

Absolute PL quantum yield spectrometer C9920-02, -02G, -03, -03G

Absolute value of the photoluminescence quantum yield can be instantaneously measured for thin films, solutions, and powders.



Quantum
Yield

Absolute photo-luminescence quantum yield values as measured instantaneously for thin films, solutions and powders.

Developing luminescent and fluorescent materials requires improving their luminous efficiency. This in turn requires a precise measurement technique for determining their quantum yield (ratio of emitted photons to absorbed photons). Our C9920-02, -02G, -03 and -03G Absolute PL quantum yield spectrometer employ the PL (Photoluminescence) method to measure absolute quantum yields quick and accurately.

Their setup comprises an excitation light source, monochromator, an integrating sphere capable of nitrogen gas flow and a CCD spectrometer for detecting the whole spectral range simultaneously. The dedicated software keeps operation easy. Two sample holders are available for thin films, powders and cuvettes holding liquid samples. This allows for the use of the C9920-02 and -03 systems in various fields like industry, biological and academic research.

The C9920 series also includes the C9920-12 which measures external quantum efficiencies of electroluminescent devices, and the C9920-11 which measures brightness and light distribution of the device. By adding the optional parts, power source meter, and dedicated measurement software to the C9920-02 and -03 configurations, it is possible to shift to the C9920-11 and C9920-12.

APPLICATIONS

- ◆ **Development of organic LEDs**
 - PL quantum yields of basic materials
 - Internal quantum efficiency measurements
 - Quantum yields of thin films and devices
- ◆ **Development of LEDs and Displays**
 - Inorganic LED materials
 - Fluorescent materials for white light LEDs
 - Fluorescent materials for flat panel displays (plasma display, field emission display etc.)
- ◆ **Fundamental research**
 - Sample characterization in physical and chemical field
 - Spectroscopy
 - Fluorescence quantum yields
 - Phosphorescence quantum yields
- ◆ **Biological research**
 - Fluorescent probes
 - Quantum dots



Absolute photoluminescence quantum yields (or internal quantum efficiency) are measured instantaneously.

The C9920-02, -02G, -03 and 03G systems employ the PL method for measuring absolute quantum yields (fluorescence or photoluminescence or internal quantum efficiency). The excitation wavelength is selected from the output of a xenon lamp by a monochromator. Various sample holders allow measurements of thin films, powder samples and solutions.

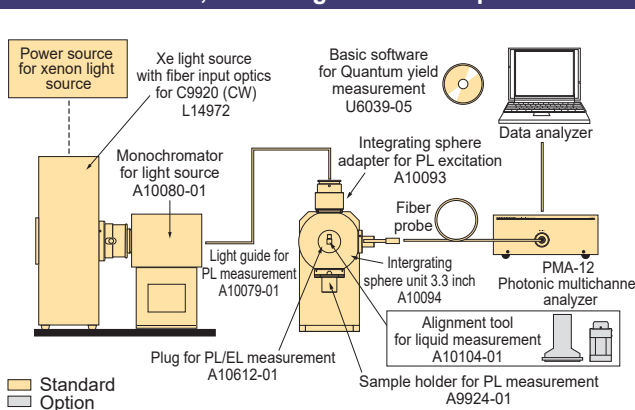
FEATURES

- **Absolute quantum yield measurement of light emitting materials by PL method**
- **Measures total flux by incorporating an integration sphere**
Instantaneous measurement of the whole spectrum by employing a high sensitivity CCD sensor
- **Measurements with ultra-high sensitivity and high signal-to-noise ratio**
- **For thin films, solutions and powder samples**
- **Temperature control** (Target samples: Powders, up to 300 C°)
- **Automatic control of excitation wavelength** (C9920-02G, -03G)
- **Absolute quantum yield measurement of solutions at -196 C° (77 K)** (Target samples: Solutions)
- **Various of analysis functions**
 - Quantum yield measurement
 - Excitation wavelength dependability (C9920-02G, 03G)
 - Emission spectrum
 - PL excitation spectrum spectrum (C9920-02G, 03G)

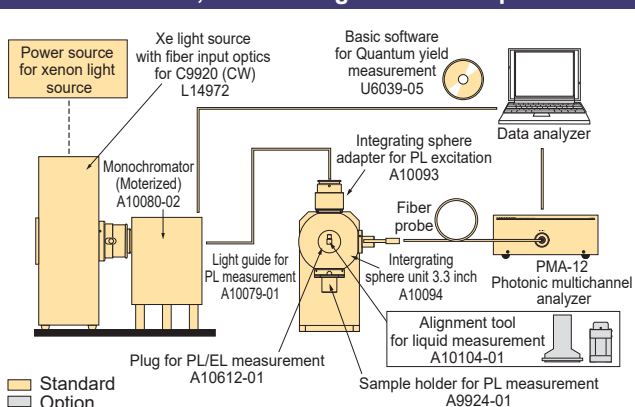
SELECTION

PL measurement wavelength range		300 nm to 950 nm	400 nm to 1100 nm
Excitation wavelength control	Manual	C9920-02	C9920-03
	Automatic	C9920-02G	C9920-03G

C9920-02, -03 configuration example



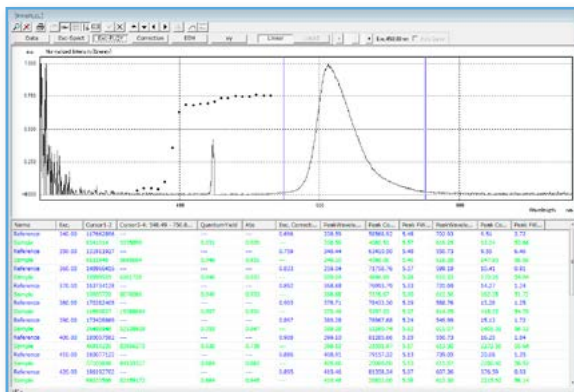
C9920-02G, -03G configuration example



Simple-to-use dedicated quantum yield measurement software

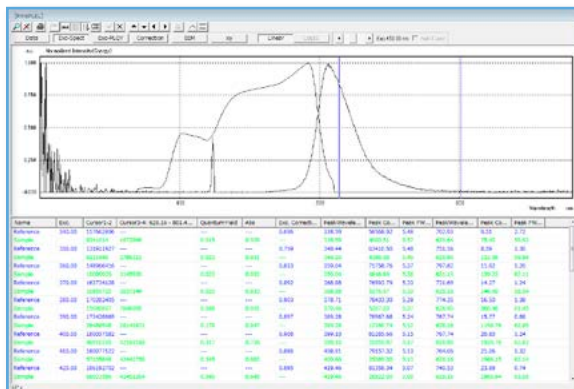
Example of analysis functions

Autoscan of excitation wavelength



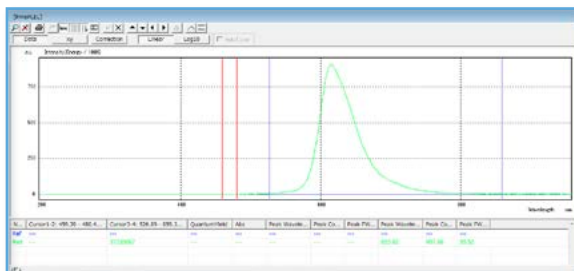
This screen shows the dependence of PL quantum yield on excitation wavelength. The excitation light through a motorized monochromator helps easily to measure wavelength dependence of the sample's PL quantum yield.

PL excitation spectrum



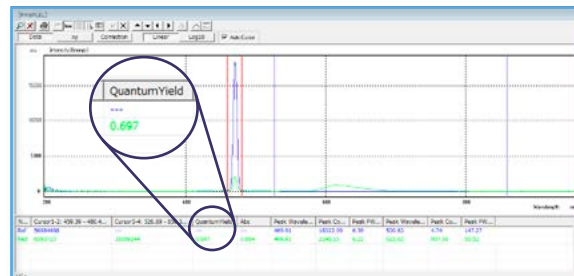
Excitation spectra produced from a sample can be measured by using a excitation light through motorized monochromator. The PL excitation spectrum in an emission wavelength range is easily obtained by selecting the range with two cursor lines.

PL spectrum



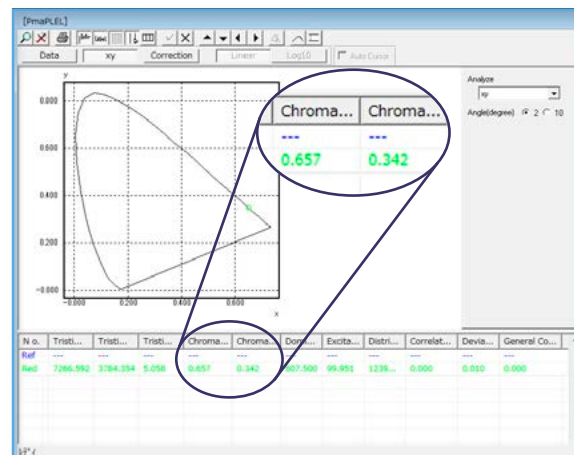
A PL spectrum is displayed after subtracting the excitation light from it. The spectrum emitted from a sample during measurement of PL quantum yield usually contains excitation light components that were not absorbed by the sample. Subtracting this excitation light allows displaying just the light spectrum emitted from the sample itself.

PL quantum yield measurement



This is a basic screen for quantum yield measurements. The luminescence quantum yield is automatically calculated after measurement. Excitation and emission bands are defined by adjusting the cursors. The value of the quantum yield is displayed in the table below the spectrum next to emission intensities, peak wavelength, peak counts, and peak band (FWHM).

x-y coordinates

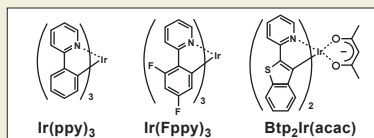
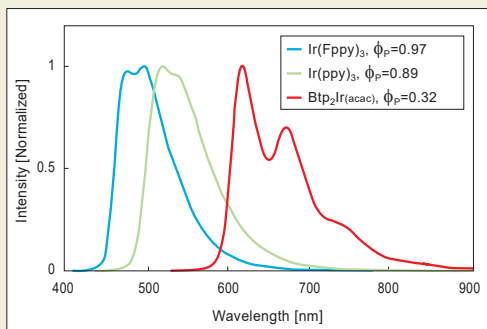


Besides displaying PL spectra and calculating quantum yields, the software also includes a function for color coordinates. Besides the chromaticity coordinates (x, y) of the measured sample, the three stimulus values (X, Y, Z) are displayed.

We offer sample holder for thin films, powders, as well as solutions to support a wide variety of applications

Example of measurements

Phosphorescence quantum yield of phosphorescent materials for organic LED



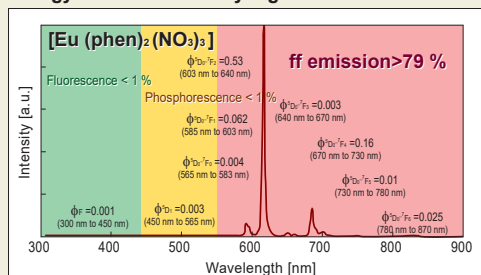
Iridium complex is the focal point of much recent research as a promising phosphorescent material for organic LEDs. We measured its phosphorescence quantum yield (φ_P) in dichloroethane solution. Results showed the blue material Ir(Fppy)₃ and green material Ir(ppy)₃ respectively indicate high φ_P values of approximately 0.97 and 0.89. The red material Btp₂Ir(acac), on the other hand, yielded a low φ_P value of approximately 0.32. Since these phosphorescent materials form a triplet state with an efficiency of about 100 %, the decrease in φ_P in Btp₂Ir(acac) is clearly due to efficient intersystem crossing from T₁ to S₀ (in other words, a non-radiating transition from a triplet state T₁ to a ground state S₀).

Collaborative research of Hamamatsu Photonics K.K.; Adachi lab, Center for Organic Photonics and Electronics Research, Kyushu Univ.; and Tobita lab, Faculty of Engineering, Gunma University.

A. Endo, K. Suzuki, T. Yoshihara, S. Tobita, M. Yahiro, and C. Adachi, *Chem. Phys. Lett.*, **460**,155 (2008).

Observing high-efficiency intermolecular energy transfer in rare-earth complex

Energy transfer efficiency Ligand → f-level >80 %



Rare-earth complexes are attracting much recent attention as a "clean energy conversion material utilizing ligands for efficient photo-excited energy conversion" that "emits light having a sharp peak in the visible region." We measured the emission quantum yield of rare-earth complex [Eu(phen)₂(NO₃)₃] in a powder state. Direct excitation on the 1,10-phenanthroline (Phen) resulted in a europium (Eu) emission quantum yield of approximately 0.8. No luminescence from Phen was observed, so we conclude that energy transfer from Phen to Eu occurred at a high efficiency of over 80 %.

Courtesy of Dr. Miki Hasegawa, Aoyama Gakuin University

Fluorescence quantum yield and levigation effect on p-terphenyl and anthracene single crystals

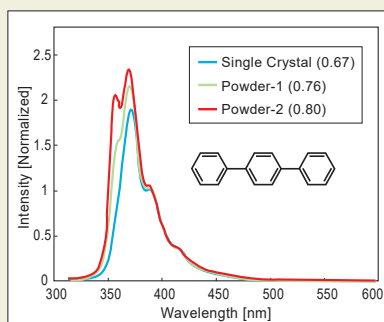


Figure A: Fluorescence spectrum of p-terphenyl

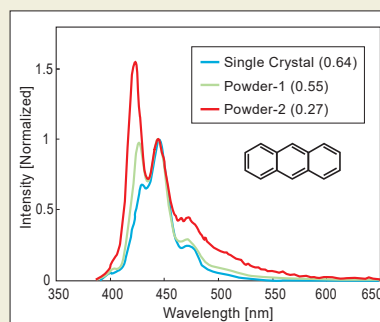


Figure B: Fluorescence spectrum of anthracene single crystal

We utilized high-purity single crystals of the typical organic materials p-terphenyl and anthracene to determine their respective fluorescence quantum yields. Measuring the p-terphenyl resulted in a fluorescence quantum yield of 0.67 for this high-purity single crystal (blue curve in Figure A). Levigating this single crystal to a fine powder increased the fluorescence quantum yield to 0.80 (red curve in Figure A). On the other hand, levigating the high-purity, single crystal anthracene decreased the fluorescence quantum yield from 0.64 to 0.27 (Figure B). Measuring the p-terphenyl showed a higher fluorescence quantum yield and appearance of structures on the short wavelength side of the fluorescence spectrum. So this higher fluorescence quantum yield was

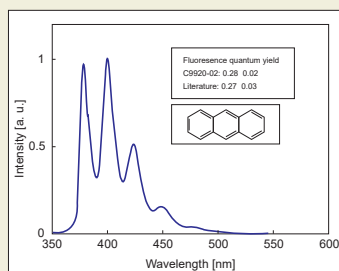
possibly caused by the fine powder from levigation that acts to inhibit reabsorption. Examining the anthracene revealed another luminescent component at longer wavelengths caused by levigation in addition to the usual luminescent components on shorter wavelengths of the fluorescence spectrum. This luminescent component on the lower wavelengths resembles the fluorescence spectrum of anthracene dimer and so was found to be luminescence from a dimer state. This fact proves that the decrease in fluorescence quantum yield of anthracene single crystal was caused by dimers induced by levigation that formed structural flaws and acted as a center for light extinction.

Collaborative research of Hamamatsu Photonics K.K.; Ryuzi Katoh, Akihiro Furube, Ph.D., Research Institute of Instrumentation Frontier, Advanced Industrial Science and Technology; Masahiro Kotani, Ph.D., Department of Chemistry, Gakushuin University; and Katsumi Tokumaru, University of Tsukuba. R. Katoh, K. Suzuki, A. Furube, M. Kotani, and K. Tokumaru, *J. Phys. Chem. C*, **113**, 2961(2009).

Potential applications in diverse fields including biology

Example of measurements

Re-evaluation of luminescence quantum yield of representative standard solutions



The C9920-0X (X=2,3) consists of an excitation light source, an integrating sphere and a multichannel spectrometer, and measures the absolute photoluminescence quantum yield. By using the C9920-0X, the quantum yields of fluorescence standard compounds in solution were measured. The compounds are commonly

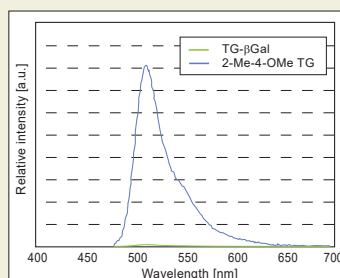
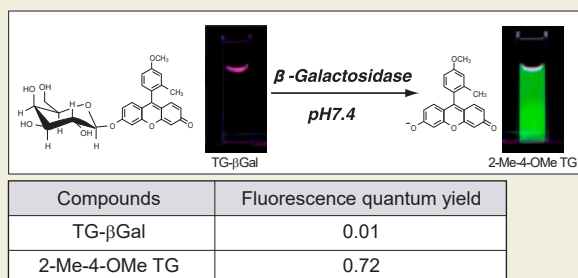
used as fluorescence standards in quantum yield measurements based on a relative method. For most of the compounds, the quantum yield measured by the C9920-0X shows excellent agreement with the values given in the literature, proving the high reliability of the C9920-0X.

Figure: Fluorescence spectrum and quantum yield of anthracene solution

Collaborative research of Hamamatsu Photonics K.K.; Tobita lab, Faculty of Engineering, Gunma University; and H. Ishida, School of Science, Kitasato University. K. Suzuki, A. Kobayashi, S. Kaneko, K. Takehira, T. Yoshihara, H. Ishida, Y. Shiina, S. Oishi, and S. Tobita, *Phys. Chem. Chem. Phys.*, **11**, 9850 (2009).

Quantum yield measurement of fluorescent bioprobe

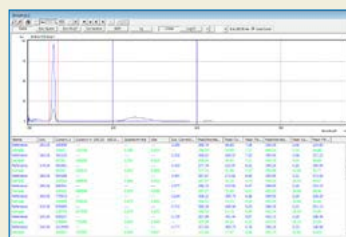
Fluorescent probe for enzyme reaction detection: Quantum yield provides a comparative measurement.



Fluorescent probe TG (Tokyo Green) -βGal for β-galactosidase activity detection is nonluminescent ($\phi_f = 0.01$) but exhibits strong fluorescence after reacting with β-galactosidase. The quantitative difference in amounts of light emitted before and after the enzyme reaction can be found by comparing their quantum yields ϕ_f .

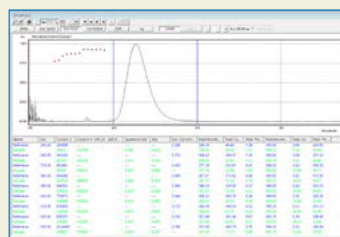
Courtesy of Yasuteru Urano, Ph.D., Graduate School of Medicine, University of Tokyo.

Fluorescent material (BAM) for white LED



BAM measurement display

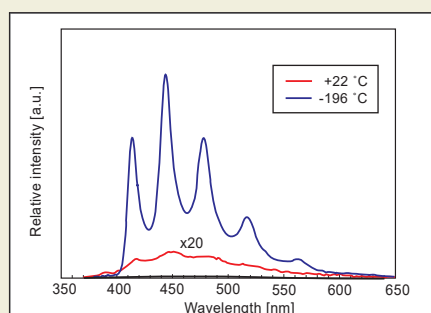
This example is a BAM measurement obtained in the C9920-02G wavelength scan mode. It shows luminescence quantum yield values at each excitation wavelength as well as excitation light and sample emission intensities, peak wavelengths, and peak counts, etc.



BAM powder data

This graph shows the BAM luminescence quantum yield versus the excitation wavelength. It proves that BAM luminescence quantum yield values differ according to the excitation wavelength.

Phosphorescence quantum yield measurement of benzophenone at -196 °C (77K)



Example of measurement

Phosphorescence quantum yields in benzophenone organic solution were measured at room temperature (22 °C (295 K)) and at a low temperature (-196 °C (77 K)) and both compared on the graph. Benzophenone is known to generate a triplet excitation state at a high efficiency (ϕ_{ISC} to 1.0) after being excited by light from the ground state to the singlet state. Observing phosphorescence from general organic compounds is usually difficult because phosphorescence is a forbidden transition. In benzophenone, a phosphorescence spectrum, though weak, was definitely observed (ϕ_P to 0.01). The result also shows that phosphorescent intensity greatly increased at low temperature compared to room temperature and produced a high phosphorescence quantum yield ($\phi_P > 0.8$).

Collaborative research of Hamamatsu Photonics K.K. and Tobita lab, Faculty of Engineering, Gunma University.

Product lineup includes 4 types of systems to match diverse user needs

SPECIFICATIONS

■ C9920-02, -02G, -03, -03G

Type number	C9920-02	C9920-02G	C9920-03	C9920-03G
PL measurement wavelength range	300 nm to 950 nm		400 nm to 1100 nm	
Monochromatic light source				
Light source	150 W Xenon light source			
Excitation wavelength	250 nm to 800 nm	250 nm to 950 nm	375 nm to 800 nm	375 nm to 1000 nm
Bandwidth	10 nm or less (FWHM)	Approx. 2 nm to 5 nm (Varies with slit)	10 nm or less (FWHM)	Approx. 2 nm to 5 nm (Varies with slit)
Degradation prevention of the sample by light	Excitation light interception by the mechanical shutter			
Excitation wavelength control	Manual	Automatic control	Manual	Automatic control
Multichannel spectroscope				
Measurement wavelength range	200 nm to 950 nm		350 nm to 1100 nm	
Wavelength resolution	< 2 nm		< 2.5 nm	
Number of photosensitive device channels	1024 ch			
Device cooling temperature	-15 °C			
AD resolution	16 bit			
Spectroscope optical arrangement	Czerny-Turner type			
Fiber type	Bundled fiber (1.5 m)			
Fiber receiving area	Φ1 mm			
Integrating sphere				
Material	Spectralon			
Size	3.3 inch			
Sample holder (Option)				
Thin film	Using Laboratory dish without caps (5 pieces) A10095-01 (not including a substrate)			
Powder	Using Laboratory dish with caps (5 pieces) A10095-03			
Solution (room temperature)	Using Alignment tool for liquid measurement A10104-01			
Solution (low temperature)	-196 °C (77 K), using Sample holder for low temperature A11238-01			
Temperature control	RT* to +300 °C, using Sample holder for temperature control A13924-03 with Controller for temperature control C13923-01			
Sample case (Option)				
Powder	Using Laboratory dish with caps (5 pieces) A10095-03			
Solution (room temperature)	Using Side-arm cell (3 sets) A10095-02			
Solution (low temperature)	-196 °C (77 K), using Sample tube for low temperature measurement (5 pieces) A10095-04			
Software				
Measurement items	PL quantum yield			
	Fluorescent materials luminance efficiency measurement (quantum yield x absorption)			
	Excitation wavelength dependence of quantum yield (-02G, -03G)			
	PL spectrum (peak wavelength, FWHM)			
	PL excitation spectrum (-02G, -03G)			
	Color measurement (chromaticity, color temperature, color rendering index, etc.)			
	Self-absorption correction (Optics for transmission and fluorescence measurement A11238-03 is required)			

* RT: Room temperature

Optional components for additional flexibility

OPTIONS

Sample holder

For solution

- **Alignment tool for liquid measurement** A10104-01
- **Sample holder for low temperature** A11238-01
This is used to cool the sample solution with liquid nitrogen.
- **Optics for transmission and fluorescence measurement** A11238-03
Optical systems that measure luminescence spectrum of solutions in liquid nitrogen.

For powder

- **Sample holder for temperature control** A13924-03
This option allows setting the maximum temperature of powder samples up to 300 °C.
Measurements can now be made in environments where phosphors for white LED are actually used.
Temperature control range: Room temperature to +300 °C
* This sample holder also requires controller C13923-01.

Other

- **Controller for temperature control** C13923-01
Sample holder A13924-03 is necessary for temperature control measurement. Power supply voltage and frequency should be informed in order time.

Excitation light source

Adapter for LED excitation

- **Adapter for LED light source** A11133
This adapter excites the sample by using an LED. It supports both bullet type and SMD type LED.
LED and its driver power supply should be prepared by the user.



Upgradable to C9920-02G, -03G from C9920-02, -03

Spectroscope

- **Monochromator (Motorized)** A10080-02
Possible to select the wavelength of xenon light source. A monochromator transmits light wavelength for measuring the excitation wavelength dependence of the luminescence quantum yield and the PL excitation spectrum.
Excitation wavelength: 250 nm to 1000 nm
Bandwidth: Approx. 2 nm to 5 nm (varies with slit)



Please prepare a xenon lamp on your own.

Spare parts / Maintenance

- **Sample holder for PL measurement** A9924-01
This is an additional sample holder.
The C9920-02, -02G, -03, and -03G include one A9924-01 as a standard.
- **Dewar for low temperature** A11238-02
This is a dewar flask for cooling sample solutions with liquid nitrogen.
- **Spare part for A9924-01** A11372-01
- **Spare part for A10612-01 (for solution)** A11372-02



- **Xe lamp** L14971
This is a replacement bulb for the xenon excitation light source.
- **PMA-12 (detector) shutter addition**
When using a PMA-12 (detector) that you already have for measuring organic electroluminescence quantum yields, it is necessary to add a function for external shutter control.
- **Sensitivity calibration**
To maintain high-precision measurements, we recommend periodically reacquiring sensitivity correction data.



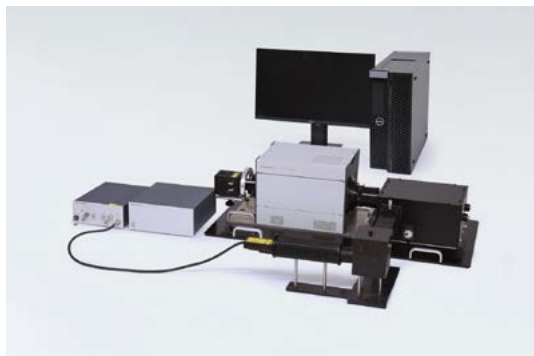
Systems for fluorescence lifetime measurements

Related Products

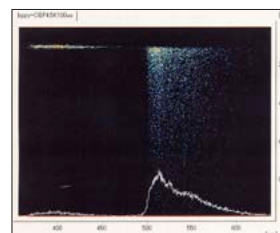
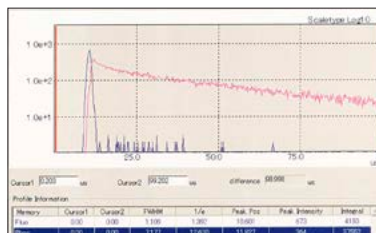
Fluorescence lifetime of a substance is closely related to the quantum yield and is an important parameter for elucidating the photophysical process. By combining our ultra-low light level measurement with spectrophotometric technologies, we offer advanced systems optimized for measurements in the UV to near infrared region.

● Picosecond fluorescence lifetime measurement system C11200

Combining a laser with a streak camera allows measuring fluorescence and phosphorescence lifetimes ranging from picoseconds to milliseconds over a wide dynamic range. Fluorescence and phosphorescence components can be captured visually since measurement results are observed as 2D images along the wavelength axis and time axis.



◆ Temporal Luminescent spectrum measurement of phosphorescent components



▲ Phosphorescence materials Ir(ppy)₃:

Fluorescence, phosphorescence and streak image of temporal resolution luminescent spectra of host CBP thin film at 4.5 K

Data courtesy of Prof. Chihaya Adachi,
Center for Organic Photonics and Electronics Research, Kyushu Univ.

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