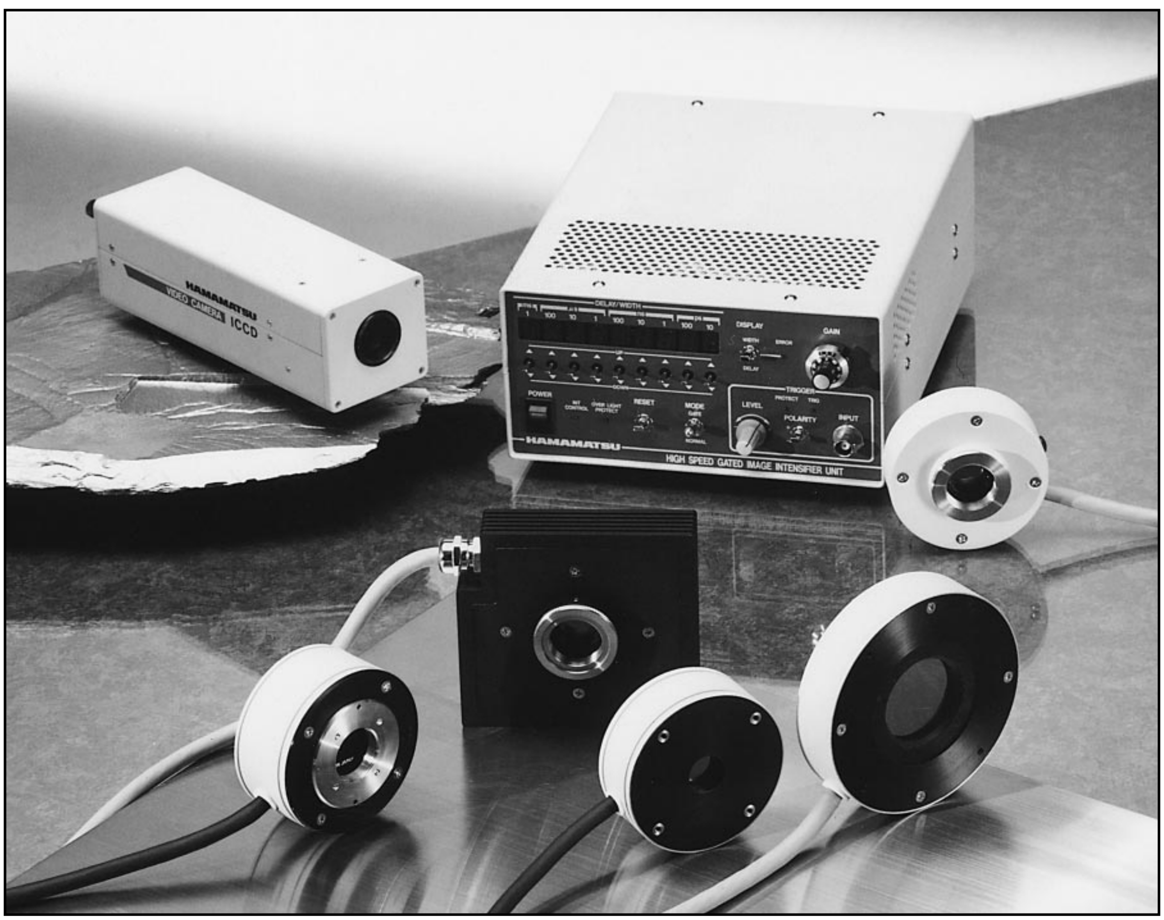
HIGH-SPEED GATED IMAGE INTENSIFIER UNITS ICCD CAMERA UNITS

SELECTION GUIDE

APPLICATION NOTES



HAMAMATSU

CONTENTS

Capturing “Instantaneous Images” of High-speed Phenomena

The high-speed gated image intensifier (hereafter referred to as the gate I.I.) is capable of capturing “instantaneous images” of high-speed phenomena in an extremely short period of time, using “gate operation” (or shutter operation).
For instance, to analyze an automotive engine turning at a speed of 6,000 rpm would require fast analysis at 1/10000 of a second or less. The gate I.I. can capture the “instantaneous images” in this kind of analysis.
Gate operation is the same as the shutter operation of a camera, but in the gate I.I. it is carried out electrically. In the example below, gating is being done at 3 ns. (The 3 ns time period is equivalent to light advancing 90 cm at a speed of 300,000 kilometers per second.) By synchronizing the gate operation to a laser or similar light source extraneous, light outside the measurement target such as background light and excitation light can be eliminated.
The gate I.I. has an internal image enhancement function, and is available in two types, one with a single-stage microchannel plate (MCP) and one with a two-stage MCP for applications requiring even higher image intensification.
A short gate time may result in an insufficient amount of light which enters the image camera. In this case, better images can be obtained using an image enhancement unit which enables image integration, and an image booster unit which compensates for insufficient light.
There are two types of gate I.I. available: a gate I.I. unit with which the user can select the camera to be used for readout, and an ICCD camera unit which combines a gate I.I. with a CCD camera. In addition to imaging in the visible light region, gated X-ray image intensifiers are also available to capture “instantaneous images” of X-ray phenomena.

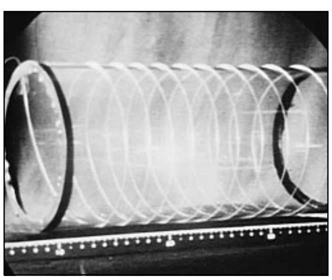
Applications

- **Engine combustion state analysis**
- **Monitoring of kinetic changes in plasma emissions**
- **Imaging of turbine blades**
- **Imaging of exploding events**
- **Imaging of gaseous and liquid bodies moving at high speed**
- **Imaging of objects moving at high speed**
- **Imaging of fluorescence lifetime**
- **Low-light-level bioluminescence/ chemiluminescence imaging**

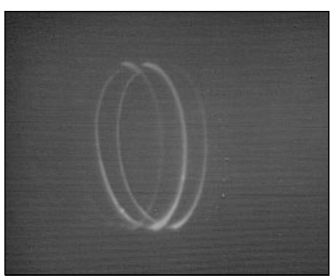
Imaging Examples

Observation of pulsed light propagation through optical fiber

Laser pulse light movements can be observed within the gate time.



Experimental setup of optical fiber



Wavelength : 550 nm
Pulse width : 50 ps

Gate time : 3 ns

For details, please see last page.

Imaging of cross-section of jet flame

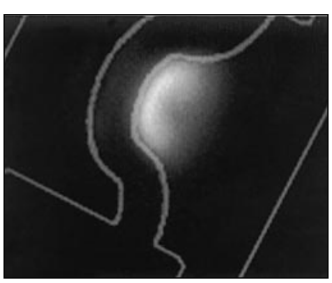
Turbulent eddies in an ethylene jet flame can be observed.

Wavelength : 530 nm
Pulse width : 10 ns
Gate time : 100 ns

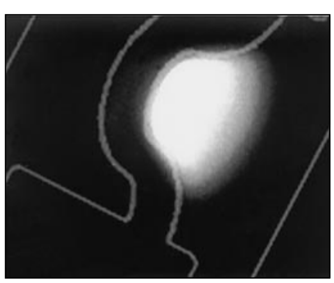
For details, please see page 13.

Kinetic changes in plasma emissions

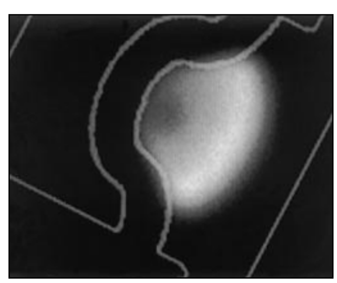
Kinetic changes in the emissions from an electrode of a plasma display panel (PDP) can be observed.



0.47 µs
after pulsed voltage is applied



0.71 µs
after pulsed voltage is applied



1.09 µs
after pulsed voltage is applied

Gate time : 100 ns
Integrated image

For details, please see page 15.

Hints to Selecting Products

The guidelines listed below help you select a gate I.I. with the optimum specifications for the measurement.
The five items noted below are especially important when selecting a product, and products can be selected by considering these five factors in combination.

Item	Description	Selection Method
Gate time	This is the time required to capture one image. “Instantaneous images” of phenomena occurring within this gate time can be captured. If the gate time is shortened, images with little movement can still be captured, but there is less light, so that a darker image results. (A unit with a gate time appropriate for the measurement target should be selected.)	Select the disired gate time according to the time period during which images are to be captured.
Gate repetition frequency	This is the number of gate operations in 1 second. This also depends on the repetition frequency of the object being measured and the number of frames of the camera being used.	Select the repetition frequency depending on how many images are to be captured per second.
Photocathode sensitivity	The higher the quantum efficiency (conversion efficiency from input light into photoelectrons), the smaller the flicker that appears in the obtained image. GaAs photocathodes have higher quantum efficiency than multialkali photocathodes over a wide spectral range from 450 to 900 nm.	What is the spectral range to be detected. -UV to visible range Use a multialkali photocathode. -Near IR range Use a GaAs photocathode. GaAs photocathodes are recommended in a spectral range of 800 to 900 nm.
Stage of MCPs	This is the factor which determines the image intensification level and the resulting detection limit. With ordinary CCD cameras, the limit for imaging is around 0.1 lux. The intensifier unit may have either a 1-stage or a 2-stage MCP. With the 1-stage MCP type, the image is enhanced around 10,000 times, enabling images to be captured at low-light-levels of 1×10^{-5} lux. With the 2-stage MCP type, images are enhanced approximately one million times, and can be captured at even lower light levels of 1×10^{-7} lux. The two-stage MCP type offers sensitivity that enables detection at single-photon level. The light levels noted above are for a gate time of 1 second. The relative quantity of light decreases as the gate time shortens, so it is necessary to increase the quantity of incident light.	When monitoring candlelight: ● Gate time : less than 1 µs ... 2-MCP type more than 5 µs .... 1-MCP type The above numeric values are general guides, and are affected by conditions such as the light level, gate time, image intensification (gain), lens, imaging device, and other factors. Please consult Hamamatsu regarding details.
Effective output size	This is the factor which determines the resolution. The size of the effective input surface is determined by the desired resolution* of the output image and the size of the incident image. The image resolution degrades as the quantity of incident light decreases.	● Commercial CCD camera (about 400,000 pixels) or high-speed camera .... ϕ18 mm ● High-resolution CCD camera ... ϕ40 mm

*** To improve the resolution**

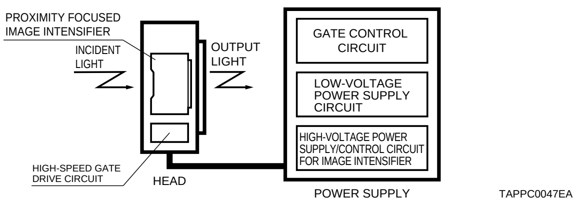
The resolution of a gate I.I. unit depends on the surface area of the output phosphor screen, because the minimum luminous spot size on the phosphor screen is limited to 30 to 50 µm. This means that higher resolution can be obtained by using a larger phosphor screen and focusing the image onto the CCD through an optical lens with a high reduction ratio.
On the other hand, GaAs photocathode types provide a higher resolution because of the characteristics of photocathode itself.

Principle

Internal Structure

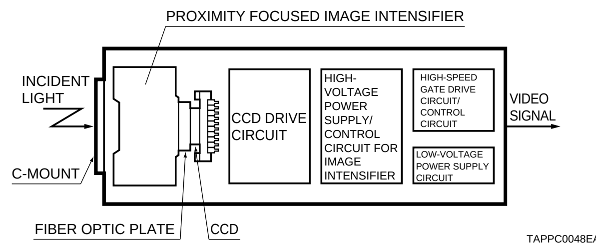
HIGH-SPEED GATED IMAGE INTENSIFIER UNIT

This is configured of a proximity focused image intensifier and a high-voltage power supply with a gate control circuit. A CCD camera with an FOP window, a CCD camera, a high-speed camera, or a similar device may be selected as the camera.



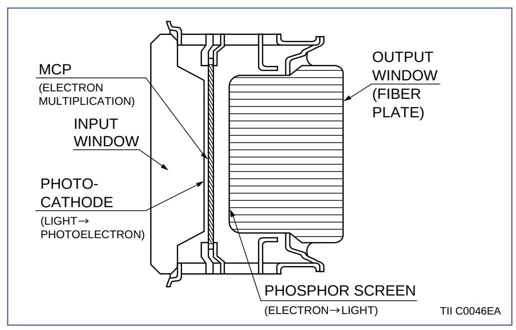
ICCD CAMERA UNIT

This is configured of a proximity focused image intensifier with an incorporated CCD.



Proximity focused image intensifier

A proximity forcused image intensifier is an image device that is capable of enhancing a low-light-level image from several thousands to several millions of times.
The optical image input to the image intensifier is converted to photoelectrons at the photocathode. The photoelectrons are drawn by an electrical field and enter a microchannel plate (MCP) where they repeatedly impinge on the inner wall more than ten times. Each time an electron impinge on the wall, secondary electrons are released, so that the total number of electrons is multiplied several thousands of times. The electrons then strike the phosphor screen and are converted back into an optical image. With a 2-stage MCP type, optical images can be enhanced several millions of times.



Proximity focused image intensifier structure

Gate operation

The light incident on the photocathode is converted to photoelectrons which are guided to the phosphor screen by an electric potential gradient. Gating is done by instantly changing the electric potential of the electrodes in the image intensifier.

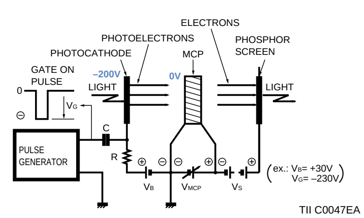
Gating with the proximity-focused image intensifier

This is done by changing the electric potential between the photocathode and the MCP.

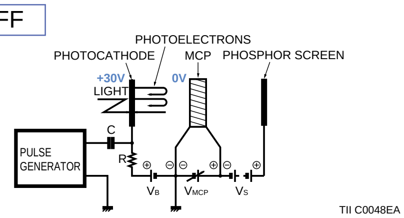
- If the MCP potential is higher than the photocathode potential: Gate is ON
  The photoelectron image converted by the photocathode is pulled to the MCP at a high electric potential. After multiplication in the MCP, the electron image is than guided to the output phosphor screen where it is output as an optical image.
- If the MCP potential is lower than the photocathode potential: Gate is OFF
  The photoelectron image converted by the photocathode is repelled away from the MCP at a low electric potential, and operation is interrupted at this point.

Gating operation (Proximity-focused image intensifier)

Gate ON



Gate OFF



Selection Guide

HIGH-SPEED GATED IMAGE INTENSIFIER UNIT
HIGH-SPEED GATED ICCD CAMERA UNIT

This guide will help customers select the optimum gate I.I. unit according to the high-speed phenomena to be measured.

Optional Equipment

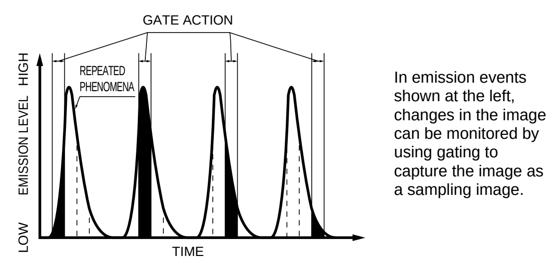
Time-resolved imaging
To capture kinetic changes in extremely short time periods

High sensitivity
To capture images at extremely low-light-levels light

Modulation
To capture phase differential using 2-dimensional images

Time-resolved imaging

Still images of repeated high-speed phenomena can be obtained, using gate operation in short time units. By gradually changing the timing at which gate signals are input to an external gate, sampling measurements of high-speed phenomena is made possible as if moving in slow motion.



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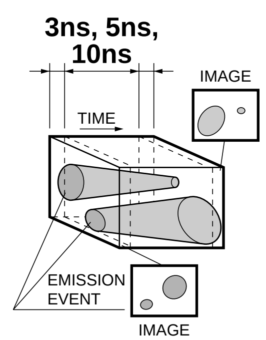
Short-time imaging

When changes in the event are occurring at an extremely fast rate, images can be captured in very short time units. This makes it possible to analyze high-speed phenomena in greater detail.



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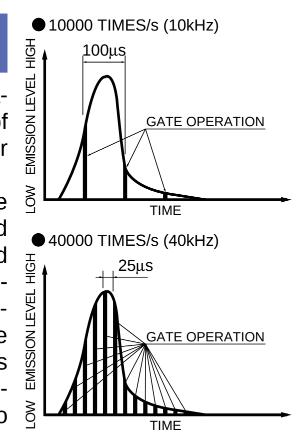
Imaging of repetitive events

This type allows gate operation at a maximum speed of 40,000 or 1 million times per second.
High-repetition gating can be used to match high-speed cameras, enabling improved time resolution for the measurement. Also, numerous integrations are possible in the same frame. This enables rapid measurement of samples which are vulnerable to deterioration.



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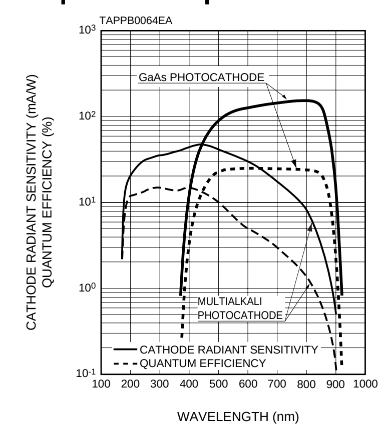
GaAs Photocathode with high-QE & sensitivity

Enhanced photocathode sensitivity allows capturing high-quality images with minimum flicker. Delivers dramatically improved image quality, especially for measurements in the near IR region.

● Spectral Response

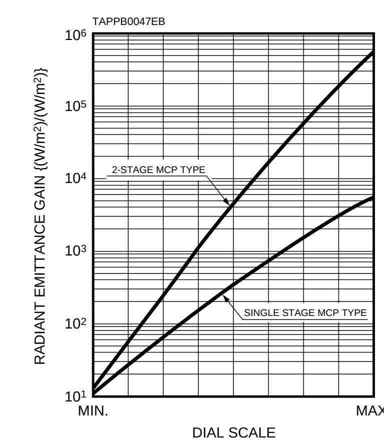


* High sensitivity type in visible region (GaAsP photocathode: 360 nm to 720 nm) is also available.

Using 2-stage MCP type

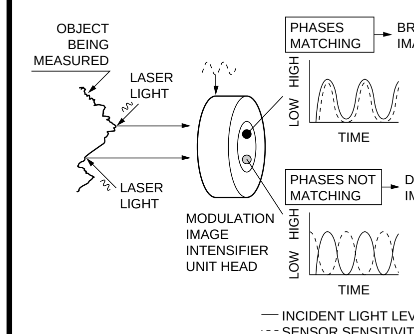
The 2-stage MCP enables imaging bio- or chemi-luminescence at extremely low light levels, or monitoring living things under dark conditions.
The 2-stage MCP type offers image intensification (gain) approximately 100 times stronger than that of the 1-stage MCP type, enabling high-sensitivity detection.

● Gain Characteristics



Phase differential imaging

In this process, the modulated light which is being measured is synchronized to the modulated image intensifier, and a two-dimensional image is obtained which contains the phase differential data.
This phase differential data can then be used for two-dimensional measurement of fluorescence lifetime, simultaneous measurement of multi-point distances, and other applications. Using this method, measurements can be done in less time than those based on the conventional time difference data method.



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STANDARD TYPE

High resolution type — ICCD camera — ICCD camera — ICCD camera — ICCD camera — High resolution type — ICCD camera

C6653
Effective input area : ϕ18mm
Gate time : 50ns Min.
Repetition frequency : 40kHz Max.
Stage of MCPs : 1
NOTE : Ⓐ Ⓑ

C7068-01
Effective input area : ϕ40mm
Effective ouput area : ϕ40mm
Gate time : 100ns Min.
Repetition frequency : 40kHz Max.
Stage of MCPs : 1

C5909
Effective imaging area of CCD : 12.8 × 9.6mm
Gate time : 1µs Min.
Repetition frequency : 2kHz Max.
Stage of MCPs : 1
Remote control*

C2925-01/C7244
Gate time : 3ns Min.
Effective input area : ϕ18mm
Repetition frequency : 10kHz/30kHz Max.
Stage of MCPs : 1
NOTE : Ⓑ
RS-232C interface (C7244)

C4078-01/C7245
Gate time : 3ns Min.
Effective input area : ϕ18mm
Repetition frequency : 10kHz/30kHz Max.
Stage of MCPs :2
NOTE : Ⓑ
RS-232C interface (C7245)

C5909-06
Gate time : 5ns Min.
Effective input area of CCD : 12.8 × 9.6mm
Repetition frequency : 2kHz Max.
Stage of MCPs :1
Remote control*

C6245
Repetition frequency : 1MHz Max. (Burst)
Effective input area : ϕ18mm
Gate time : 10ns Min.
Stage of MCPs : 1
NOTE : Ⓐ Ⓑ

C7786
GaAs Photocathode
Stage of MCPs : 1
Effective input area : ϕ18mm
Gate time : 100ns Min.
Repetition frequency : 10 kHz Max.
Limiting resolution : 45 Lp/mm

C7787
GaAs Photocathode
Stage of MCPs : 2
Effective input area : ϕ18mm
Gate time : 100ns Min.
Repetition frequency : 10 kHz Max.
Limiting resolution : 36 Lp/mm

C5909-10
GaAs Photocathode
Stage of MCPs : 1
Effective imaging area of CCD: 12.8mm×9.6mm
Gate time : 100ns Min.
Repetition frequency : 1 kHz Max.
Limiting resolution : 450 TV line
Remote control*

C5909-12
GaAs Photocathode
Stage of MCPs : 2
Effective imaging area of CCD: 12.8mm×9.6mm
Gate time : 100ns Min.
Repetition frequency : 1 kHz Max.
Limiting resolution : 450 TV line
Remote control*

C6654
Stage of MCPs : 2
Effective input area : ϕ18mm
Gate time : 50ns Min.
Repetition frequency : 40kHz Max.
NOTE : Ⓐ Ⓑ

C7069-01
Stage of MCPs : 2
Effective input area : ϕ40mm
Effective ouput area : ϕ40mm
Gate time : 100ns Min.
Repetition frequency : 40kHz Max.

C5909-08
Stage of MCPs : 2
Effective imaging area of CCD : 12.8 × 9.6mm
Gate time : 5ns Min.
Repetition frequency : 2kHz Max.
Remote control*

C5825
Modulation Frequency : 300kHz to 300MHz
Effective input area : ϕ18mm
Stage of MCPs : 2

NOTES: Scanning device information
Ⓐ Compatible with high-speed camera
Ⓑ Use of image booster unit recommended (see page 11 for details).
* With remote gain controller C5979 (sold separately)

Specifications

● High-speed Gated Image Intensifier Units

	Type No.	Gate Time	Maximum Repetition Frequency (kHz)	Effective Input Area (mm)	Input Window	Effective Output Area (mm)	Output Window	Spectral Ⓐ Response (nm)	Stage of MCPs	Luminous Gain	EBI Radiant at 430nm (W/cm^2)	Limiting Resolution (Lp/mm) Typ.	NOTES	Ⓑ Dimensions No.
High resolution, High repetition frequency	C7068-01	100ns to DC	40	ϕ40	Synthetic Silica	ϕ40	Fiber Plate	185 to 900	1	1.1×10^4	3×10^{-14}	36		①
High resolution, High sensitivity, High repetition frequency	C7069-01	100ns to DC	40	ϕ40	Synthetic Silica	ϕ40	Fiber Plate	185 to 900	2	4×10^6	3×10^{-14}	32		①
Standard, High repetition frequency	C6653	50ns to DC	40	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	1	1.1×10^4	3×10^{-14}	36		②
High sensitivity, High repetition frequency	C6654	50ns to DC	40	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	2	4×10^6	3×10^{-14}	32		②
High resolution, High sensitivity	C7786	100ns to DC	10	ϕ17.5	Borosilicate Glass	ϕ17.5	Fiber Plate	370 to 920 Ⓒ	1	3×10^4	4×10^{-14}	45		②
High resolution, High sensitivity	C7787	100ns to DC	10	ϕ17.5	Borosilicate Glass	ϕ17.5	Fiber Plate	370 to 920 Ⓒ	2	8×10^6	4×10^{-14}	36		②
High repetition frequency, High-Speed, External control	C7244	3ns to 100ms	30	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	1	1.1×10^4	3×10^{-14}	36	RS-232C interface	③
High sensitivity, High repetition frequency, High-Speed, External control	C7245	3ns to 100ms	30	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	2	4×10^6	3×10^{-14}	32	RS-232C interface	③
High-Speed	C2925-01	3ns to DC	10	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	1	1.1×10^4	3×10^{-14}	36		④
High-Speed, High sensitivity	C4078-01	3ns to DC	10	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	2	4×10^6	3×10^{-14}	32		④
High-Speed, High repetition frequency	C6245	10ns to DC	1000(Burst)	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	1	1.1×10^4	3×10^{-14}	36	C-mount	⑤

● High-speed Gated ICCD Camera Units

	Type No.	Gate Time	Maximum Repetition Frequency (kHz)	Input Window	Spectral Ⓐ Response (mm)	Effective Imaging Area of CCD (mm)	Effective Number of CCD Cells (HXV)	Stage of MCPs	Minimum Photocathode Illuminance (lx)	Limiting Resolution (TV Lines)	NOTES	Dimensions No.
Standard	C5909	Internal: 1µs to 300µs External: 1µs to DC	2	Synthetic Silica	185 to 900	12.8×9.6 (1inch)	768×494	1	4×10^{-5}	420	C-mount	⑥
High-Speed	C5909-06	Internal: 5ns to 100µs External: 5ns to DC	2	Synthetic Silica	185 to 900	12.8×9.6 (1inch)	768×494	1	4×10^{-5}	420	C-mount	⑦
High-Speed, High sensitivity	C5909-08	Internal: 5ns to 100µs External: 5ns to DC	2	Synthetic Silica	185 to 900	12.8×9.6 (1inch)	768×494	2	4×10^{-7}	380	C-mount	⑦
High resolution, High sensitivity	C5909-10	Internal: 100ns to 300µs External: 100ns to DC	1	Borosilicate Glass	370 to 920 Ⓒ	12.8×9.6 (1inch)	768×494	1	1×10^{-6}	450	C-mount	⑥
High resolution, High sensitivity	C5909-12	Internal: 100ns to 300µs External: 100ns to DC	1	Borosilicate Glass	370 to 920 Ⓒ	12.8×9.6 (1inch)	768×494	2	4×10^{-7}	450	C-mount	⑥

● High Frequency Amplitude Modulation Image Intensifier Units

	Type No.	Modulation Frequency (MHz)	Modulation Depth (%)	Effective Input Area (mm)	Input Window	Effective Output Area (mm)	Output Window	Spectral Ⓐ Response (nm)	Stage of MCPs	Luminous Gain	EBI Radiant at 430nm (W/cm^2)	NOTES	Dimensions No.
Modulation	C5825	0.3 to 300	0 to 100	ϕ17.5	Synthetic Silica	ϕ17.5	Fiber Plate	185 to 900	2	3×10^5	5×10^{-14}	C-mount	⑧

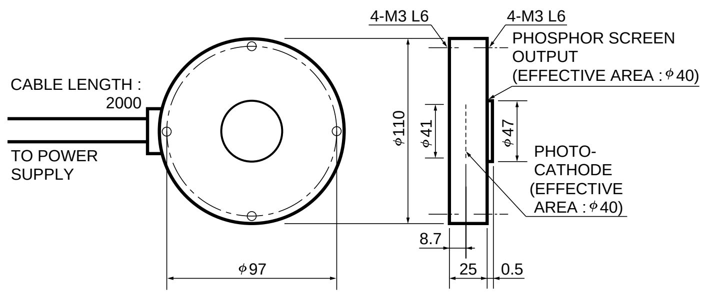
NOTES: Ⓐ Other spectral response ranges area also available. Please consult our sales office.
Ⓑ Please see pages 7, 8, and 9.
Ⓒ GaAs Photocathode

Dimensions

Unit : mm

① C7068-01, C7069-01

Image Intensifier Head

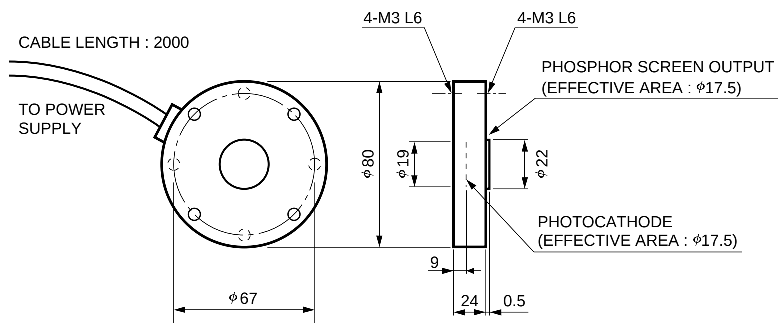


TAPPA0030EB

Power Supply : 230(W) × 118(H) × 228(D)

② C6653, C6654, C7786, C7787

Image Intensifier Head

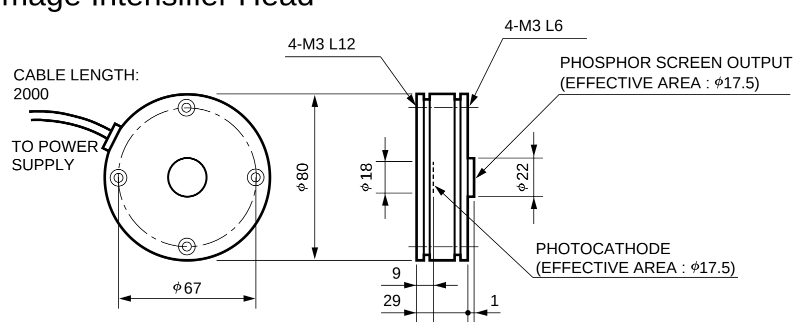


TAPPA0027EA

Power Supply : 230(W) × 118(H) × 228(D)

③ C7244, C7245

Image Intensifier Head



TAPPA0035EB

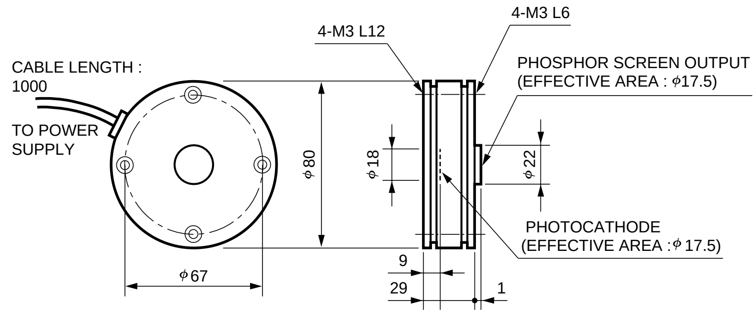
Power Supply : 200(W) × 100(H) × 225(D)

Dimensions

Unit : mm

④ C2925-01, C4078-01

Image Intensifier Head

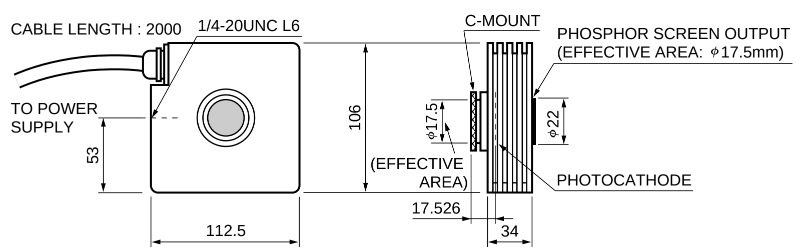


TAPPA0022EA

Power Supply : 242(W) × 63(H) × 270(D)

⑤ C6245

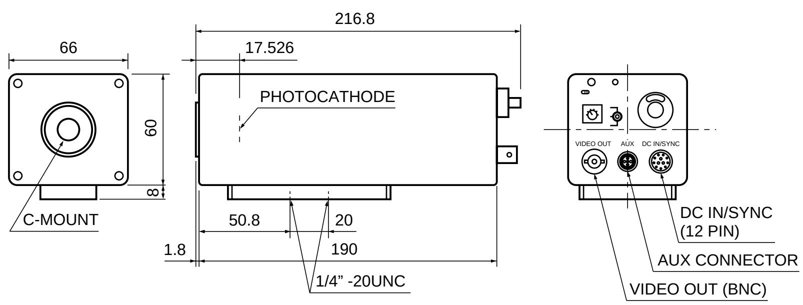
Image Intensifier Head



TAPPA0020EA

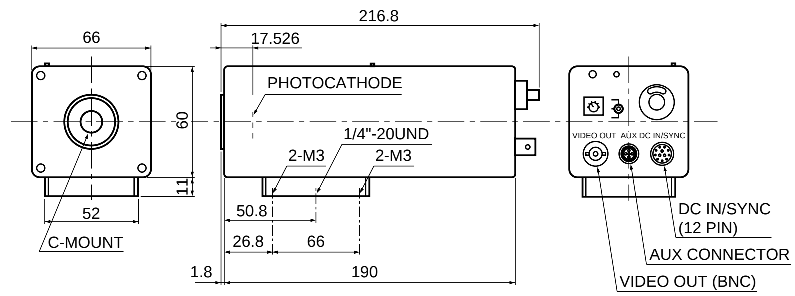
Power Supply : 230(W) × 118(H) × 288(D)

⑥ C5909, -10, -12



TAPPA0021EB

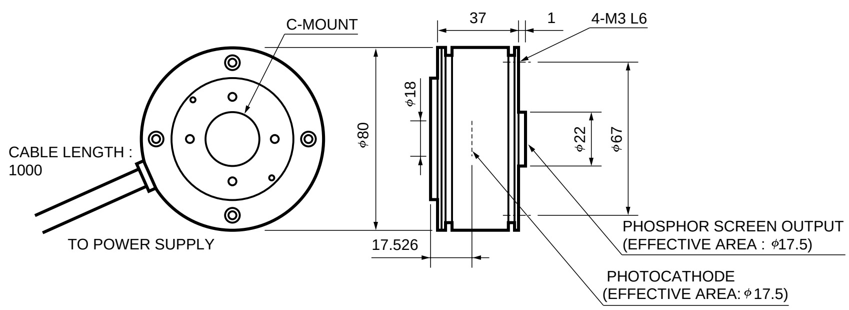
⑦ C5909-06, -08



TAPPA0029EC

⑧ C5825

Image Intensifier Head

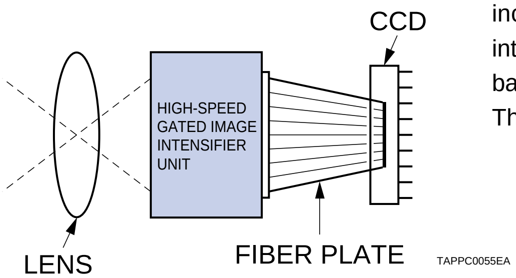


TAPPA0033EA

Power Supply : 330(W) × 67(H) × 300(D)

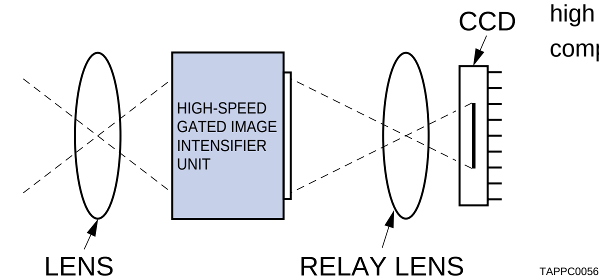
Readout Methods

Fiber Plate Coupling



The output image from the gate I.I. unit is transferred directly to the CCD with a fiber coupling, for highly efficient readout. Higher efficiency means that the quantity of incident light can be suppressed, which in turn extends the lifetime of the image intensifier. In addition, a more compact optics system can be used. The only drawback to this construction is that the readout system is difficult to replace.
The C5909 series have internal fiber coupling.

Relay lens coupling

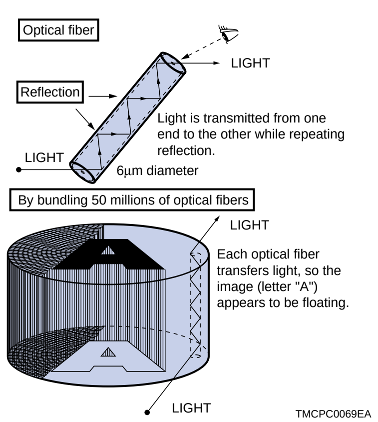


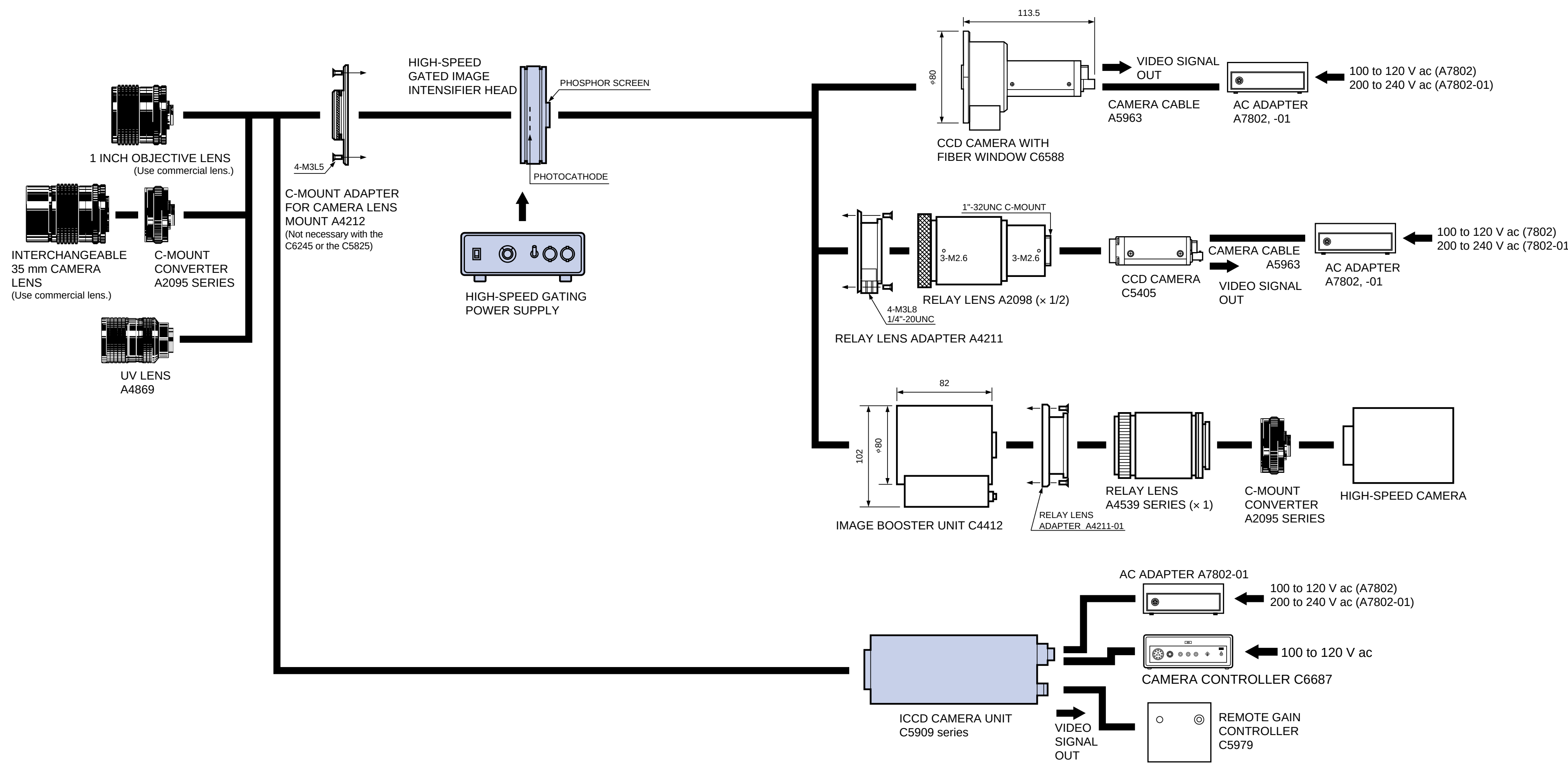
This makes it easy to replace the relay lens with one of a different magnification, or to attach the lens to a different camera. The transmission efficiency is not as high as that of fiber coupling, however, and the optics system as a whole is less compact.

Readout Device Selection Guide

Fiber Optic Plate (FOP)

The FOP is an optical device consisting of millions of glass fibers of 6 micrometers in diameter, bundled parallel to one another.
Since light is transmitted through each fiber, an image can be transferred from one end of the fiber to the other without any distorion. FOPs are widely used as optical devices that replace optical lens.





* The C7068-01 and C7069-01 use a 35 mm camera mount on the image input side because the effective input size is 40 mm.

Camera Controller C6687

The C6887 is a camera controller with frame memory for long time exposure, designed exclusively for the C5909-06, -08, -10, -12. By simply supplying an external trigger signal, the C6687 controls sophisticated functions for long time exposure and stores still images. The C6687 also has a wide range of shutter time settings from 1/30 up to 1000 seconds.
The input/output synchronization in the frame memory is separate, so the standard output format is maintained even if the synchronization signal input from the camera is changed to a special format by restart reset. This makes connections to a general monitor TV and image processor easier.

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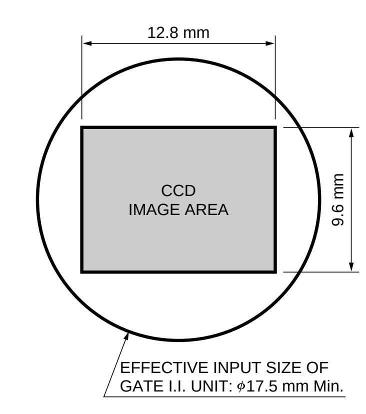
CCD Camera with Fiber Window

Direct fiber-coupling to the output surface of a gate I.I. allows image readout with a minimum loss of light.
Commercial CCD cameras cannot be coupled directly to the fiber optic plate of the output surface of a gate I.I. unit, because the image is blurred by the glass used to the CCD element. A CCD camera with a fiber window, on the other hand, is designed so that the fiber optic plate can be coupled directly to the CCD element, with no protective glass to interfere.

Image Booster Unit

This amplifies the intensity on the output surface of the gate I.I. unit. If output images are read with a high-speed camera, saturation of the MCP in the gate I.I. unit causes saturation of the image output on the phosphor screen. The image booster unit compensates for insufficient light that results from saturation of the phosphor screen.
When using a high-speed camera, it may be advantageous to use an image booster unit as well.

Image Area



The minimum effective input diameter of the gate I.I. unit is 17.5 mm. However, if the C6588 and C5405 are used in combination as shown above, the image area is 12.8 mm × 9.6 mm.

APPLICATION NOTE

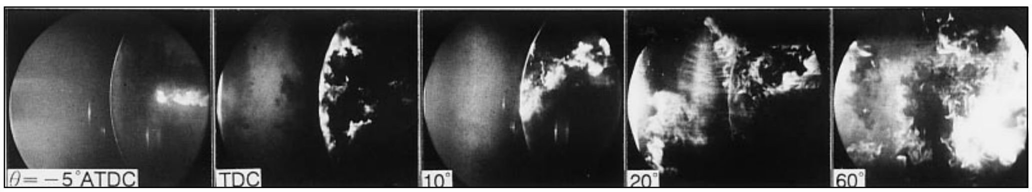
Monitoring of Soot Produced From Diesel Flame

When using C6653 or an equivalent

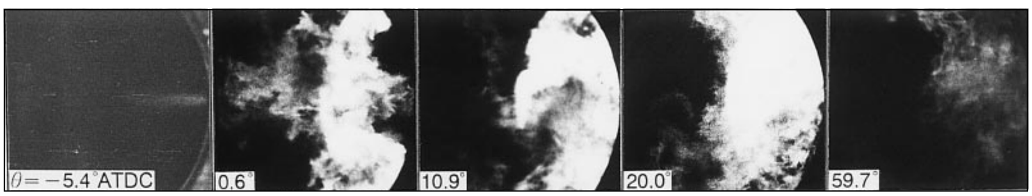
The degree of soot clouds produced in a diesel flame was monitored using the laser sheet method and a gate I.I. unit. Using the gate I.I. unit, it was possible to measure faint scattered light at high sensitivity. Also, by using gating at a high repetition rate, it was possible to capture kinetic changes in the amount of soot being produced. Images of the flame taken directly with a high-speed camera were compared with simultaneous photographs of the scattered image, enabling changes in the degree of soot being produced from the diesel combustion to be observed over time, and showing the relationship between soot conditions and the flame.

Comparison of scattered soot image and direct flame image [1)]

Scattered soot image (photographed with high-speed gated image intensifier unit)



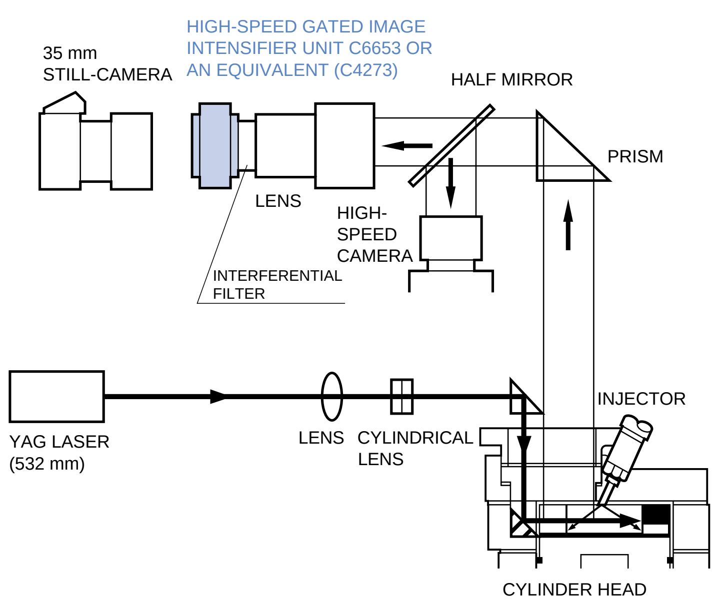
Direct flame image (photographed with high-speed camera)



ATDC : After top dead center
TDC : Top dead center
θ : Crank angle based on ATDC as reference

Imaging system configuration

The YAG laser is directed into a sheet configuration and the interior of the combustion chamber is irradiated with the laser sheet. Scattered light from the soot particles is detected using the gate I.I. unit. The gate operation of the gate I.I. unit is synchronized to the light source, enabling moving images of the scattered light to be captured. To further clarify the flame conditions, a half-mirror is introduced and the direct flame image captured with a high-speed camera.



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Courtesy of professer M. Shioji from Kyoto University.

APPLICATION NOTE

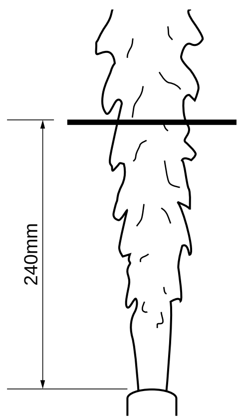
When using C2925-01

Turbulent Eddies in a Jet Flame as Visualized by a Laser Sheet Method

Visual images of the cross-section of a high-speed jet flame were captured, using the laser sheet method and a gate I.I. unit. The axes of a laser beam of 0.2 mm thickness in a sheet configuration is irradiated across, producing faint scattered light. Gating operation was synchronized to the timing at which the scattered light was produced, to obtain high-sensitivity images with little noise. Using a short gate time enabled detailed analysis of the conditions of the high-speed jet flame.

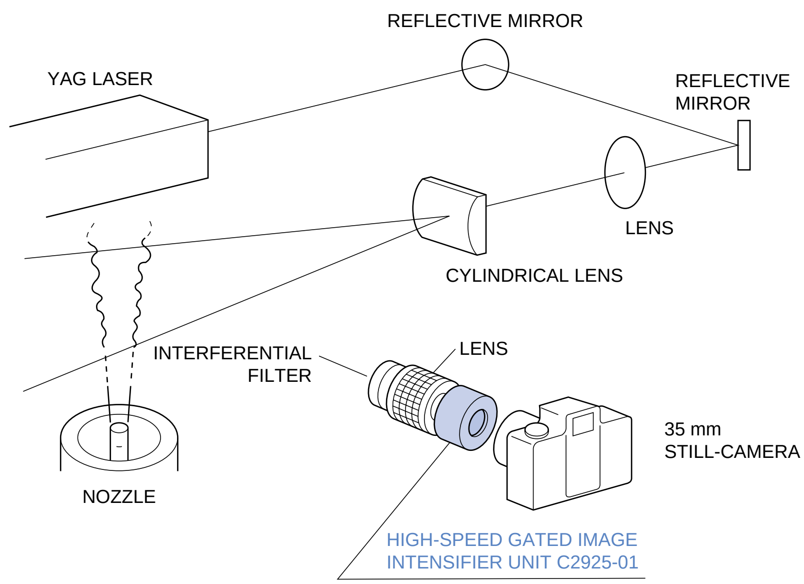
Imaging of turbulent eddies in ethlylene jet [2)]

LASER PULSE WIDTH : 10ns
GATE TIME : 100ns



Imaging system configuration [2) 3)]

The YAG laser beam is directed into a sheet configuration and irradiated across the axis of a jet flame to obtain a horizontal cross section of scattered images. Images are captured from right angles using the gate I.I. unit in synchronization with the laser beam, and are then photographed with a 35 mm still camera.



Courtesy of professer M. Shioji from Kyoto University.

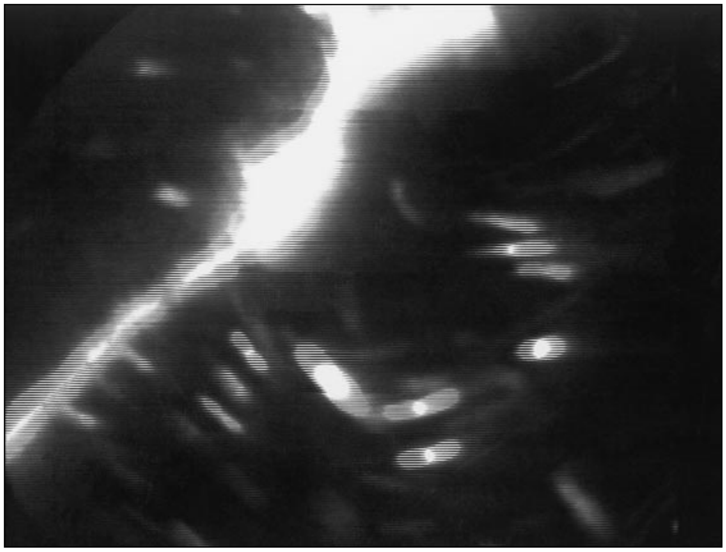
APPLICATION NOTE

When using C6653

Flow Analysis of Dragonfly Aerodynamic Mechanisms Using Particle Image Velocimetry

Using a laser beam in a sheet configuration and a gate I.I. unit, visual images of the stream of air surrounding the wings of a dragonfly in flight were captured in order to analyze the mechanisms by which flight is enabled. Using laser light enabled faint scattered light to be captured at high sensitivity, and gate action enabled measurement in extremely small time units, producing stop-action images of high-speed phenomena.

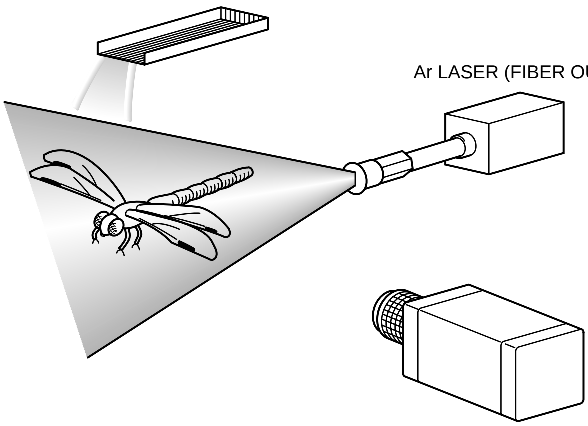
Imaging of air stream around dragonfly in flight [3)]



Formation of vortices (clockwise) in the corrugated pleats near the wing root on the morphological bottom side of the hindwing during supination. At 10% span position. (Forward is right.)

Imaging system configuration

Finely powdered granules with a diameter of around 10 µm were scattered around the target (dragonfly wing) and irradiated with a laser beam in a sheet configuration, producing faint scattered light which was captured with a high-sensitivity camera (with a built-in gate I.I. unit) to obtain visual images.



Courtesy of Research Development Corporation of Japan (JRDC)
Development of Research Adiministration Kawachi Milibioflight Project

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APPLICATION NOTE

When using C4078-01

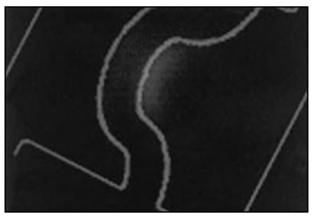
Evaluation of Plasma Display Panels (PDP) [4)]

Kinetic changes in the extremely faint and high-speed plasma emissions from a PDP were captured using a gate I.I. unit. Gate operation at a high repetition rate enabled changes in the PDP emissions which take place as time elapses following the application of pulsed voltage to be monitored. Analyzing the status of the plasma emissions then enabled evaluation of the PDP.

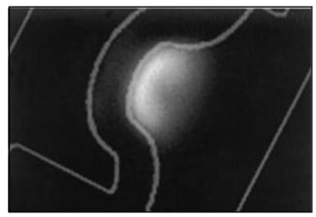
Image of kinetic changes in PDP emissions

(Plasma emissions are shown superimposed on the PDP electrode outline. Time indicated is elapsed time after an electrical pulse has been supplied to the PDP.)

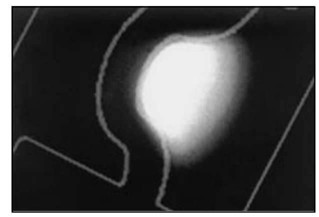
① 0.30 µs



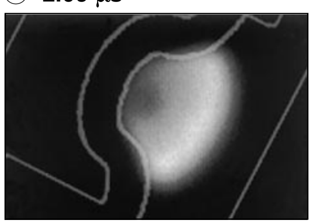
② 0.47 µs



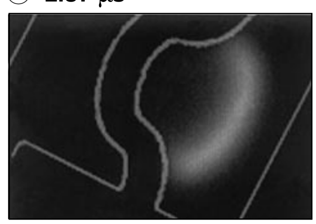
③ 0.71 µs



④ 1.09 µs



⑤ 1.37 µs

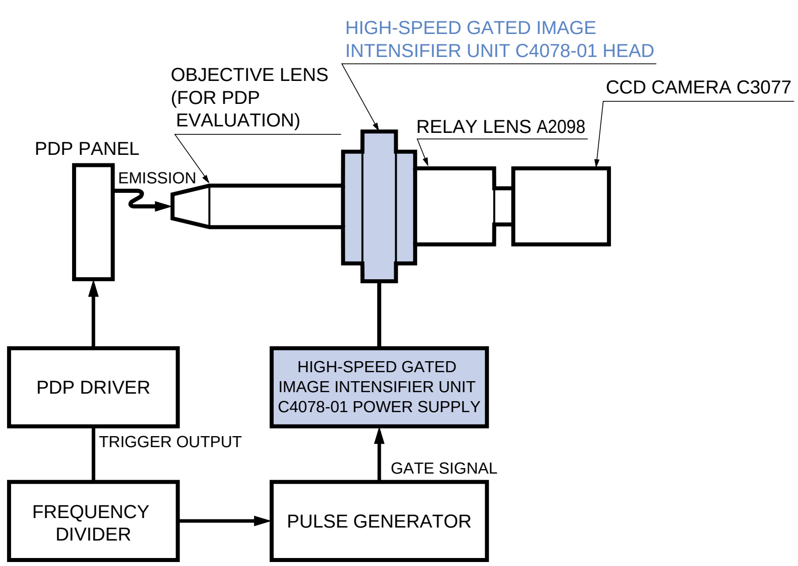


Measurement Conditions

- PDP
  Filled gas : Ne + Xe (4 %) 67 kPa
  Cell pitch : 1 mm
  Supply voltage : 160 V (Emitting electrode at negative potential)
- Gate I.I. unit
  Gate time : 100 ns
  Repetition frequency: 10 kHz
  An exclusive magnifying lens (×20) is used.

Imaging system configuration

Emissions from the PDP were passed through an objective lens and input to a gate I.I. unit. The trigger pulse from a PDP driver was guided through a divider and an external trigger applied to a pulse generator, with the gating of the gate I.I. unit taking place at the pulse width and delay timing specified by the pulse generator.
Because the PDP emissions were extremely faint, a gate I.I. unit with two MCPs was used.



Courtesy of associate professor H. Uchiike from Hiroshima University.

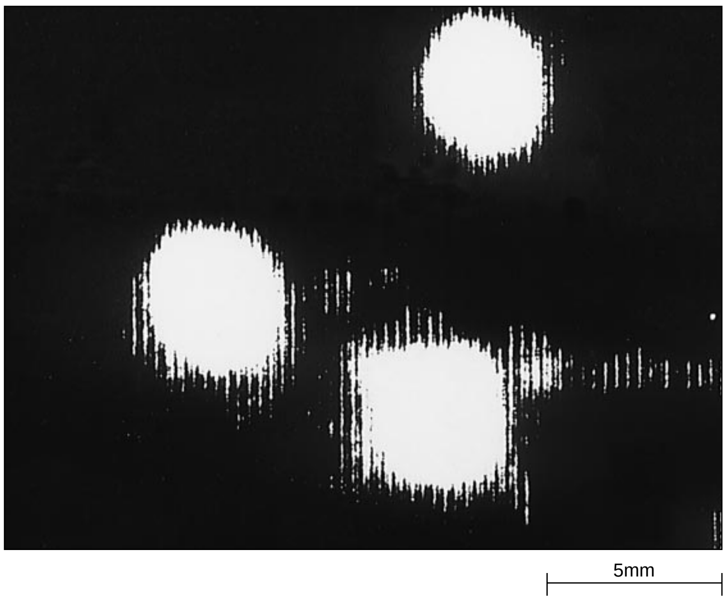
APPLICATION NOTE

When using C6654 or an equivalent

Detecting Fine Particles on LSI Wafers [5)]

Faint lateral scattered light from tiny particles caused by laser light were detected using a gate I.I. unit, enabling detection of the extremely small particles themselves. Optical noise originating from the wafer surface can be reduced and faint lateral scattered light from 38 nm diameter particles detected. The measurement time is short because a large area can be measured.

Photo Example : Detection of fine particles (particle diameter: 38 nm)

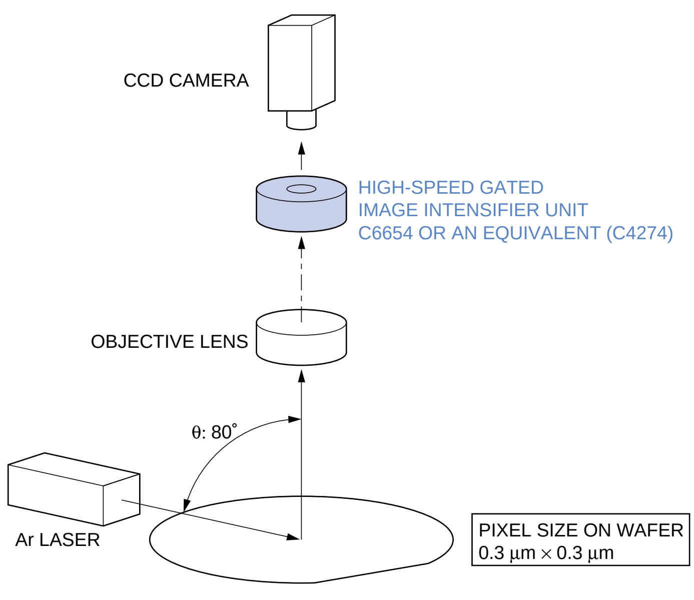


Example showing detection of 38 nm diameter

Because of the spatial spread of the image intensifier, individual particles appear to have spread out to 7 to 8 μm. (Particle diameter of 38 nm confirmed using SEM)

Imaging system configuration

38 nm particles were placed on an Si wafer and irradiated with a laser beam at an irradiation angle of 80 degrees. Lateral scattered light from the particles was detected using a gate I.I. unit. Measurements were made with a minimum optical noise by reducing the pixel size but enlarging the laser irradiation angle.



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Courtesy of Hitachi, Ltd. Production Engineering Research Laboratory.

APPLICATION NOTE

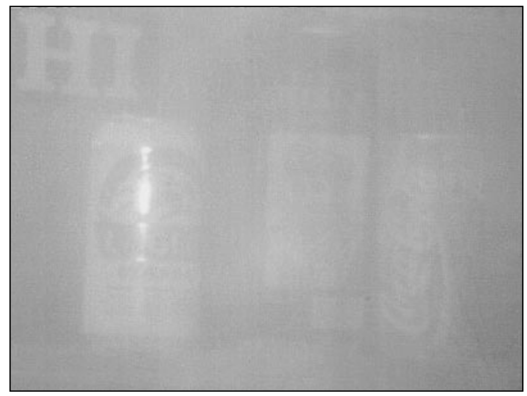
When using C2925-01

Underwater Laser Television

Using a gate I.I. unit in combination with the laser range gate method enabled underwater photography in muddy water.
Gating was activated only at a specific timing governed by the irradiation of reflectance light from the laser (laser range gate method), enabling confirmation of underwater photography at a high level of sensitivity and with little noise.
This underwater laser television is capable of outstanding visibility in muddy water, and is expected to sharply improve the efficiency of underwater operations in the future.

Imaging in muddy water Turbidity: 1.042 ppm Visibility: 2 m

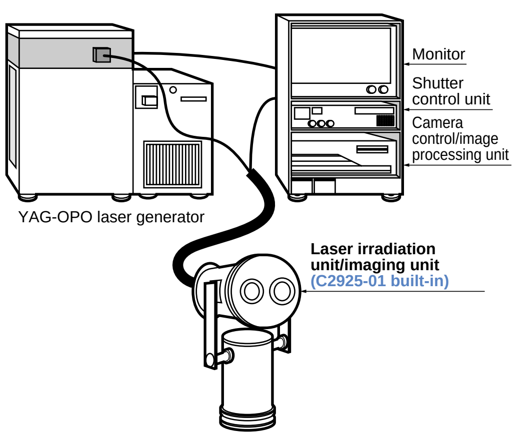
Underwater laser television
(using gate I.I. unit)
Laser used: YAG-OPO laser oscillator



Conventional type
Underwater television camera
(using SIT camera)
Illumination: Halogen light (underwater) 500 W

Basic configuration of underwater laser television

The muddy water is irradiated with a pulsed laser, and light reflected from objects is captured using a camera with a built-in gate I.I. unit. Gating was activated only at a specific timing governed by the irradiation of reflectance light from the laser, enabling clear, detailed underwater images to be obtained.



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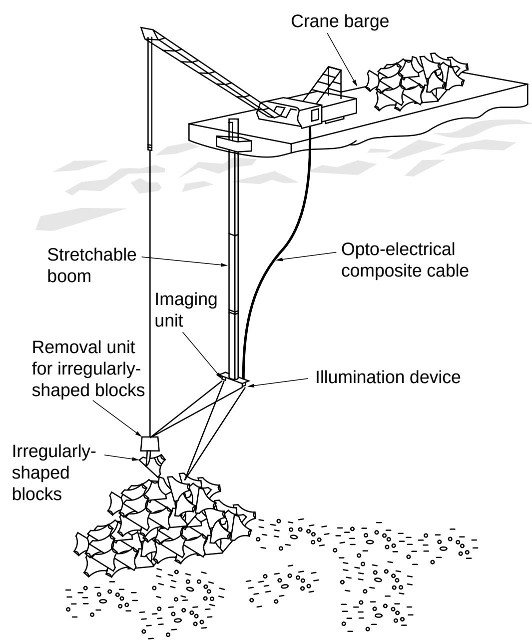
Underwater removal and installation of irregularly-shaped blocks



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Courtesy of Ishikawajima-Harima Heavy Industries Co.,Ltd. ULVS (Underwater Laser Viewing System)
This product was developed as a result of joint cooperation among The 1st District Port Construction Bureau Ministry of Transport, Port and Harbor Research Institute Ministry of Transport, and Ishikawajima-Harima Heavy Industries Co. Ltd.

APPLICATION NOTE

Observation of Pulsed Light Propagation Through Optical Fiber

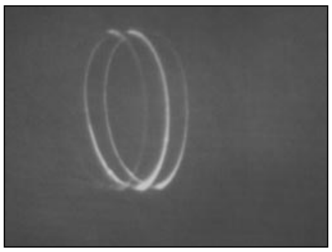
When using C2925-01

This is what pulsed laser light passing through an optical fiber looks like when observed with a high-speed gated image intensifier. This allows verifying the distance that the light pulse travels after emission per the gate time.

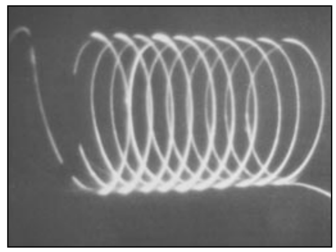
* Unsheathed optical fiber was used to observe light pulse from external side.
* Optical fiber refractive index: 1.5

Image at 3 ns gate time: Image shows light moved 60 cm.
Image at 100 ns gate time: Light has moved 50 to 60 m, so entire fiber is emitting light.

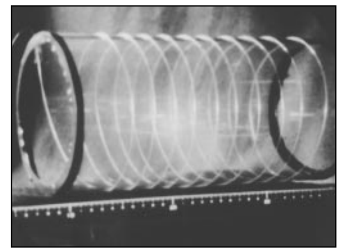
Image examples: Laser pulsed light passing through optical fiber



Gate time: 3 ns



Gate time: 100 ns

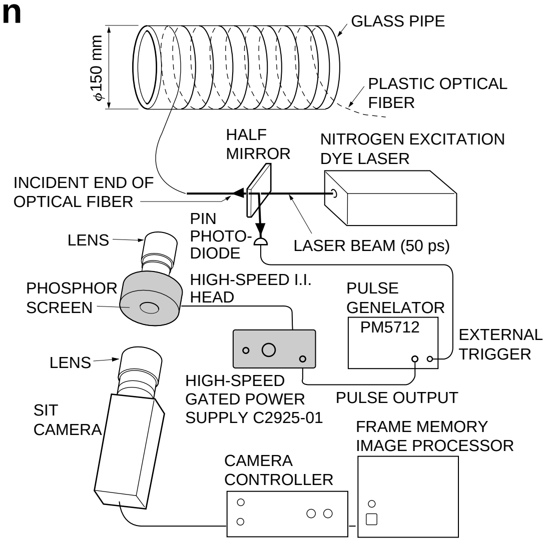


External view of fiber optic cable used in this test

Imaging system configuration

Pulsed laser light is guided into the fiber optic cable wound around a glass pipe. A high-speed gated image intensifier is used to capture an image of pulsed light passing through to optical fiber optic. The image captured with the gated image intensifier is then read out with an SIT camera.

To control the gate time (shutter speed), pulsed light is split by a beamsplitting mirror into two paths. A PIN photodiode detects light on one path and generates a trigger signal for input to a pulse generator. This pulse generator provides a TTL signal output for the high-speed gated image intensifier power supply.



Laser Wavelength : 550 nm
Pulse Width : 50 ps
Repetition Frequency: 1 Hz

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REFERENCE
1) M. Shioji, et al. : 1992 JSAE Autumn Convention Proceedings, 924, 41-44 (1992). (Published in Japanese)
2) M. Shioji, et al. : Transactions of the Japan Society of Mechanical Engineers, 57-542, 3562-3568 (1991). (Published in Japanese)
3) M. Shioji, et al. : Transactions of the Japan Society of Mechanical Engineers, 59-566, 3271-3276 (1993). (Published in Japanese)
4) S. Zhang, Y. Harano, H. Uchiike: IDW '96 Workshop on Plasma Displays, PDP 1-2 (1996).
5) Minori Noguchi and Yukio Kembo : Jpn. J. Appl. Phys., Vol. 32, 352-357 (1993).

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