high time resolution - 25 ps fwhm with the best detectors
- Ultra-high sensitivity - down to the single photon level
- High dynamic range - high linearity
- Excellent Signal-to-Noise Ratio
- Count Rate > 3 MHz
- Short measurement times
- Compatible with fast scanning speed of an LSM

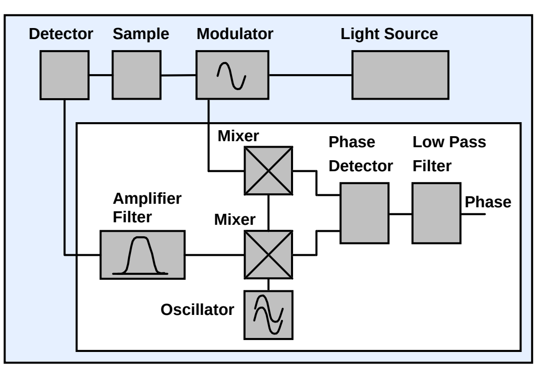
FIFO Mode for BIFL Measurement



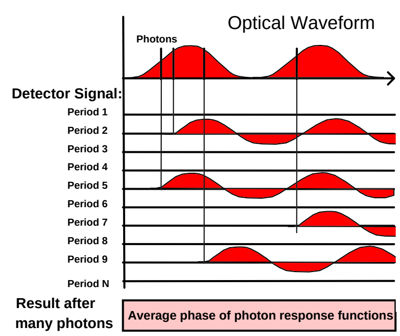
Modulation Technique

Phase Measurement

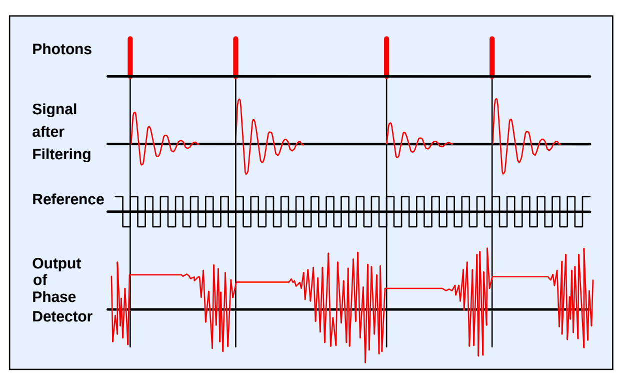




Phase Measurement for High Gain Detector Signals

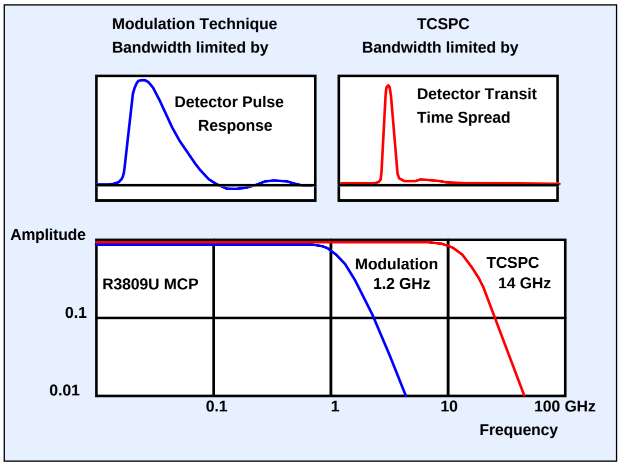


PMT Signals: The Phase Noise Disaster



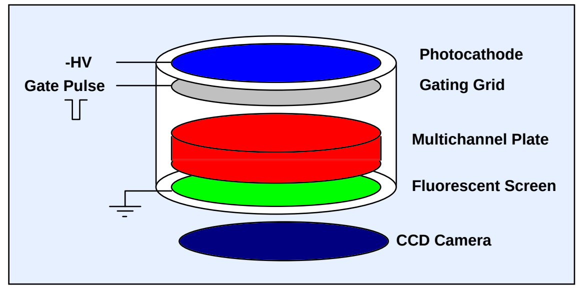
Phase detector delivers noise if no signal is present
Damatical decrease of SNR for low photon rates

Modulation Technique vs. TCSPC: System Bandwidth for PMTs



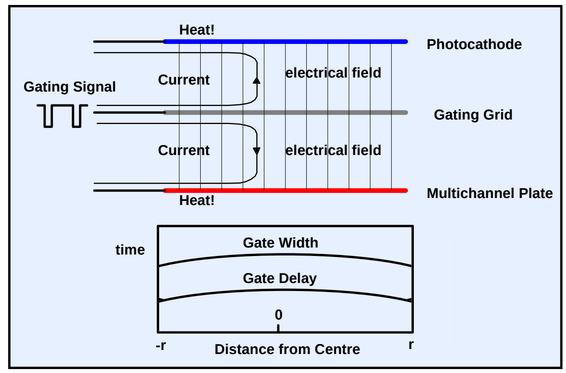
Sytem Bandwidth is higher for TCSPC

Gated Image Intensifiers



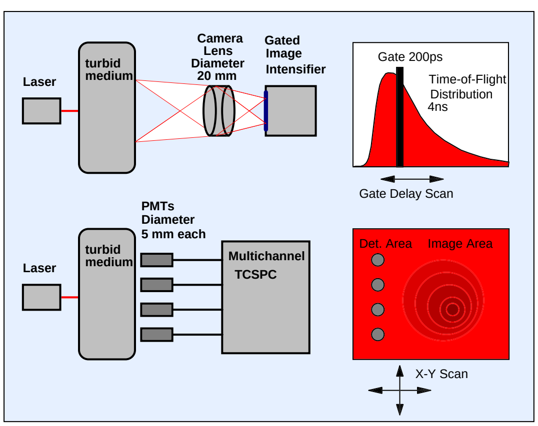
Full image in one shot
Time resolution by scanning the gate pulse
Gating discards most of the photons

High Speed High Repetition Rate Gating



Gated Image Intensifier versus TCSPC

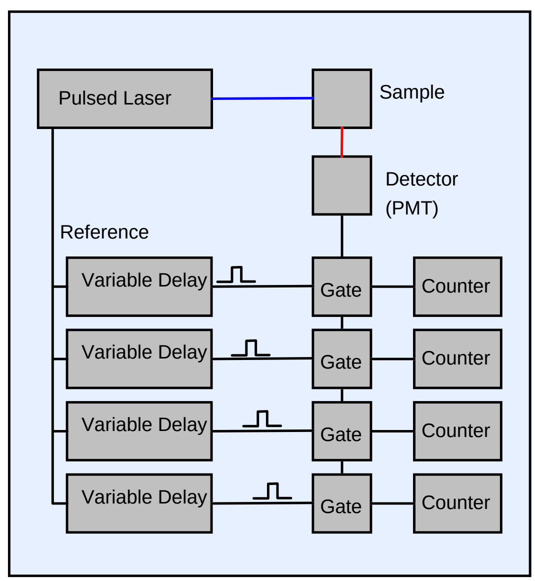
An Example from Optical Tomography



	Gated Img. Intensifier	TCSPC 1 Channel	TCSPC 8 Channels
Detector Area (mm^2)	314	20	160
Gate FWHM (ns)	0.2		
Distribution FWHM (ns)	4	4	4
Counting Efficiency	0.05	1	1
Counting Efficiency * Area (rel. No of Photons in Image)	15.7	20	160

Conclusion: TCSPC is more efficient than Gated Image Intensifier

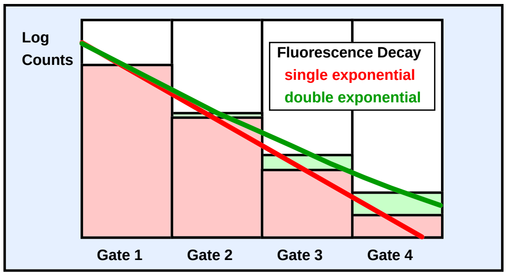
Multi-Gate Photon Counting



High count rate
High counting efficiency

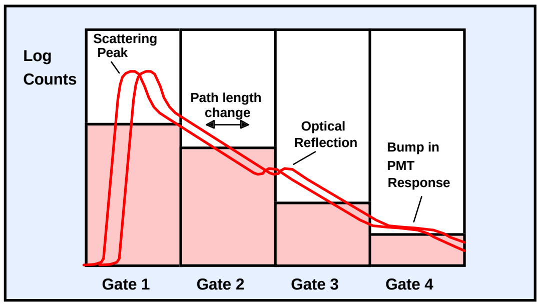
Low Time Resolution: 500ps per Channel
Imaging: Slow scan only. Local heating of sample when used in LSM
Aliasing problems due to small number of gates

Multi-Gate Photon Counting



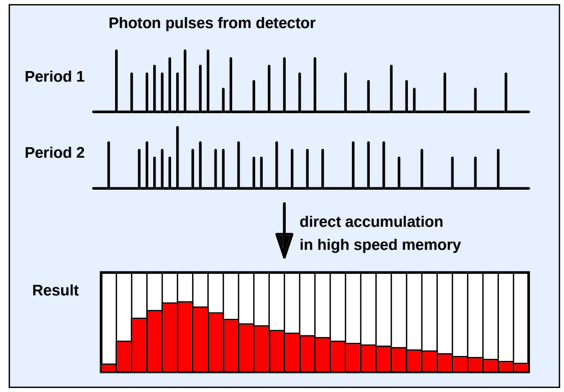
Single exponential decay: Calculated from ratio of two time windows
Double expeonential decay: Calculated from three time windows
Triple exponential decay: From four time windows

Non-ideal IRF: The Aliasing Problem



Details of IRF are heavily undersampled
Result depends on signal delay
Correct data analysis for short lifetime components impossible

Multiscalers



Ultra-high count rate - up to 1 GHz electronically
Many photons per shot
High counting efficiency
No dead time between bins
No dead time between sweeps
Up to 100,000s of time bins

Time resolution 1 ns per memory location
Single detector operation only
Imaging by slow scanning only (accumulate and step)
Danger of aliasing effects

Key Parameters

	Resolution	Efficiency	Photons / s	Imaging
TCSPC	25 ps	high	0 to 5 * 10^6	Fast and slow Scanning
Modulation Methods	25 ps	low	> 10^5	Slow Scanning
Gated Image Intensifiers	100 ps	low	0 to 50 * 10^6*	Wide Field
Multi-Gate Photon Counting	500 ps	high	0 to 50 * 10^6*	Slow Scanning
Multiscalers	1 ns	high	0 to 50 * 10^6*	Slow Scanning

* limited by detector

Typical Applications

TCSPC	Laser Scanning Microscopy, Two-Photon FLIM, Optical Tomography, Single Molecule Detection, Fluorescence kinetics, UV to NIR range
Modulation Technique	Measurements in the IR, Distance measurement
Gated Image Intensifiers	Wide-field illumination FLIM, UV to NIR
Multi-Gate Photon Counting	High count rate applications with medium time resolution, UV to NIR
Multiscalers	LIDAR, Luminescence of inorganic samples, Phosphorescence, TOF mass spectrometry

Boston Electronics Corporation, 91 Boylston St, Brookline MA 02445 USA * (800)3477-5445 or (617)566-3821 * fax (617731-0935 * tcspc@boselec.com

	SPC-630	SPC-730	SPC-830	SPC-134	Time Harp 200
Target Application	Standard lifetime experiments Single Molecule Detection Stopped Flow Correlation Experiments FCS Experiments	Standard lifetime experiments, Lifetime imaging, Confocal and two-photon scanning Microscopy Multi parameter experiments Stopped Flow	Standard lifetime experiments, Lifetime imaging, Confocal and two-photon scanning Microscopy Multi parameter experiments Stopped Flow Single Molecule Detection Correlation Experiments FCS Experiments	Optical tomography Single Molecule Stopped Flow Correlation Experiments FCS Experiments	Standard lifetime Single Molecule Microscope with scan stage Correlation Experiments FCS Experiments
No. of TCSPC Channels	1	1	1	4	1
Modules operable in parallel	4 x SPC-630	4 x SPC-730	4 x SPC-830	1 x SPC-134	
Conversion Principle	TAC - ADC with error reduction Patent DE 43 39 784 A1	TAC - ADC with error reduction Patent DE 43 39 784 A1	TAC - ADC with error reduction Patent DE 43 39 784 A1	TAC - ADC with error reduction Patent DE 43 39 784 A1	Time-to-Digital Converter
Detector Channel Sync Channel	Constant Fraction Constant Fraction	Constant Fraction Constant Fraction	Constant Fraction Constant Fraction	Constant Fraction Constant Fraction	Constant Fraction Level Trigger
Time Resolution	820 fs per time channel	820 fs per time channel	820 fs per time channel	820 fs per time channel	40 ps per time channel
Diff. nonlinearity	0.6% to 1% pp, <0.5% rms	0.6% to 1% pp, <0.5% rms	0.6% to 1% pp, <0.5% rms	0.6% to 1% pp, <0.5% rms	<6%pp, <0.5% rms
Detectable Lifetimes	2 ps to 2µs	2 ps to 2µs	2 ps to 2µs	2 ps to 2µs	<100ps to 4.5µs
Histogramming Process	Hardware, on board histogram memory	Hardware, 4-dimensional, on board histogram memory	Hardware, 4-dimensional, on board histogram memory	Hardware, on board histogram memory	Hardware, on board histogram memory
Image size for fast scan modes		max. 256 x 256 pixels	max 4096 x 4096 pixels		
Dead Time	125 ns	180 ns	125 ns	125 ns	<350 ns
Useful continuous count rate, Histogram Modes, 50% loss, per module	4 MHz	2.8 MHz	4 MHz	16 MHz (overall for 4 channels)	1.4 MHz
Peak Count Rate, histogram modes, 50% loss, per moduel	4 MHZ	2.8 MHz	4 MHz	16 MHz (overall for 4 channels)	1.4 MHz
Continuous count rate, time-tag modes	0.4...0.8 MHz, depends on computer speed and background activity		3...4 MHz, depends on computer speed and background activity	0.4...0.8 MHz, depends on computer speed and background activity	Depends on computer speed and background activity
Peak count rate, time-tag modes, 50% loss	4 MHz independent of computer speed		4 MHz independent of computer speed	16 MHz independent of computer speed	Depends on computer speed and background activity
on-board FIFO buffer size, time tag modes	128,000 photons or 256,000 photons		8 Million photons	512,000 photons	128,000 photons
Macro time resolution in time tag (FIFO) modes	50 ns		50 ns from internal clock or 12ns to 100 ns from sync (laser)	50 ns from internal clock or 12ns to 100 ns from sync (laser)	100ns
Scan rate, Scan syn in mode		down to 100ns per pixel independent of computer speed	down to 100ns per pixel independent of computer speed		
Multi-Detector Operation	yes Patent DE 43 39 787 A1	yes Patent DE 43 39 787 A1	yes Patent DE 43 39 787 A1	yes Patent DE 43 39 787 A1	yes
No of curves in memory	2 x 64 to 4096	1024 to 65,536	4096 to 2,000,0000	2 x 32 to 2 x 2048 per TCSPC channel	2 x 32
Min. time per histogram	1µs in continuous flow mode	100ns in scan sync in/out mode	100ns in scan sync in/out mode	1µs in continuous flow mode	1µs in ext sync mode

	SPC-630	**SPC-730**	**SPC-830**	**SPC-134**	**Time Harp 200**
Available multi-detector extension devices for	4 MCPs, 4 PMTs 8 MCPs, 8 PMTs 8 APDs 16 channel pmt head	4 MCPs, 4 PMTs 8 MCPs, 8 PMTs 8 APDs 16 channel pmt head	4 MCPs, 4 PMTs 8 MCPs, 8 PMTs 8 APDs 16 channel pmt head	4 MCPs, 4 PMTs 8 MCPs, 8 PMTs 8 APDs	4 APDs
Operating Modes	Single Oscilloscope 2 dimensional f(xyt) Sequence f(t,T), fi(t,ext) Spectrum fi(T), fi(ext) Continuous Flow (unlimited seq.) Time Tag (FIFO)	Single Oscilloscope 2 dimensional f(xyt) Sequence f(t,T), fi(t,ext) Spectrum fi(T), fi(ext) Imaging (Sync In, Sync Out, XY in, XY out)	Single Oscilloscope 2 dimensional f(xyt) Sequence f(t,T), fi(t,ext) Spectrum fi(T), fi(ext) Imaging (Sync In, Sync Out, XY in) Time Tag (FIFO)	Single Oscilloscope 2 dimensional f(xyt) Sequence f(t,T), fi(t,ext) Spectrum fi(T), fi(ext) Continuous Flow (unlimited seq.) Time Tag (FIFO)	Integration Oscilloscope Sequence f(t,T) Contiuous Time-tag (Option)
Experiment Trigger	Start of measurement Start of sequence Each step of sequence	Start of measurement Start of sequence Each step of sequence Frame Clock, Line Clock, Pxl Clock	Start of measurement Start of sequence Each step of sequence Frame Clock, Line Clock, Pxl Clock	Start of measurement Start of sequence Each step of sequence	Start of measurement Start of sequence
Triggered accumulation of sequences	yes	yes		yes	yes
Detector / Experiment control (Own products only)	Preamplifiers with detector overload protection, PMH-100 Detector modules, PML-16 multichannel detector head, DCC-100 Detector Controller , STP-340 Step Motor Controller, Routers for MCPs, PMTs, APDs, Dual ADC module for XY In operation	Preamplifiers with detector overload protection, PMH-100 Detector modules, PML-16 multichannel detector head, DCC-100 Detector Controller , STP-340 Step Motor Controller, Routers for MCPs, PMTs, APDs, Dual ADC module for XY In operation, Adapters for Zeiss, Leica, Olympus and Biorad laser scanning microscopes	Preamplifiers with detector overload protection, PMH-100 Detector modules, PML-16 multichannel detector head, DCC-100 Detector Controller , STP-340 Step Motor Controller, Routers for MCPs, PMTs, APDs, Dual ADC module for XY In operation, Adapters for Zeiss, Leica, Olympus and Biorad laser scanning microscopes	Preamplifiers with detector overload protection, PMH-100 Detector modules, PML-16 multichannel detector head, DCC-100 Detector Controller , STP-340 Step Motor Controller, Routers for MCPs, PMTs, APDs	Preamplifiers with detector overload protection, Routers for APDs
Free Documentaion available on web site	SPC Manual, 165 pages; TCSPC Introduction, 5 pages; Upgrading laser scanning microscopes for lifetime imaging; Controlling SPC modules; Protecting Photomultipliers; FRET measurements by TCSPC lifetime microscopy; Multi-wavelengthe TCSPC lifetime imaging; High count rate multichannel TCSPC for optical tomography; Optical Tomography: TCSPC Imaging of Female Breast; Setting up High Gain Detector Electronics for TCSPC Applications; Testing SPC Modules; 16 Channel Detector Head for TCSPC Modules; Routing Modules for Time-Correlated Single Photon Counting; Detector Control Module DCC100 Manual; **TCSPC Software is available and FREE**; Manual: Multi - SPC 32 bit Dynamic Link Library				Measurement examples
Related Products (Own products only)	SPC-300, SPC-330 TCSPC; SPC-400, SPC-430 TCSPC; SPC-500, SPC-530 TCSPC; MSA-100 1ns multiscaler; MSA-300 5ns multisclaer; PMS-400 and PMM-328 Gated photon counters / multiscalers; Picosecond Diode Lasers				Time Harp 100 Picosecond Diode Lasers