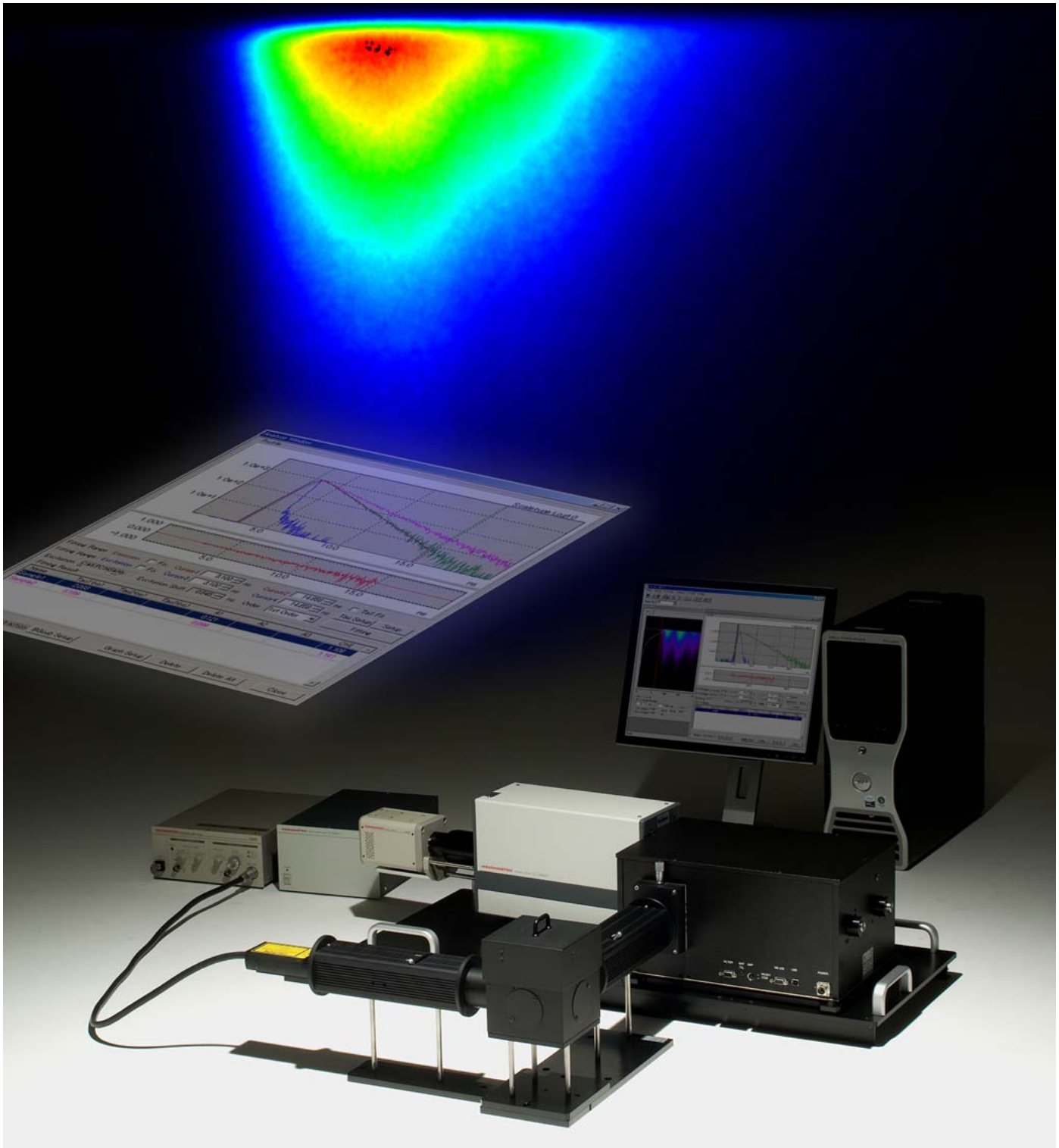
Picosecond Fluorescence Lifetime Measurement System C11200

Captures fluorescence phenomena with 5 ps temporal resolution using 2D photon counting method. Enables simultaneous fluorescence lifetime analysis and time-resolved spectrophotometry.



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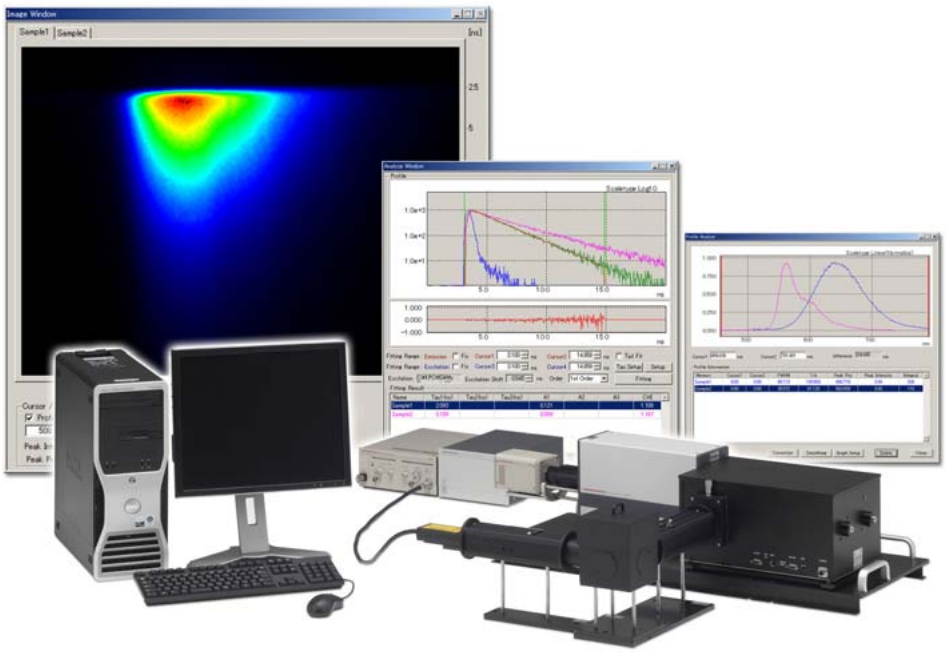


Directly captures temporal variations of laser-excited fluorescence with 5 ps resolution.

The current emphasis on development of new photofunctional materials has focused research attention on many basic photochemical experiments and measurements.
Among the more common are studies on structural changes in molecules caused by photo-excitation, electronic energy transfer, formation of molecular complexes, electron transfer and proton transfer.
An example of research on light-induced structural changes in molecules is the study of the photochromic phenomenon a reversible change in color state induced by light excitation and caused by an isomerization reaction due to a fluorescence state.
This phenomenon is being studied in the development of organic light recording materials.
For evaluating the dynamic structure of very thin, functional organic films such as LB films, liquid crystal, deposition films, etc., the study of electronic energy transfer and the formation of molecular complexes is important.
In addition, it is expected that electron transfer and proton transfer will be actively studied in the development of photofunctional materials of the 21st century. Understanding such initial-stage chemical reactions at the molecular level is, in fact, becoming an important subject in the biophysics and bio-chemistry fields.

On the other hand, in the fields of semiconductor physics and nonlinear optics, studies of basic photonic phenomena such as the relaxation process of an exciton are becoming essential in the development of materials for fast-response optical switches and light-emitting elements the core of ultra-fast optical calculation and data processing.
The most effective method for studying these initial stage phenomena in photophysics and photochemistry is obviously the direct measurement of the ultra-fast light excitation process itself. What is required is time-resolved spectrophotometry capable of capturing a spectrum in the photoexcited state, and studying its dynamic behavior with a time resolution of nanoseconds and picoseconds.
The Hamamatsu Picosecond Fluorescence Lifetime Measurement System has been developed in response to the requirements of researchers studying such materials. The use of a "streakscope", an optical transient recorder with picosecond time response, makes ultra-fast time-resolved spectrophotometry a reality.
The use of streakcamera technology allows detection sensitivities in the photon counting region. For simultaneous wavelength and time measurements, a spectrograph can be added to the system. Measurement parameters such as wavelength and time settings are controlled by a computer for simplified laboratory use.

Applications

- **Study of initial stages of photophysics and photochemistry**
- **Study of microscopic environments and dynamic structures of surfaces and interfaces**
- **Study of dynamic structures of 2D molecular aggregates such as macromolecule film, LB film, liquid crystal, and deposition film**
- **Study of exciton dynamics and quantum size effect** (for example, semiconductor doped glass and quantum wire)
- **Time-resolved fluorescence and phosphorescence spectrum evaluation of organic LED materials**
- **Study of photonic crystals**
- **Study, evaluation, and inspection related to fluorescence lifetime measurements in various other fields**

Fluorescence phenomena at multiple wavelengths can be measured simultaneously.

Features

5 ps temporal resolution

The system uses a streakscope that can achieve a temporal resolution of 15 ps. Through deconvolution processing, a temporal resolution of 5 ps is obtained.

Simultaneous multi-wavelength measurement

Time-resolved spectrum is acquired in a very short time since fluorescence lifetimes are measured over multiple wavelengths without scanning.

Two-dimensional photon counting

Ultra-high sensitivity and simultaneous multiple-wavelength measurement capabilities are realized by the combination of photon counting and streakcamera techniques. Because fluorescence phenomena at multiple wavelengths can be measured simultaneously, even very-low fluorescence can be detected and measured with high efficiency, a feature not available with previous methods.

A wide dynamic range better than 100 000 : 1

Measures very-low fluorescence with a dynamic range better than 100 000 : 1. This allows the an analysis of multi-component fluorescence lifetime with high accuracy.

Measures fluorescence lifetime with good S/N ratio with short integration time

The streak sweep can be operated at up to 20 MHz. Through integration of this high-speed repetitive sweep, measurement with a high S/N ratio can be carried out quickly.

Covers fluorescence phenomena from picoseconds to milliseconds

Because the sweep time can be varied from 1 ns to 10 ms, a wide range of fluorescence lifetime measurements from picoseconds to milliseconds is possible. For higher temporal resolution, an universal streak camera is optional selection.

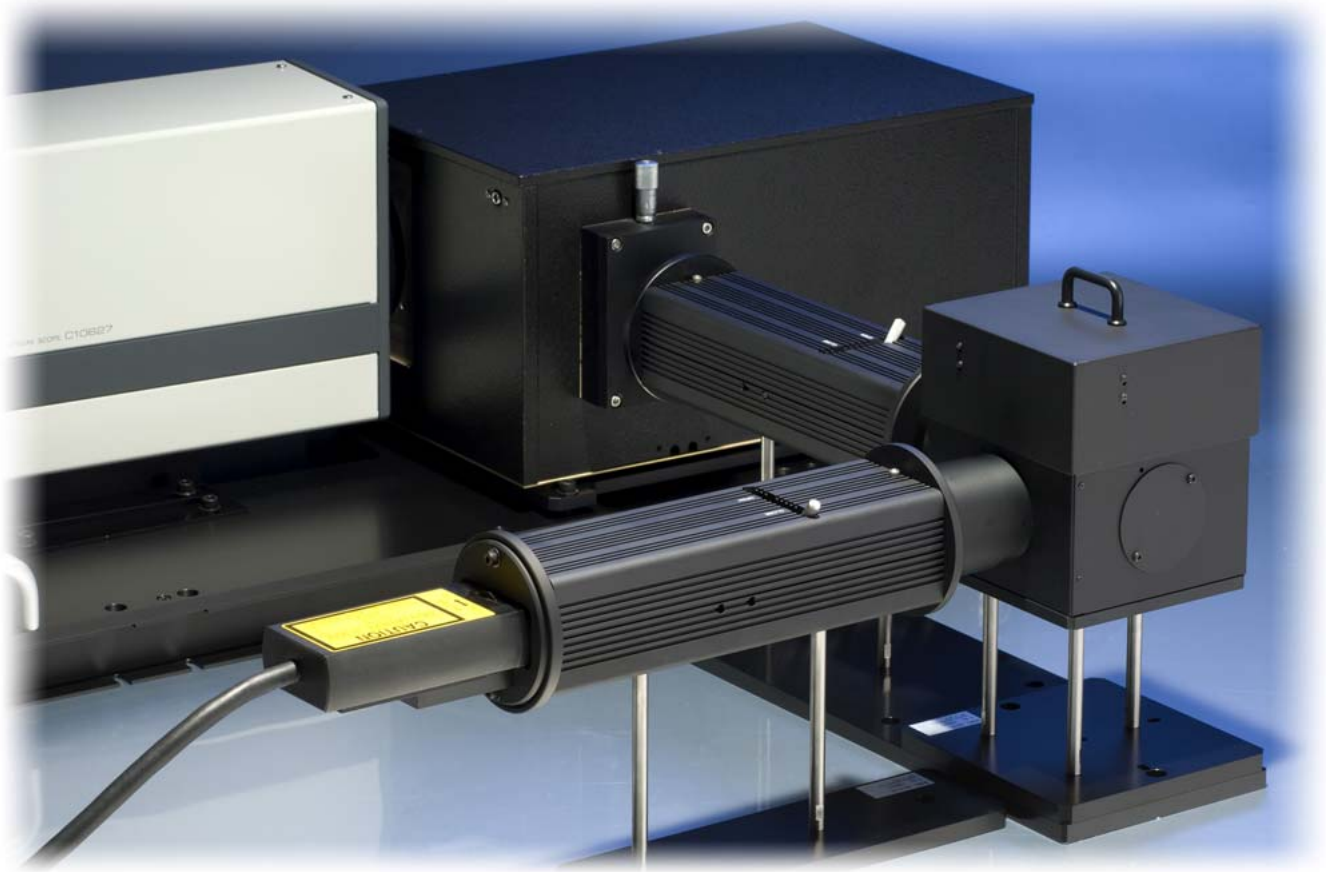
Covers a wide wavelength range from UV to NIR

Two streakscopes are available, with sensitive regions of 200 nm to 850 nm or 400 nm to 900 nm. NIR streak camera is the optional for the measurement from 1000 nm to 1650 nm.

High-precision measurement due to a temperature controlled picosecond laser diode

As an excitation light source, picosecond laser diodes are available. Of course, other types of lasers can also be used.

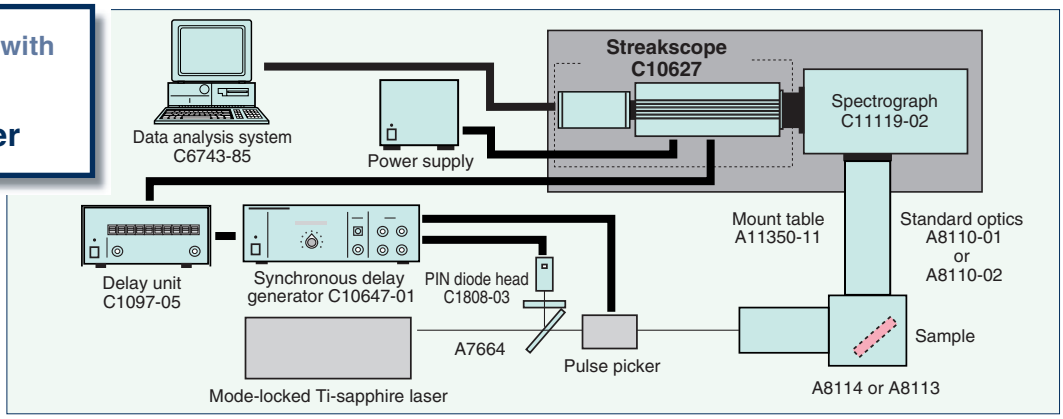
Standard optical system allows easy optical alignment



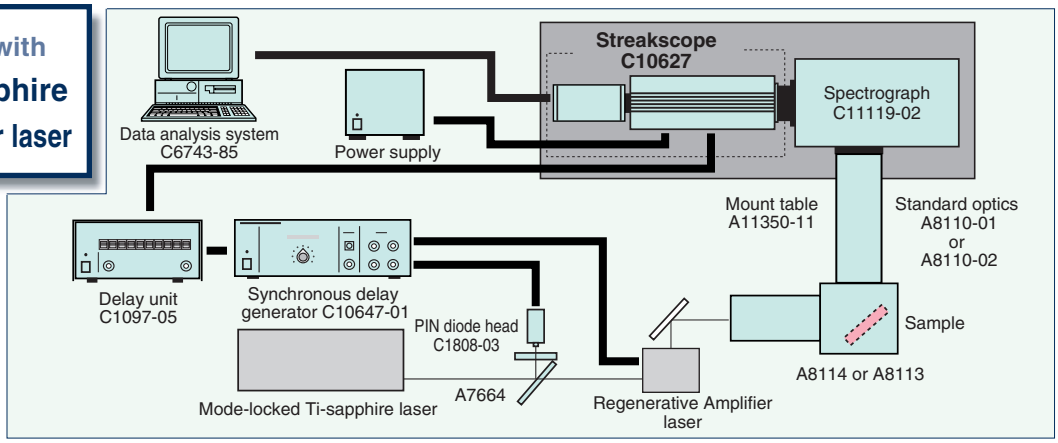
Flexible system configuration supports various types of fluorescence phenomena

System configuration

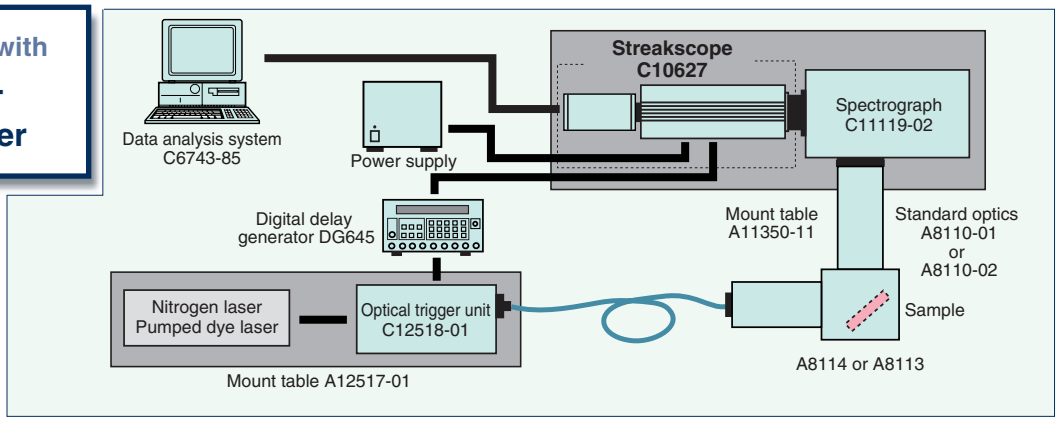
Example when used with
Mode-locked Ti-sapphire laser



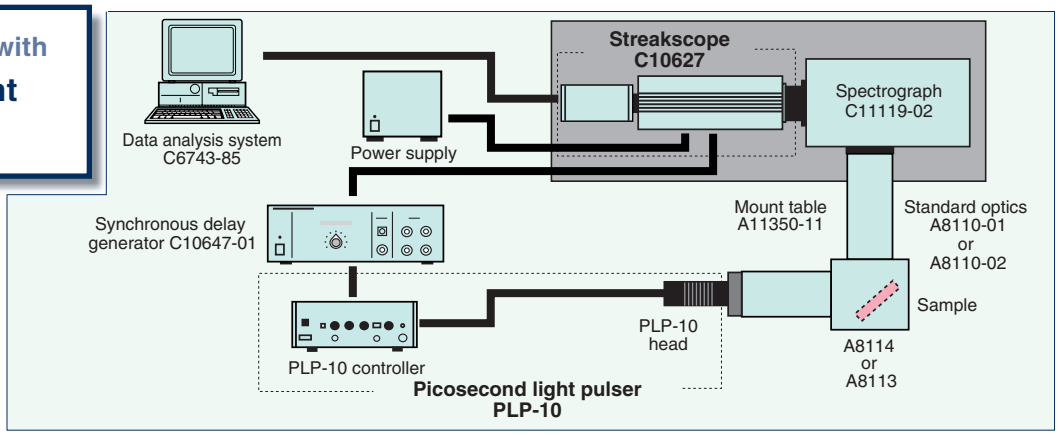
Example when used with
Mode-locked Ti-sapphire + Regenerative Amplifier laser



Example when used with
Nitrogen-laser-Pumped dye laser



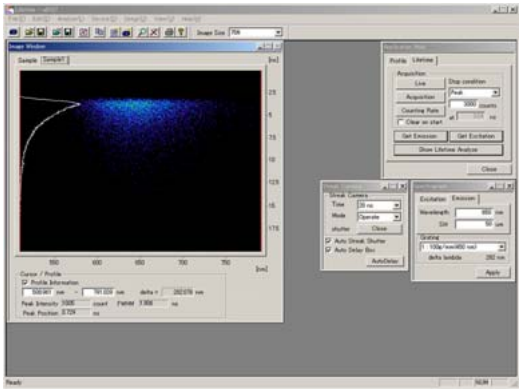
Example when used with
Picosecond light pulser PLP-10



Fluorescence lifetime measurement software with enhanced functions

Fluorescence lifetime measurement software

Measurement screen



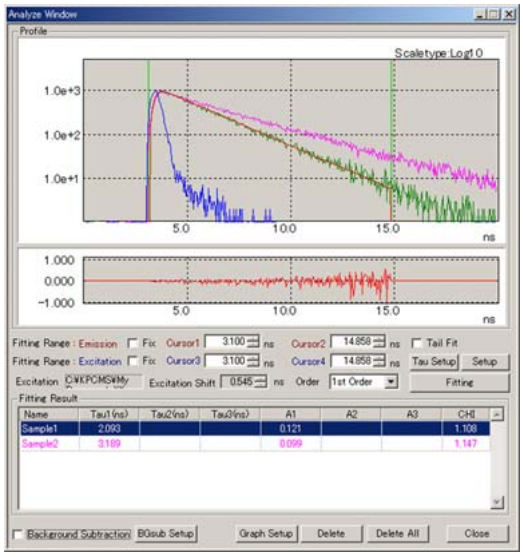
Controls a streakcamera, a spectrograph and a delay generator from a PC.

The streakcamera, spectrograph and delay generator control windows are displayed on the PC monitor, which make it easy to change measurement parameters such as time scales and monitor wavelength selection. The "Auto delay" function eliminates the need to adjust the timing for each time scale even when the scale was changed.

Real-time display of time profiles and spectrum

Time profiles or spectrum are displayed on the monitor screen in real-time. This is a useful function for selecting the time scale during measurement or determining the analysis data range.

Lifetime analysis



Multi-component analysis

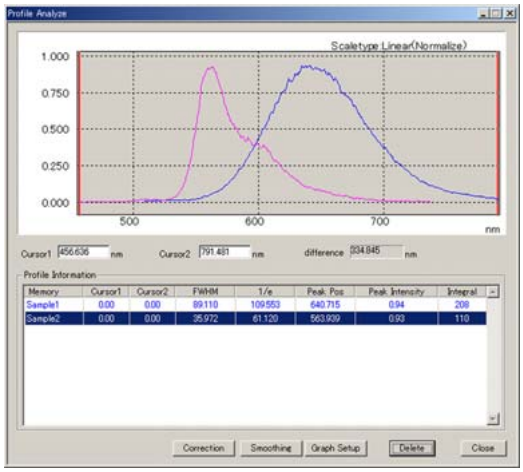
Multiple data analysis on the same screen

Calculated fluorescence lifetime values are also displayed on the same screen for easy comparison analysis.

Highly accurate analysis by deconvolution

Deconvolution processing enables fluorescence lifetime analysis with high accuracy. When analyzing longer lifetime components such as phosphorescence, the "Tail Fit" function can be used instead of deconvolution processing.

Profile analysis



Time-resolved spectrum display

Allows time-resolved spectrum display the greatest feature offered by streakcamera systems.

Spectrum and fluorescence decay curve display

Displays the full width at half maximum (FWHM), peak position and peak intensity for each profile

Multiple data loading and comparison on the same screen.

Normalized processing makes multiple data comparison easy.

The streakscope enables time-resolved photon counting at multiple wavelengths in a single measurement.

Operating principle, functions and performance

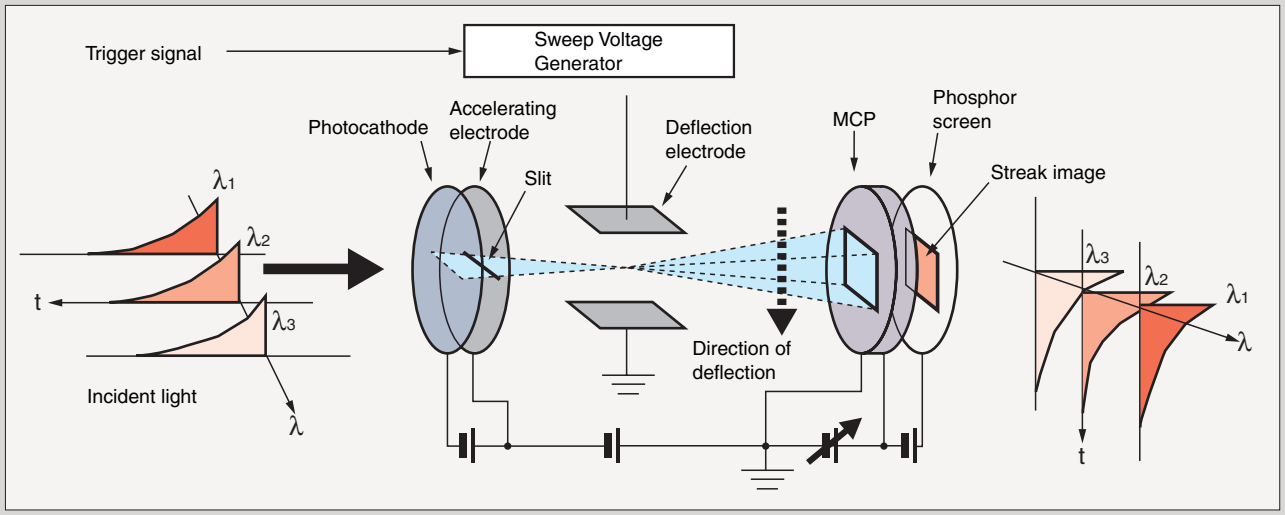


Figure 1: Operating principle of the streakscope

1. Principle of streak method

This section explains the principle and features of fluorescence lifetime measurements using the streakscope C10627. (In the following description, this method is simply called the "streak method").

The heart of the streakscope is an electron tube called the "streak tube". Figure 1 shows the operating principle of a streak tube. When fluorescence pulses enter the photocathode, they are converted into photoelectrons in proportion to the number of incident photons. Being accelerated by the accelerating electrode, these photoelectrons pass through a pair of deflection plates. At the instant they pass through the deflection plates, a high-speed sweep voltage is applied to the deflection plates so that the photoelectrons' trajectories are swept from top to bottom.

The swept photoelectrons are then multiplied in the microchannel plate (MCP) by a factor of 10^4, and reconverted into an optical image by the phosphor screen. The optical image produced on the phosphor screen is called the "streak image". In this way, time is converted into the spatial axis (vertical axis): thus, the time in which the photons reached the photocathode and the intensity can be determined by the position and luminance of the streak image. In addition, because the position information in the horizontal direction on the photocathode is contained in the horizontal direction of the streak image, if a spectrograph is used to focus a spectrum onto the photocathode, a streak image can be obtained in which the vertical axis serves as the time axis and the horizontal axis as the wavelength axis, and in which the luminance is proportional to the intensity on the phosphor screen.

The streak images thus obtained are read out by a CCD camera coupled to the streak tube. To perform data measurement with a high S/N ratio, the read-out streak images are integrated in a memory of computer. In this case, there are two methods of integration: 1) the analog integration method, in which the output signal from the CCD camera is directly integrated to create an image, and 2) the photon counting method, in which the signal is separated from noise by setting a threshold level, and only the signal is integrated. (See Section 2.) By using these two methods properly, a wide variety of fluorescence intensity can be measured, ranging from extremely weak fluorescence, for example, in cases where only one photon is detected as a result of hundreds of excitations, to bright fluorescence which is visible to the human eye.

The above figure shows the principle how intensity profiles are extracted from a time-resolved spectrum image. After the full spectrum has been recorded, the fluorescence decay curves can be extracted at arbitrary wavelength bands by just placing vertical sampling windows at the desired positions. Alternatively, by using horizontal windows, it would also be possible to extract spectral profiles at various time positions and "gate" lengths.

2. Principle of photon counting method using streakscope

The photoelectrons emitted from the photocathode of the streak tube are multiplied by the MCP with a high gain. One photoelectron can be observed as one light spot produced on the phosphor screen.

This photoelectron image is read out by a CCD camera, and then undergoes digitization. Because the noise level of the CCD is exceptionally low, the photoelectron image can be clearly separated from the noise by setting a threshold level. Figure 2 shows this threshold level setting.

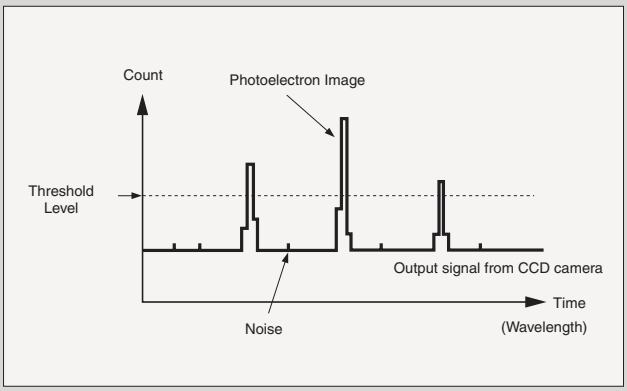


Figure 2: Separating the photoelectron image from noise

With the threshold set at an appropriate level, detecting the position of the photoelectron image and integrating it in the memory allow data measurement with a high S/N ratio, wide dynamic range. Moreover, this photon counting method is carried out over the entire surface of the 2 dimensional streak image, enabling photon counting measurement to be made at simultaneous multiple wavelengths. Also, even if multiple photoelectrons are produced by one excitation, they can be counted. Consequently, in the case of time-resolved spectrophotometry, the streak method offers high-sensitivity measurement which is two orders of magnitude higher than the conventional time-correlated single photon counting method requiring a wavelength scan in a spectrograph for wavelength isolation.

3. Functions of the streakscope

The streak method offers the following features:

- **High temporal resolution**
- **Wide dynamic range and high S/N ratio due to photon counting integration**
- **Simultaneous multiple-wavelength measurement for fluorescence lifetime analysis and time-resolved spectrophotometry**

[High temporal resolution]

Conventional time-correlated single photon counting methods using a photomultiplier tube have proven inadequate in fluorescence lifetime measurement and rise-time analysis in the order of subnanoseconds, because temporal resolution is limited to about 1 ns and the signal waveform may be distorted by the TTS (photoelectron transit time spread) of the photomultiplier. The streakscope C10627 used with the streak method has a superior temporal resolution of better than 15 ps, and furthermore, it is free of waveform distortion. (Figure 3 shows the device function of the streakscope C10627.) As seen from the figure, the device function is negligibly small. Therefore, the streak method is capable of fluorescence lifetime measurement and rise-time analysis from several picoseconds to nanoseconds with high accuracy, both of which have been difficult with conventional methods. The streak sweep time is switchable between 1 ns and 10 ms full scale, allowing a wide range of fluorescence analysis from picoseconds to milliseconds.

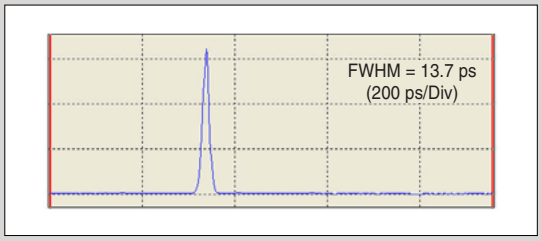


Figure 3: Device function of the streakscope C10627

[Wide dynamic range and S/N ratio due to photon counting]

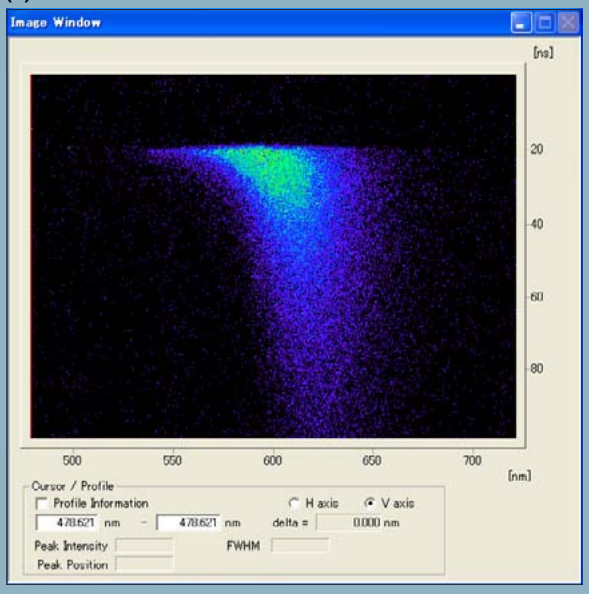
In addition to high temporal resolution, the streakscope features high sensitivity and a wide dynamic range.
In photon counting integration, a major factor that determines the detection limit of the light level is the dark current (noise) of the photocathode. The photocathode dark current of the C10627 is smaller than that of the photomultiplier tube used in the conventional time-correlated single photon counting method by 3 orders of magnitude: thus, the streak method offers a high S/N ratio in measuring even very low fluorescence. Also, low dark current assures a low noise level, thereby easily achieving a wide dynamic range better than 100 000 : 1. This enables multi-component fluorescence lifetime analysis to be made with high accuracy. On the other hand, in cases where fluorescence intensity is so high that it may saturate in the photon counting method, the C10627 can be switched from the photon counting integration method mode to the analog integration mode, making possible highly efficient measurement without reducing the signal light level. Consequently, the C10627 is the most ideal device currently available in optical measurements.

[Simultaneous multiple-wavelength measurement]

As explained in the section on "Principle of Streak Method", the combination of the C10627 with a spectrograph enables simultaneous multiple wavelength measurement to be made. In conventional time-correlated single photon counting, because simultaneous multiple-wavelength measurement is not possible, the wavelength range to be observed must be scanned for time-resolved spectrophotometry and multiple-wavelength fluorescence lifetime analysis. These measurements sometimes require several hours. As the streakscope C10627 is capable of simultaneous multiple-wavelength measurement without doing the wavelength scan in the spectrograph, it greatly reduces the time needed to obtain a time-resolved spectrum. In particular, this will prove dramatically effective when fluorescence is very low.

Measurement examples

(a)



(b)

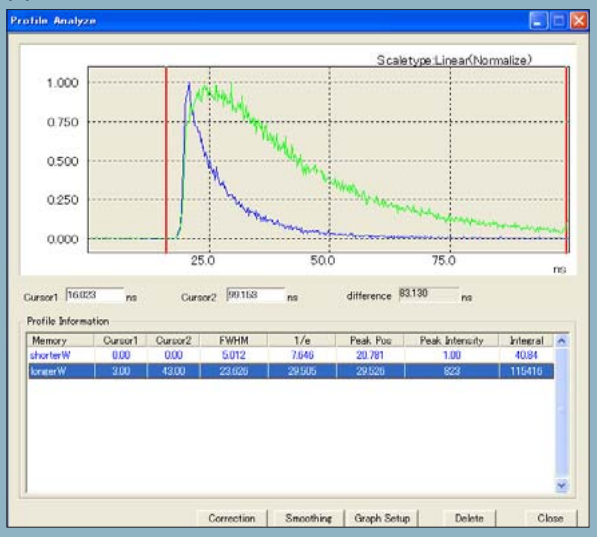


Figure 4: Colloidal quantum dots (CdSe/ZnS Core/Shell structure)
(a) Streak image of time-resolved luminescence spectra.
(b) Decay curves at different wavelength ranges.

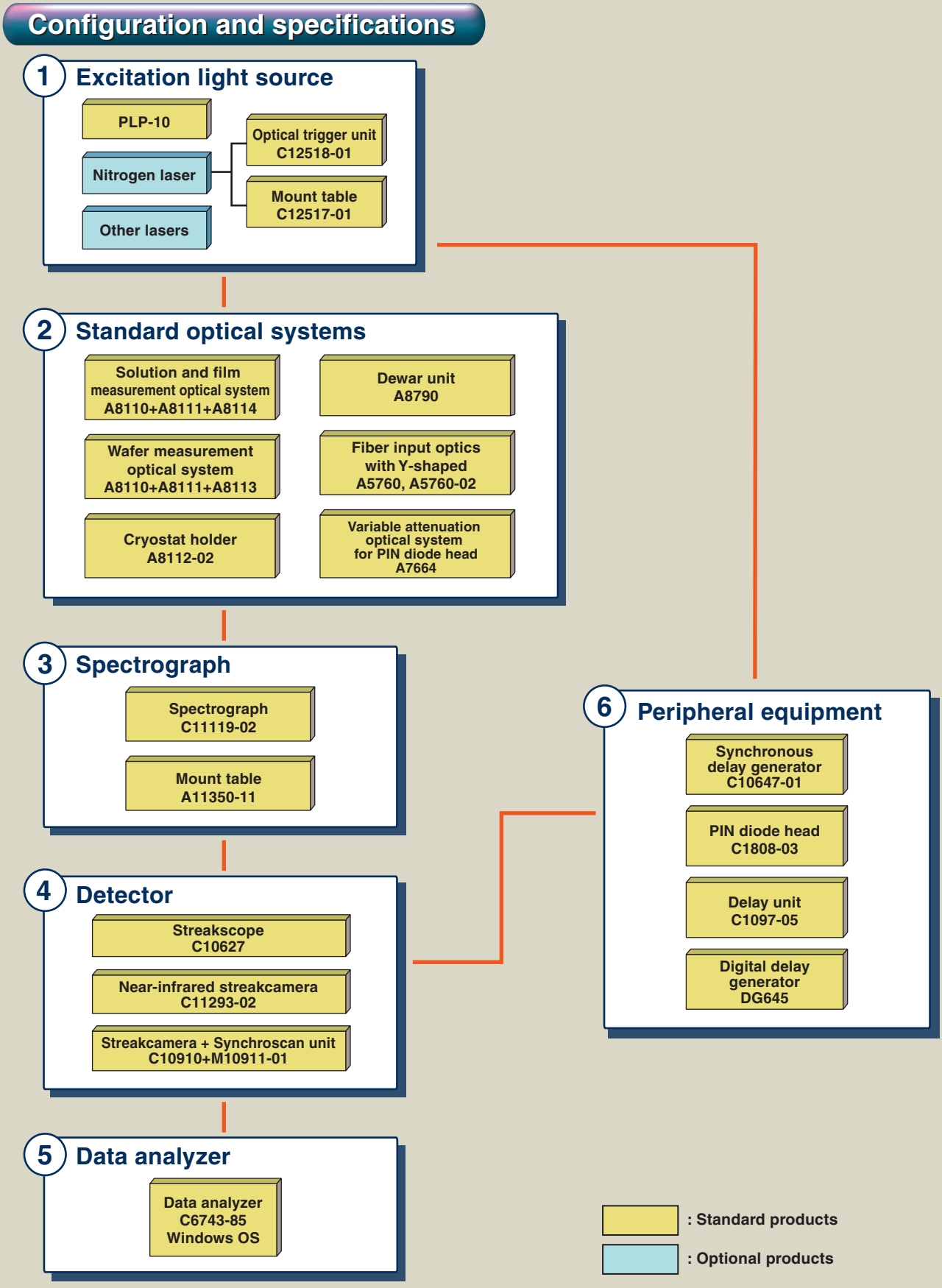
- The lifetime of QDs at different longer wavelength (600 nm to 670 nm) is longer than that of shorter wavelength (540 nm to 600 nm). The lifetime distribution does not correspond to the photoluminescence peak distribution.

This novel material is expected to be applied for fluorescent material, LED material, single photon source, and bio-labeling. These results open the possibility to experimentally study the behavior of exciton dynamics of colloidal QDs including energy transfer between QDs.

*Data produced by Professor Yong-Hoon Cho
Nano-Bio-Photonics Laboratory, Dept. of Physics,
Korea Advanced Institute of Science and Technology (KAIST), Korea

The optimum system can be tailored to your samples by selecting the excitation light source, optics, spectrograph, etc.

Configuration and specifications



1 Excitation light source

To excite a specimen, various pulsed light sources are provided.

● Picosecond light pulser PLP-10

The PLP-10 is a picosecond light pulser using a temperature controlled laser diode. It is virtually maintenance-free and generates stable picosecond pulsed light over a long period of time.

● Laser diode head M10306

Type	Laser diode (temperature-controlled)
Laser wavelength*	375 nm, 405 nm, 445 nm, 465 nm, 483 nm, 510 nm, 655 nm, 785 nm, 850 nm, 980 nm
Output pulse width	70 ps ～
Repetition rate	max. 100 MHz
Peak power (typ.)	10 mW to 100 mW (It depends on each laser head.)

* Select one wavelength from among these wavelengths.

● Other excitation light sources

Besides the PLP-10 above, various types of excitation light sources can be used according to the specimens to be measured. These include a nitrogen-laser-pumped dye laser, semiconductor-laser-pumped Q-switched YAG laser, and mode-locked laser.

● Optical trigger unit C12518-01

C12518-01 generates trigger signal synchronized with pulsed laser being input, and output pulsed laser light through an optical fiber which transmits UV light. For use in combination with C12518-01, C10627 streak camera and laser such as nitrogen laser which generate relatively high trigger jitter.

Optical fiber	UV transmission fiber
Time range	1 ns to 200 ns/full scale*
Output impedance	50 Ω
Output signal	TTL

* The time range is for use in the combination with C10627 streak camera, if you require longer time range, please contact.

● Mount table A12517-01

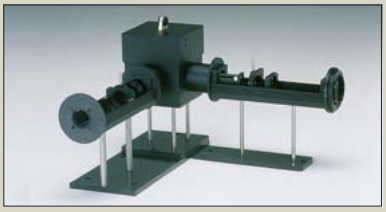
The A12517-01 is a mount table for coupling an optical trigger unit and a nitrogen laser.

2 Standard optical systems

Various optical systems are available for solution and solid state specimens. Select from the list below the optical system that best matches the specimen of interest. Fiber optics and excitation light guide adapters for microscopes are also available. Please consult Hamamatsu should the specimen of interest require temperature control.

A8110-01	Standard optics (370 nm～)
A8110-02	Standard optics for UV (200 nm～)
A8111	Base plate for standard optics
A8112-02	Optistat DN* cryostat holder
A8113	Semiconductor wafer holder
A8114	Organic chemistry sample (solution and film) holder
A8790	Dewar unit (330 nm～)
A7664	Variable attenuation optical system for PIN diode head
A5760	Fiber input optics with Y-shaped for nitrogen laser
A5760-02	Fiber input optics with single fiber (3 m)

* Cryostat manufactured by Oxford.
Aside the above optical systems, we also design custom optical systems ideal for the specimens of interest. Your own optical systems can also be used.



◀ A8110 and A8114

▲A8113

▲A8790

The streakscope C10627 can be controlled by a personal computer.

3 Spectrograph

● Spectrograph C11119-02

The C11119-02 is a Czerny-Turner type spectrograph with a focal length of 300 mm and an aperture of F/4. Due to the aberration-corrected optics, it is highly efficient in focusing light to the streakscope detector, enabling high-sensitivity measurements.
More than twenty optional gratings are available for the C11119-02, and up to three gratings can be installed at one time.
Grating and wavelength selection is controlled by the integrated streakscope software, in addition to the entrance slit width, for fine control of incident light.

Optics system	Czerny-Turner type (with aberration-corrected toroidal mirror)
Focal length	Collimating 300 mm
Aperture ratio	F/4
Incident slit	Variable between 10 μm and 3000 μm
Grating mount	Grating mount accommodates up to 3 gratings. (It is possible to add turret as an optional extra.)

● Gratings (typical examples)

No. of Grooves	Blaze Wavelength	Wavelength Range	Measurement Wavelength Range *	Resolution
40 g/mm	500 nm	335 nm to 750 nm	Approx. 316 nm	Approx. 5.1 nm
50 g/mm	600 nm	400 nm to 1200 nm	Approx. 253 nm	Approx. 4.2 nm
100 g/mm	450 nm	300 nm to 700 nm	Approx. 126 nm	Approx. 2.1 nm
150 g/mm	300 nm	335 nm to 750 nm	Approx. 84 nm	Approx. 1.4 nm
150 g/mm	500 nm	335 nm to 750 nm	Approx. 84 nm	Approx. 1.4 nm
300 g/mm	500 nm	335 nm to 750 nm	Approx. 41 nm	Approx. 0.7 nm
600 g/mm	500 nm	335 nm to 750 nm	Approx. 20 nm	Approx. 0.34 nm
1200 g/mm	500 nm	335 nm to 750 nm	Approx. 9 nm	Approx. 0.15 nm

* This is the wavelength range within which simultaneous measurement is possible when used in combination with the streakscope C10627.

● Mount table A11350-11

The A11350-11 is a mount table for coupling the C10627 streakscope and the C11119-02 spectrograph.

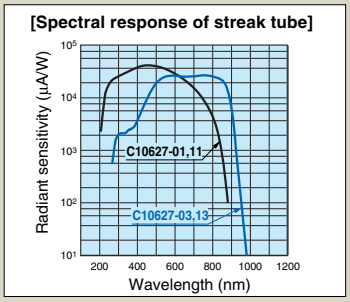
4 Detector

The heart of the C11200 system is an ultrafast optical detector - the C10627 Streakscope. It can capture very weak luminescence phenomena, from picoseconds to milliseconds, achieving very high signal-to-noise ratio within short measuring times due its high repetition rates of up to 20 MHz. The spatial axis of the C10627 allows multichannel spectral measurement, making it the ideal detector for time-resolved spectroscopy. The integrated readout camera has a high frame rate of up to 150 Hz, so that high photon count rates can be exploited in case of stronger emissions. The system is completely remote-controlled from the data analyzer. For any demanding applications where the temporal resolution of the C10627 is not sufficient, you can choose among several alternative detectors such as the C10910 with a resolution of better than 1 ps, the C11293 with a high sensitivity in a near-infrared region.

● Streakscope C10627 (standard)

Streak camera type	C10627-01, -11*1	200 nm to 850 nm
	C10627-03, -13*2	400 nm to 900 nm
Temporal resolution		< 15 ps (in single shot)
Sweep time		1 ns to 10 ms/full scale
Trigger jitter		< 20 ps (fastest range)
Sweep repetition rate		Single to 20 MHz max.
Interface		USB 2.0

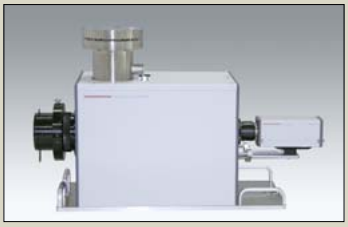
*1: C10627-01 and C10627-03 are streakscopes with readout CCD camera C9300-508.
*2: C10627-11 and C10627-13 are streakscopes without readout CCD camera.



● Near-infrared streak camera C11293-02 (for near-infrared)

Wavelength range	1000 nm to 1650 nm*
Sweep time	1 ns to 10 ms/full scale
Temporal resolution	<20 ps (FWHM)*
Sweep repetition frequency (Max.)	20 MHz (Sweep time; 1 ns or 2 ns)
Cooling method	Liquid nitrogen
Interface	USB 2.0

* C11293-02 only



● Streakcamera + Synchroscan unit C10910+M10911-01 (for high temporal resolution)

Temporal resolution	< 1 ps (FWHM)*1
Synchroscan frequency	Selectable from 75 MHz to 165 MHz
Synchroscan frequency range	fs ±0.2 MHz*2
Sweep time	Approx. 80 ps, Approx. 200 ps, Approx. 600 ps, Approx. 1200 ps, Approx. 2080 ps/full scale*3
Interface	USB 2.0

*1: C10910 only
*2: fs=synchroscan frequency
*3: Sweep time is dependent on synchroscan frequency.
Above value is typical sweep time when selected synchroscan frequency is 80 MHz.

Fitting analysis enables 5-component analysis.

5 Data analyzer C6743-85

The dedicated software controls the streakscope, spectrograph and peripheral units to perform fluorescence lifetime analysis. The software runs under Windows. Fitting analysis enables 5-component analysis.

Control functions	● **Streakscope C10627** Time axis setting Gain setting Shutter control (only for C10627 accessory) ● **Spectrograph C11119-02** Center wavelength setting Grating selection
Data acquisition functions	Photon-counting integration (Peak Detection, Slice)
	Analog integration
Correction and calibration functions	Time axis calibration (Calibrated prior to shipment)
	Wavelength calibration (Requires optional light source for calibration)
	Dark current correction
	Shading correction (Requires optional light source for calibration)
Data analysis functions	5-component exponential function analysis by fitting
	Profile analysis (wavelength axis, time axis)

6 Peripheral equipment

● Synchronous delay generator C10647-01

When using a Ti-Sapphire laser in conjunction with a pulse picker, this unit generates low-jitter trigger signals synchronized with the laser repetition rate. Also, it is generated for to adjust performance timing of PLP-10 and streakscope.

● Trigger mode

INTERNAL mode, EXTERNAL mode, DUMP mode

● Input signal, Output signal

Mode-lock IN	Input signal frequency	10 MHz to 200 MHz
	Input signal level	0 dBm to 15 dBm
	Impedance	50 Ω
TRIG.IN	Input signal frequency	0 MHz to 16 MHz
	Input signal level	+0.25 V to +3 V
	Impedance	50 Ω/High Z (10 kΩ)
OUTPUT A	Output signal level	2 V
	Impedance	50 Ω
OUTPUT B, C, D	Output signal level	2.5 V
	Impedance	50 Ω
Interface	RS232C	

● PIN diode head C1808-03

The C1808-03 generates a low-jitter trigger signal when coupled with various lasers including passive mode-locked lasers. A specially designed circuit produces a highly stable trigger signal compatible with the C10627 streakscope.

Input level (Min.)	1 mW (f=80 MHz, λ=800 nm, FWHM < 1ps)
Saturation output level	1.5 Vp-p (50 Ω)
Frequency band width	< 100 MHz

● Delay unit C1097-05

The C1097-05 is a passive delay unit, with zero jitter, used for fine tuning the trigger delay times to match the selected streak time.

Variable delay range	0 ns to 31.96 ns
Delay setting range	30 ps, 60 ps, 120 ps, 250 ps, 500 ps, 1 ns, 2 ns, 4 ns, 8 ns, 16 ns,
Interface	USB 2.0

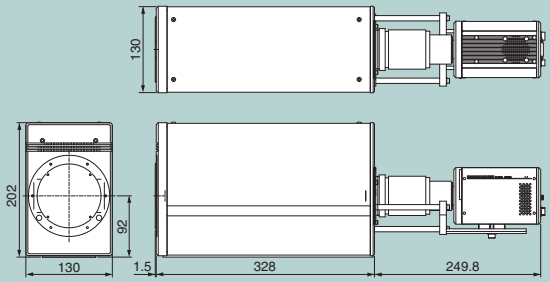
● Digital delay generator DG645

This is a general-purpose delay generator that matches the streakcamera timing with the pulsed laser timing, mainly for slower streak times.

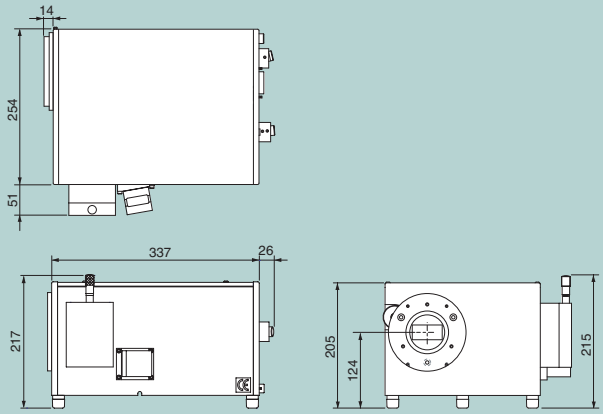
Number of output channels	4 ch (AB, CD, EF, GH output terminal)
Output level	0.5 V to 5.0 V 50 Ω
Variable delay range	0 ps to 2000 s
Delay resolution	5 ps
Internal delay time	85 ns
Repetition rate	Single to 10 MHz
Jitter	25 ps rms
Interface	GPIB, RS232C, Ethernet

Dimensional outlines (Unit: mm)

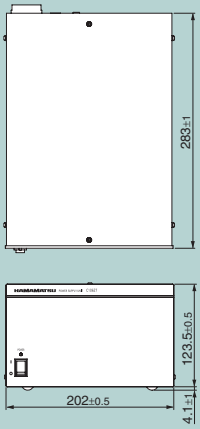
● Streakscope C10627 (Approx. 7.5 kg)



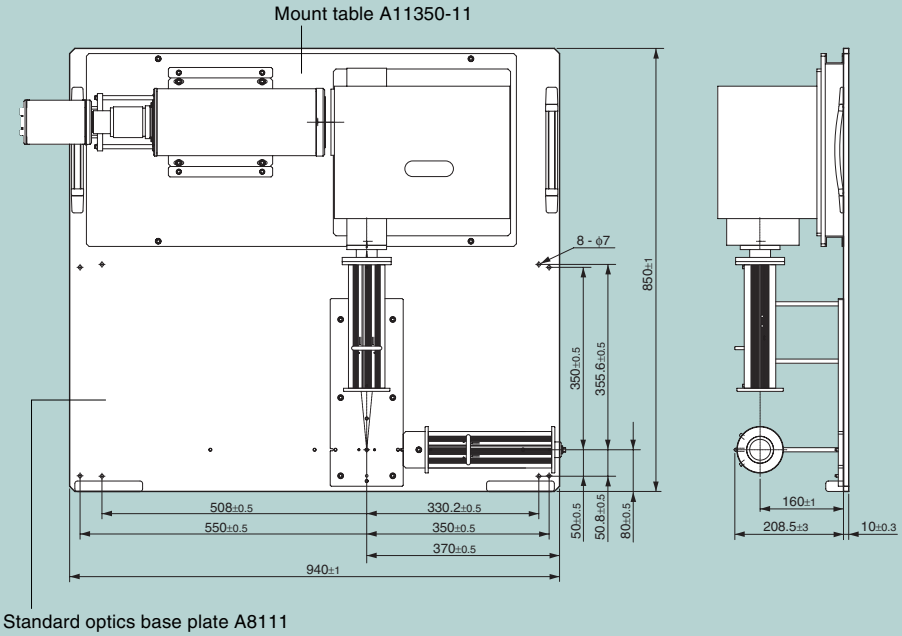
● Spectrograph C11119-02 (Approx. 16 kg)



● Power supply unit C10627 (Approx. 3 kg)



● Standard optics base plate A8111, Mount table A11350-11 (Approx. 24 kg) (Approx. 14 kg)



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