



High-performance opto-semiconductors based on optical technology accumulated by Hamamatsu Photonics

In order to meet increasingly sophisticated needs, Hamamatsu Photonics is constantly pursuing optical technology that is one step ahead and is developing high-performance opto-semiconductors.



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Hamamatsu opto-semiconductors

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Wide variety of product lineup

In addition to opto-semiconductors including photodiodes, photo ICs, image sensors, infrared detectors, and LEDs, we offer applied products such as mini-spectrometers. Our product lineup supports various light wavelengths (infrared, visible, ultraviolet, X-ray, high energy).

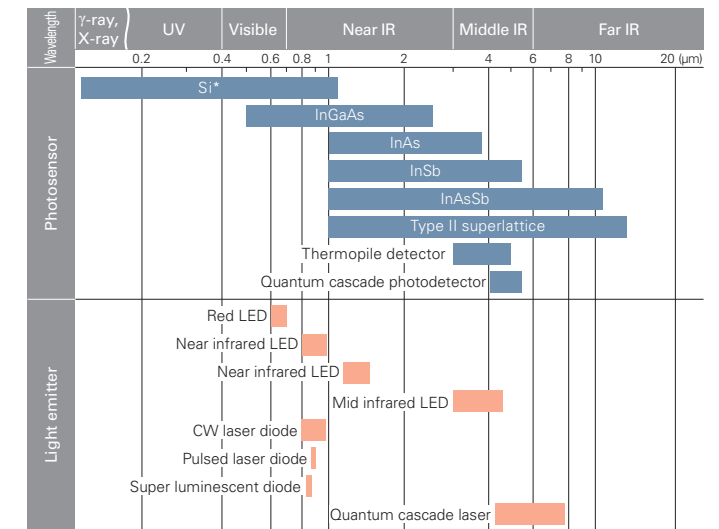
Wide application fields

Hamamatsu Photonics opto-semiconductors are used in many fields, including scientific measurement, medicine, automobiles, industry, and consumer products.

Flexible customization

At Hamamatsu's own factories, we have established a production system covering design, semiconductor process, assembly, and inspection. Custom products are also available by request. Please feel free to consult us.

Products supporting each wavelength range



* A light-input-windowless type and a scintillator type can detect X-rays or gamma-rays.

Optical technologies in Hamamatsu Photonics Solid State Division

Opto-semiconductor technology

High-performance opto-semiconductors

Semiconductor process (Si, compound)

- Wavelength range (infrared, visible, ultraviolet, X-ray, high energy)
- Photosensitive area (large area, multi elements)
- High sensitivity
- High-speed response
- High UV resistance
- Sophisticated device (CMOS technology)

Mounting/packaging

- Ready for low- and high-volume production
- Variety of package types (surface mount type, chip size package, windowless, etc.)
- Flip-chip bonding
- TE-cooled type

MEMS

- Etching
- Nanoimprint
- Three-dimensional mounting

Module technology

High-performance made easy to use

Optical system

- Excellent optical design (lens, mirror, filter, etc.)
- Utilizing simulations

Circuit

- Analog and digital circuits
- ASIC, FPGA

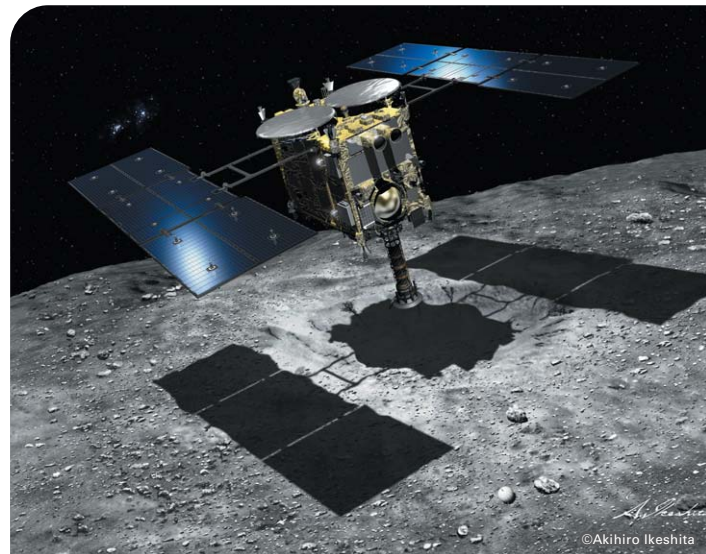
Software

- Application software, firmware
- Supports various interfaces



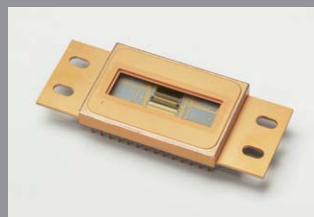
Flexible customization

Applications of Hamamatsu opto-semiconductors

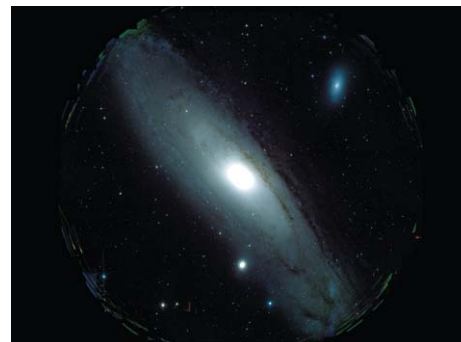


Hayabusa2

Hamamatsu Photonics manufactured an InAs linear image sensor which was included in the near-infrared spectrometer mounted on the spacecraft Hayabusa2. It was used for a mission that revealed minerals containing water are present on the surface of the asteroid Ryugu.



InAs linear image sensor



Andromeda galaxy



Subaru Telescope
(by courtesy of NAOJ (National Astronomical Observatory of Japan))

CCD area image sensors

Astronomical observation

The world's highest sensitivity CCDs manufactured by Hamamatsu are installed in the ultra-wide-field prime focus camera HSC (Hyper Suprime-Cam) of the Subaru Telescope at the summit of Mauna Kea, Hawaii.



InAsSb photovoltaic detectors

Quantum cascade laser

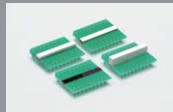
Gas measurement

InAsSb photovoltaic detectors, which have high sensitivity in the mid infrared region, can detect gas concentration with the use of the absorption wavelength unique to each type of gas molecule.

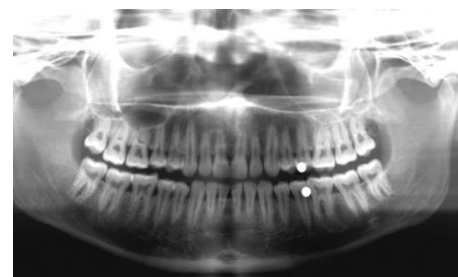


X-ray non-destructive inspection

Hamamatsu Si photodiode arrays are widely used as detectors in X-ray baggage inspection systems.



Si photodiode arrays



X-ray radiography

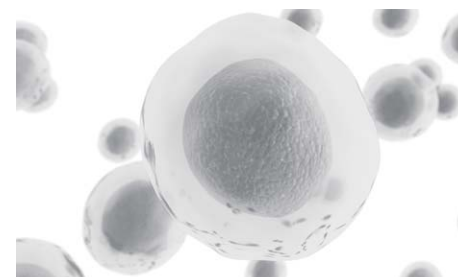
CMOS area image sensors are used in imaging equipment for dental diagnosis.



CMOS area image sensors



CCD image sensor



Flow cytometry

Flow cytometry is a method for analyzing the properties and structure of cells. It works by irradiating a laser on cells flowing in a row at high speed through a flow cell, and measuring their scattered light and fluorescence.

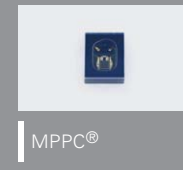


APD module

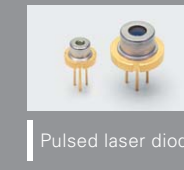


LiDAR

LiDAR (light detection and ranging) is remote sensing technology that measures distance by irradiating a laser light on objects and catching the light reflected back using an optical sensor.



MPPC®



Pulsed laser diode



Industrial optical data link

High-speed optical fiber communications using plastic optical fiber (POF) are not prone to disruption by external noise, so it is commonly used in FA, and the like.

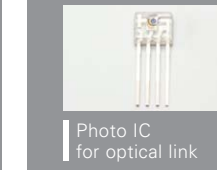
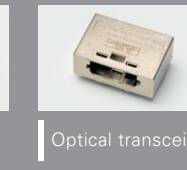


Photo IC for optical link

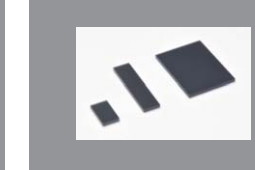


Optical transceiver



Robot cleaner

A distance image sensor measures the distance to objects in all directions while rotating, in order to recognize shapes and detect obstacles in the room.



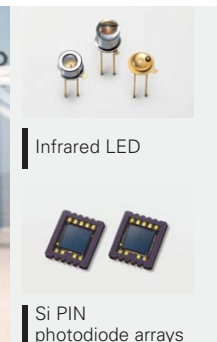
Distance image sensors

Hamamatsu opto-semiconductors have been used in wide-ranging fields including communications, industry, and general electronics as well as medical and scientific applications.



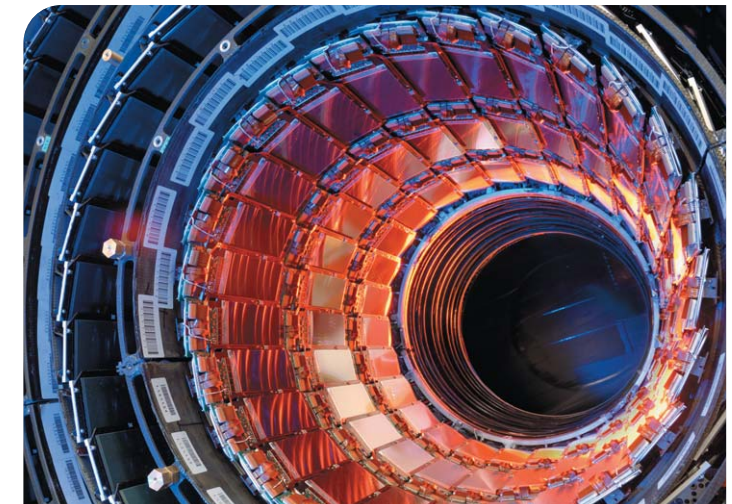
Industrial robots (control encoder)

Infrared LED and Si PIN photodiode arrays are used to configure encoders built into robots for position control.



Infrared LED

Si PIN photodiode arrays



CMS project
(by courtesy of CERN)

High energy experiments

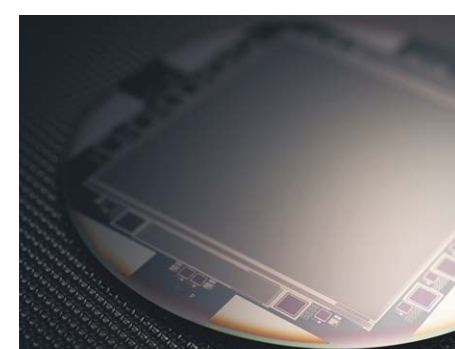
The European Organization for Nuclear Research (CERN) in Switzerland is conducting a project involving the Large Hadron Collider (LHC). The Si strip detectors by Hamamatsu are being used as the particle track detectors in the collider, and are detecting particle tracks with a precision on the order of several tens of μm.



Si strip detector

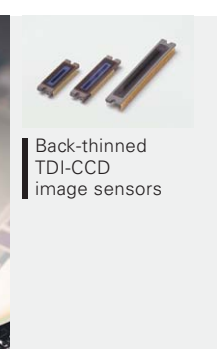


Si APD

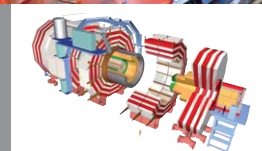


Semiconductor manufacturing equipment (wafer defect inspection)

Back-thinned TDI-CCD image sensors are used for wafer defect inspections.



Back-thinned TDI-CCD image sensors



Manufacturing process of opto-semiconductors



Main factory (Ichino)

Design

- New products
- Custom products



Examples of custom order

- Electrical and optical characteristics
- Photosensitive area
- Number of elements
- Package
- Reliability

Epitaxial growth process [Typical compound semiconductor fabrication process]




Thin-film crystal growth under ultra-high vacuum in MBE equipment



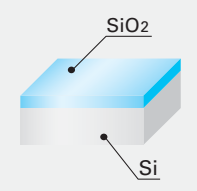

Thin-film crystal growth with MOCVD equipment

Wafer process [Typical process of Si photodiode fabrication]



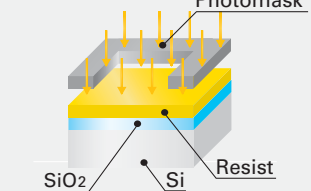

Si wafer (before process)

Oxidation

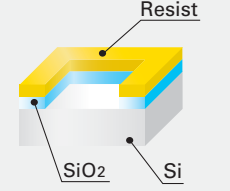

Thin films are formed on wafers by oxidation or CVD process.

Photolithography

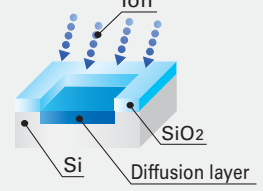

Device patterns are formed by photolithographic technique.

Etching

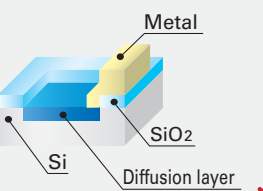

Selective etching is performed on the thin film on wafers.

Ion implantation

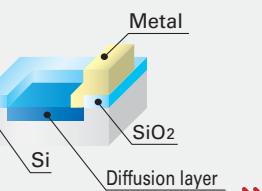

Doping impurities are injected into wafers.

Metallization

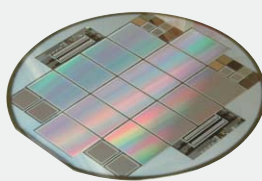



Metal pattern is formed.

Wafer inspection

Devices on the wafer are inspected electrically and optically.



To assembly process

Semiconductor technologies

» Semiconductor process technologies

■ PIN bipolar process

Fabricates high-speed photodiodes by integrating a PIN photodiode and high-speed signal processing circuit onto a single chip.

■ Back-thinned CCD process

Back-thinned CCD area image sensors have a very thin photosensitive layer for high sensitivity yet low dark current.

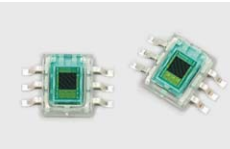
■ CMOS process

The integration of circuit functions in photodetectors helps to achieve high performance, multifunctionality, and cost reduction in systems.

■ Compound semiconductor process

Utilizing compound semiconductor process technologies that include MBE, MOCVD, and dry etching techniques optimized for precision processing, we have been developing high-performance devices for optical communications, chemical analysis, and measurement.

▼ Product examples produced using CMOS process




Digital color sensors CMOS image sensors

▼ Product examples produced using compound semiconductor process




InGaAs APD InGaAs linear image sensors

» MEMS technologies

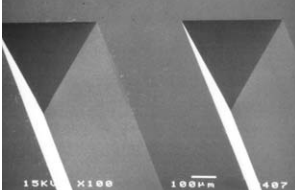
Hamamatsu is developing highly functional opto-semiconductors using a wide range of MEMS technologies.

■ Etching

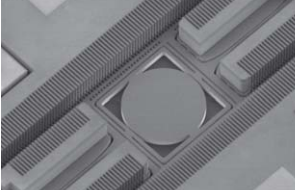
Anisotropic etching (deep etching) and sacrificial layer etching (etching that makes a hollow structure) can provide functions not possible with conventional opto-semiconductors.

■ 3D mount

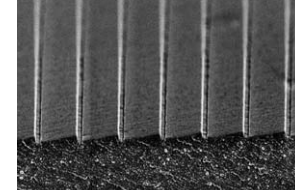
3D mount technology can be broadly grouped into "electrode technology" for fabricating structures with 3D electrical connections and "bonding technology" for making wafer level packages. Electrode technology is essential for achieving more sophisticated functions and smaller size opto-semiconductors. Electrode technology involves techniques for forming Si through-hole electrodes to extract electrodes from the backside of devices and flip-chip bonding to make electrical connections between different materials. Bonding technology includes anodic bonding and room-temperature bonding that need no adhesives and that apply direct sealing on devices to achieve ultra-small packages.



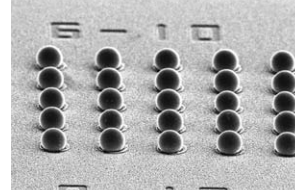
V grooves formed by anisotropic etching



Actuators formed by anisotropic etching and sacrificial layer etching


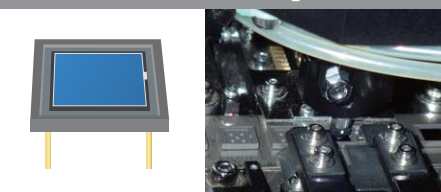

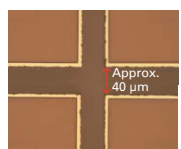
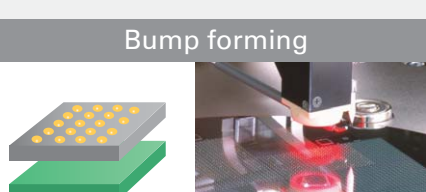


Nanoimprint



20 μm pitch indium bump electrodes

Assembly process [Typical process]

Metal package	»	<p>Dicing</p> <p>▼ Blade dicing</p>  <p>Wafers are cut by a spinning blade.</p>	»	<p>Die bonding</p>  <p>Chips are bonded to metal bases.</p>	»	<p>Wire-bonding</p>  <p>Chips are connected to metal bases using gold wires.</p>	»	<p>Cap sealing</p>  <p>Metal caps are welded to metal bases.</p>	<p>Test</p>
Ceramic package	»	<p>▼ Stealth dicing</p>  <p>A laser cuts a wafer by irradiating the interior of the wafer.</p>	»	<p>Die bonding</p>  <p>Chips are bonded to ceramic bases.</p>	»	<p>Wire-bonding</p>  <p>Chips are connected to ceramic bases using gold wires.</p>	»	<p>Resin encapsulation</p>  <p>Resin is injected into ceramic bases.</p>	<p>Electrical & optical test</p> <p>▼ Metal package test equipment</p> 
Plastic package	»	<p>[Dicing examples]</p>   <p>Blade dicing (Approx. 40 μm)</p> <p>Stealth dicing (Approx. 1 μm)</p>	»	<p>Die bonding</p>  <p>Chips are bonded to lead frames.</p>	»	<p>Wire-bonding</p>  <p>Chips are connected to lead frames using gold wires.</p>	»	<p>Resin molding</p>  <p>Resin is molded along lead frames and chips.</p>	<p>▼ Plastic package test equipment</p>  <p>Electrical & optical characteristics are tested.</p>
COB (chip on board)	»	<p>Bump forming</p>  <p>Gold bumps or solder bumps are formed on wafers.</p>	»	<p>Die bonding</p>  <p>Chips are bonded to substrates.</p>	»	<p>Wire-bonding</p>  <p>Chips are connected to substrates using gold wires.</p>	»	<p>Resin molding</p>  <p>Resin is injected on substrates.</p>	<p>Appearance inspection</p> <p>▼ Appearance inspection system</p> 
Chip size package	»	<p>Dicing</p> <p>Blade dicing or Stealth dicing</p>	»	<p>Flip chip bonding</p>  <p>Chips with bumps are bonded to substrates by being flipped (inverted).</p>	»	<p>Underfill filling</p>  <p>The space between the substrate and chip is filled in with resin.</p>	»	<p>Underfill filling</p>  <p>The space between the substrate and chip is filled in with resin.</p>	<p>▼ X-ray & appearance inspection system</p>  <p>The appearances of finished products are inspected.</p>

Semiconductor technologies

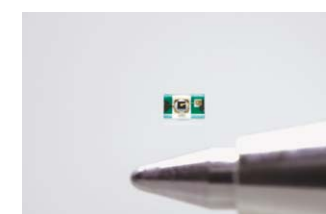
» Module mounting technology

We aim to provide sophisticated module products at low-cost and with short lead-times, by in-line mounting of photosensors and electronic components.



Mounting device for sophisticated module products

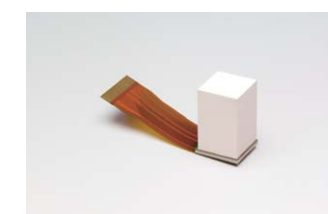
» Various package examples



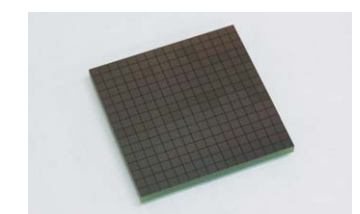
Glass epoxy board



Long and narrow type



With flexible cable



Flip-chip bonding

Si photodiodes

Product lineup for wide-ranging applications

Si photodiodes are used in various applications covering optical fiber communications, copiers, analytical instruments, and baggage inspection, and are available in various packages including metal, ceramic, and plastic packages, as well as surface mount packages.

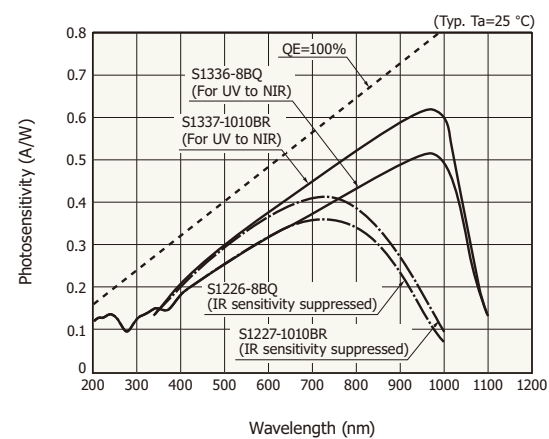


Features

- Excellent linearity with respect to incident light
- Low noise
- Wide spectral response range
- Mechanically rugged
- Compact and lightweight
- Long life

Spectral response (typical example)

S1226/S1336-8BQ, S1227/S1337-1010BR

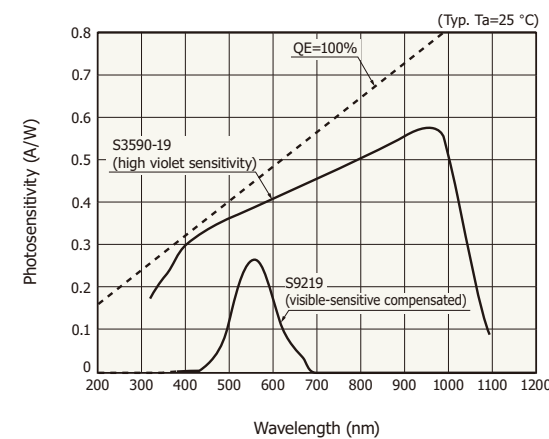


KSPD80300EC

Major applications

- Analytical instruments
- General photometry
- Baggage inspection
- Optical fiber communications

S3590-19, S9219



KSPD80301ED

Product lineup

Product name	Product examples
1 Si photodiode	<ul style="list-style-type: none"> ■ For UV to near IR range ■ For visible to near IR range ■ For visible range ■ RGB color sensor ■ For monochromatic light detection ■ For VUV (vacuum ultraviolet) detection ■ For electron beam detection
2 Si PIN photodiode	<ul style="list-style-type: none"> ■ Cutoff frequency: 1 GHz or more ■ Cutoff frequency: 500 MHz to less than 1 GHz ■ Cutoff frequency: 100 MHz to less than 500 MHz ■ Cutoff frequency: 10 MHz to less than 100 MHz ■ For YAG laser detection ■ For encoders
3 Multi-element type Si photodiode	<ul style="list-style-type: none"> ■ Segmented type ■ One-dimensional type
4 Si photodiode with preamp 5 TE-cooled type Si photodiode	<ul style="list-style-type: none"> ■ For analytical instrument and precision measurement
6 Si photodiode for X-ray	<ul style="list-style-type: none"> ■ With scintillator ■ Large-area Si PIN photodiode

Modules for photodiode

To make our photodiodes easier to use, we offer several different types of modules.



Photodiode modules



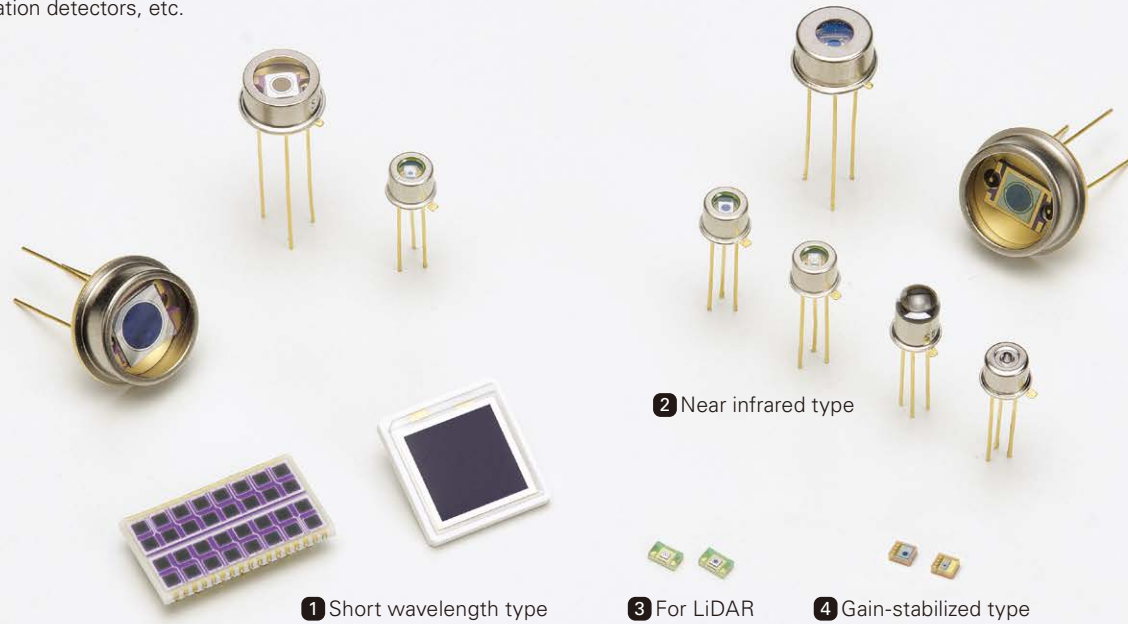
Photosensor amplifiers

Product name	Features
Photodiode module	These modules are high-precision photodetectors integrating a Si photodiode or InGaAs photodiode with a current-to-voltage conversion amplifier into a compact case.
Photosensor amplifier	Photosensor amplifiers are current-to-voltage conversion amplifiers used to amplify very slight photocurrent from a photodiode with very low noise.

Si APD

High-speed, high-sensitivity photodiodes with an internal gain mechanism

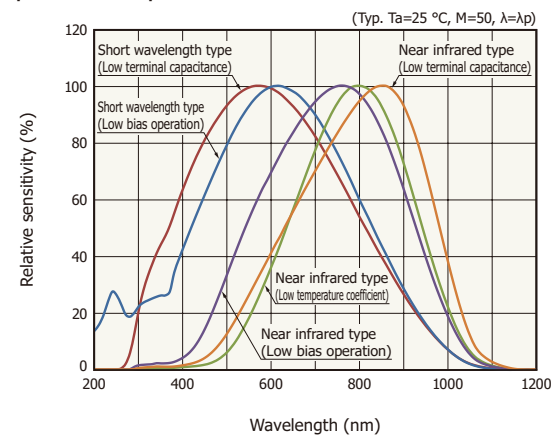
APD (avalanche photodiodes) are high-speed, high-sensitivity photodiodes that internally amplify photocurrent by the application of a reverse voltage. They deliver a higher S/N than PIN photodiodes and are widely used in optical rangefinders, FSO (free space optics), and scintillation detectors, etc.



Features

- Excellent linearity with respect to incident light
- Low noise
- Wide spectral response range
- Mechanically rugged
- Compact and lightweight
- Long life

Spectral response

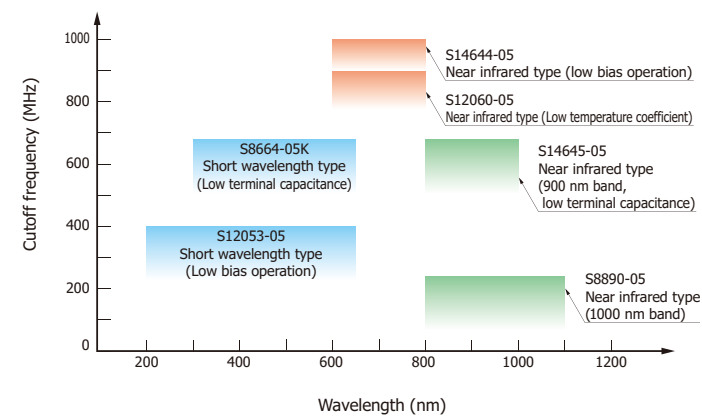


KAPDB0195EF

Major applications

- Low-light-level detection
- Analytical instruments
- FSO
- Optical rangefinders
- Optical fiber communications
- LiDAR
- YAG laser detection

Cutoff frequency vs. recommended wavelength



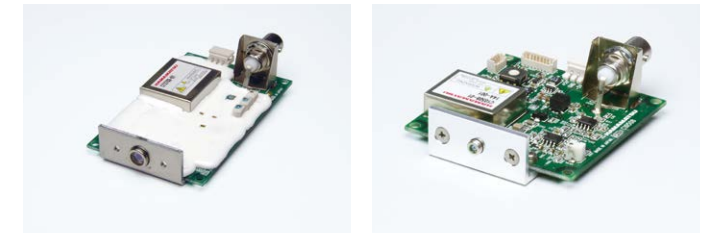
KAPDB0196EG

Product lineup

Type	Recommended wavelength (nm)	Package	Features
1 Short wavelength type	Low-bias operation	200 to 650	Metal Enhanced sensitivity in the UV to visible range
	Low terminal capacitance	320 to 650	
2 Near infrared type	Low bias operation	700 to 900	Metal FSO (free space optics), optical fiber communications, analytical instruments
	Low temperature coefficient		
	850 nm band	700 to 1000	Metal FSO, optical fiber communications
	900 nm band		
	1000 nm band		
TE-cooled type	700 to 900	FSO, analytical instruments, YAG laser light detection	
3 For LiDAR	700 nm band	600 to 800	Surface mount type Type with low dark current, wide operating temperature range, and improved sensitivity in the LiDAR wavelength band Little variation in breakdown voltage
	800 nm band	700 to 900	
	900 nm band	800 to 1000	
4 Gain-stabilized type	700 nm band	600 to 800	Surface mount type Gain-stabilized APD (GS APD) with a built-in temperature compensation function inside the sensor.
	800 nm band	700 to 900	
	900 nm band	800 to 1000	

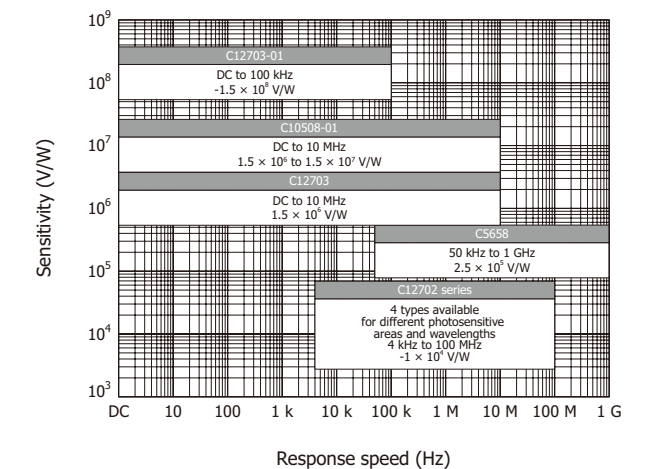
APD modules

This high-sensitivity light detection modules integrate an APD, temperature-compensation bias circuit, and I/V converter. They are easy to handle and can be used simply by supplying DC voltage externally.



Type	Features
Standard type	Contains a near infrared or short wavelength type APD. FC/SMA fiber adapters are also provided.
High-sensitivity type	High gain type for detection under low illuminance
High-stability type	Digital temperature-compensation, high-stability APD module
High-speed type	Operates over a wide range of frequencies (up to 1 GHz)

Sensitivity vs. response speed (APD modules)

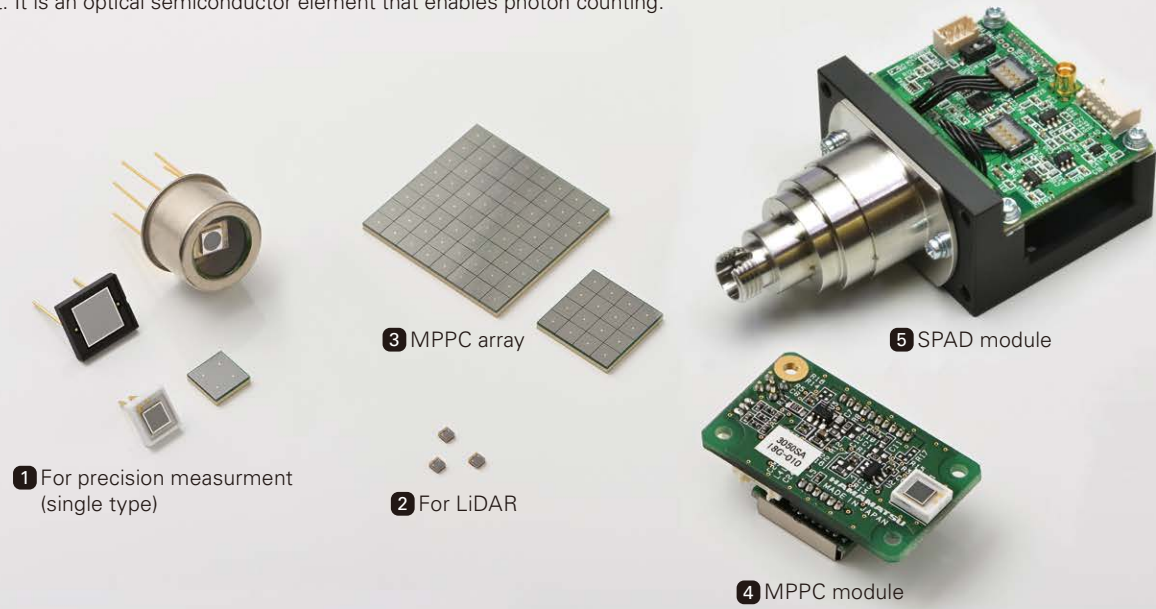


KACCB0355EB

MPPC® (SiPM) · SPAD

Compact opto-semiconductors with excellent photon-counting capability

MPPC (Multi-Pixel Photon Counter) is a photon counting device that is a multi-pixelized Geiger mode APD. Hamamatsu's SPAD (Single Photon Avalanche Diode) is an element with a structure of a single pixel that combines a Geiger mode APD and a quenching resistor into one set. It is an optical semiconductor element that enables photon counting.



Features

- Excellent photon-counting capability
- High gain: 10^5 to 10^6
- Low-bias operation
- Insensitive to magnetic fields
- Simple readout-circuit operation
- Low afterpulses, low crosstalk (compared to our previous products)
- Excellent time resolution
- Room temperature operation

Major applications

- Flow cytometry
- Laser scan microscopes
- Single molecule detection
- Fluorescence analysis, fluorescence lifetime measurement
- PET
- Scintillation light detection
- LiDAR

What is the MPPC ?

The MPPC is so-called Si-PM (silicon photomultiplier) photosensor. It is a photon-counting device consisting of multiple APD pixels operating in Geiger mode. Each APD pixel of the MPPC outputs a pulse signal when it detects one photon. The signal output from the MPPC is the total sum of the outputs from all APD pixels. The MPPC offers the high performance needed in photon counting and is used in diverse applications for detecting extremely weak light at the photon-counting level.



Product lineup

Type	Features
1 For precision measurement (single type)	These are low-noise MPPCs for precision photometry. Low crosstalk and low afterpulses in addition to high photon detection efficiency achieve excellent S/N. They are suitable for precision measurement, such as flow cytometry, DNA sequencer, laser microscope, and fluorescence measurement, that requires low noise characteristics. They are available in two types: ceramic package and surface mount. We also have TE-cooled single photon avalanche diode (SPAD).
2 For LiDAR	This compact type offers high sensitivity in the near infrared region.
3 MPPC array	These are MPPCs with several MPPC chips arranged in an array. The CSP (chip size package) type MPPCs can be tiled together to fabricate large-area devices and can be coupled efficiently to scintillators or the like.
4 MPPC module	MPPC modules are optical measurement modules with built-in MPPC. They can measure light over a wide range (10 orders of magnitude) from the photon counting region to nW (nanowatt) region. They are available in two types: non-cooled modules, which are equipped with a temperature compensation function for stable measurement, and cooled modules, which feature low dark count.
5 SPAD module	SPAD modules are photon counting modules with digital output built-in TE-cooled SPAD.

Measurable light level ranges of MPPC modules and SPAD modules (product examples)

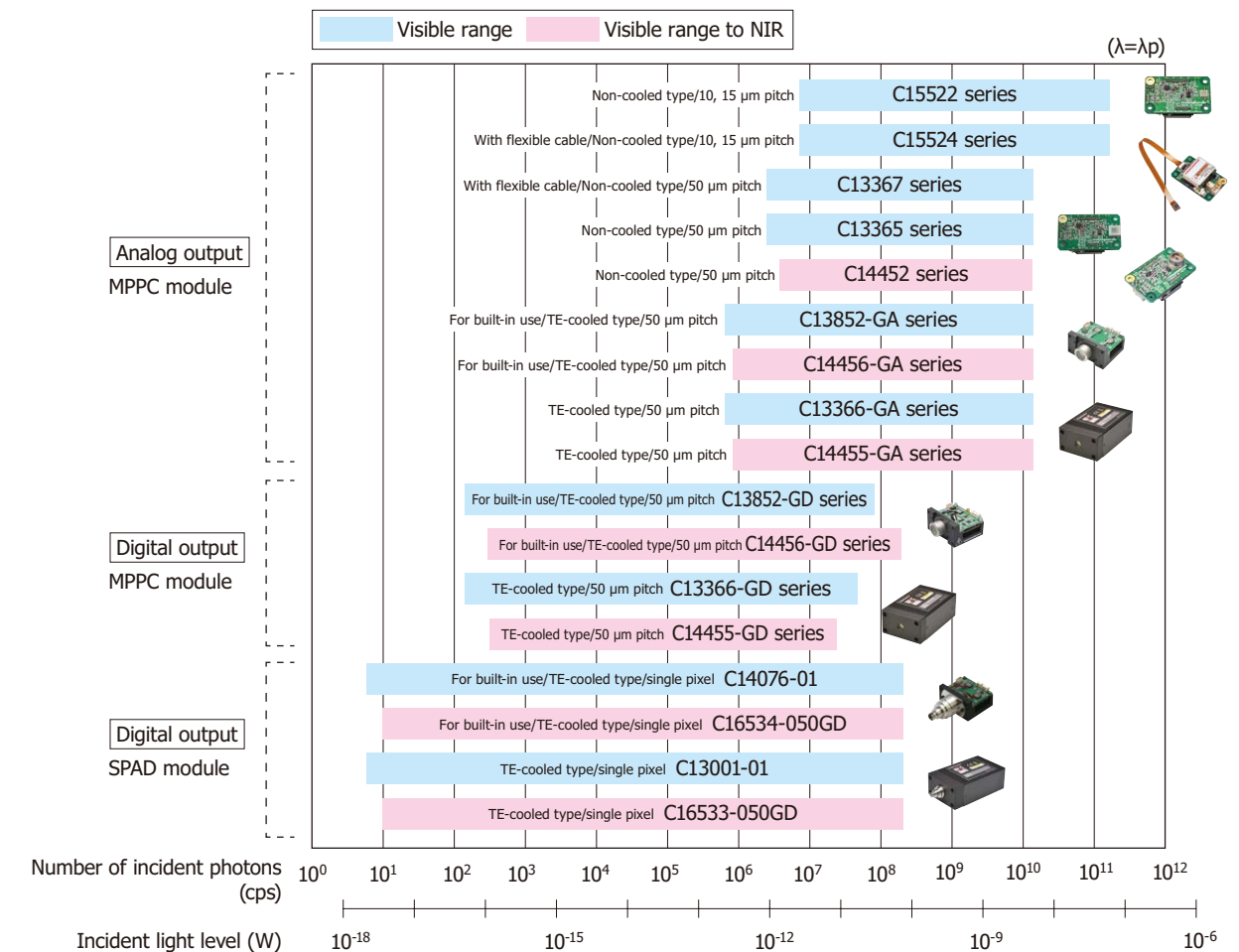
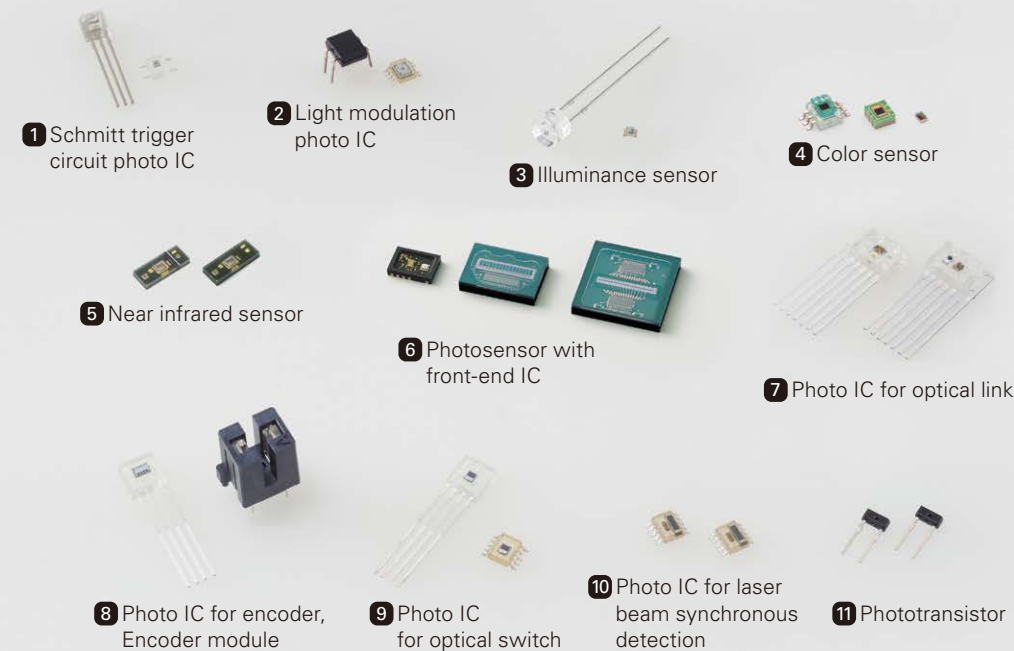


Photo IC

Highly functional devices integrating a photodiode with a signal processing circuit

The photo IC is a light receiver element with various functions. It integrates a photosensor and a signal processing circuit into one package.



Features

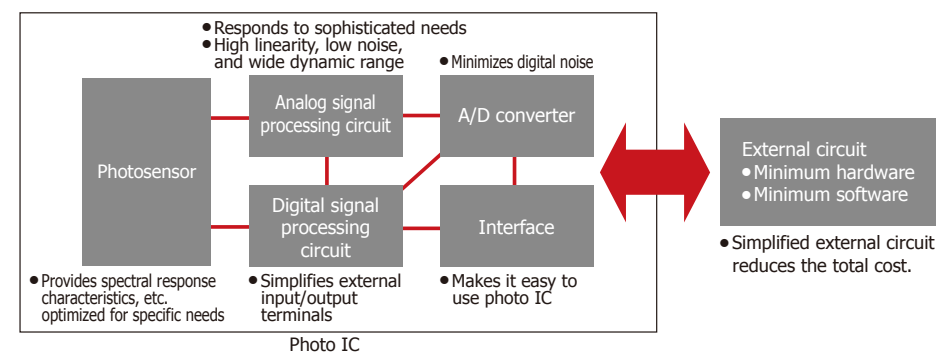
- Small and lightweight
- Highly resistant to noise from electromagnetic induction
- High reliability

Major applications

- Paper detection in office machines (copier, fax machines, etc.)
- Optical switches
- Light dimmers for liquid crystal panels and large-screen TV, etc.
- Color adjustment for display
- Plastic optical fiber communications
- Encoders

Hamamatsu photo IC technology

- Offers custom designs for producing optical sensors to meet specific applications
- Merges IC design technology, CMOS circuit technology, optical device technology, and packaging technology
- Allows the fabrication of subminiature devices that integrate multiple functions



Product lineup

Type	Output	Features
1 Schmitt trigger circuit photo IC	Digital	Photo IC integrates a photodiode, amplifier, schmitt trigger circuit, and output transistor, etc. into one chip
2 Light modulation photo IC	Digital	Employs optical synchronous detection to ensure stable output even under fluctuating background light
3 Illuminance sensor	Analog/Digital	Spectral response close to human visual sensitivity
4 Color sensor	Digital	Has sensitivity to red, green, and blue light
5 Near infrared sensor	Digital	Compact optical device that integrate a InGaAs photodiode and IC. Built-in LED type is also available.
6 Photosensor with front-end IC	Analog	Compact devices that integrate a Si APD and front-end IC. APD arrays for LiDAR are also available for installation in automatic carriers.
7 Photo IC for optical link (POF)	Digital	Photo IC transmitters and receivers for plastic optical fiber communications. The optical transceiver with a built-in transmitter and receiver is also available.
8 Photo IC for encoder, Encoder module	Digital	Uses a 4-element photodiode that can be used to easily configure an encoder with 2-phase digital output
9 Photo IC for optical switch	Analog/Digital	Has functions needed for industrial optical switches
10 Photo IC for laser beam synchronous detection	Digital	For detecting laser beam print-start timing in laser printers and digital copiers
11 Phototransistor	Analog	Amplifies the photocurrent generated by input light. Allows a larger current to be derived even from a small photosensitive area when compared to photodiodes.

Application examples

Hamamatsu photo ICs are widely used for many different needs.

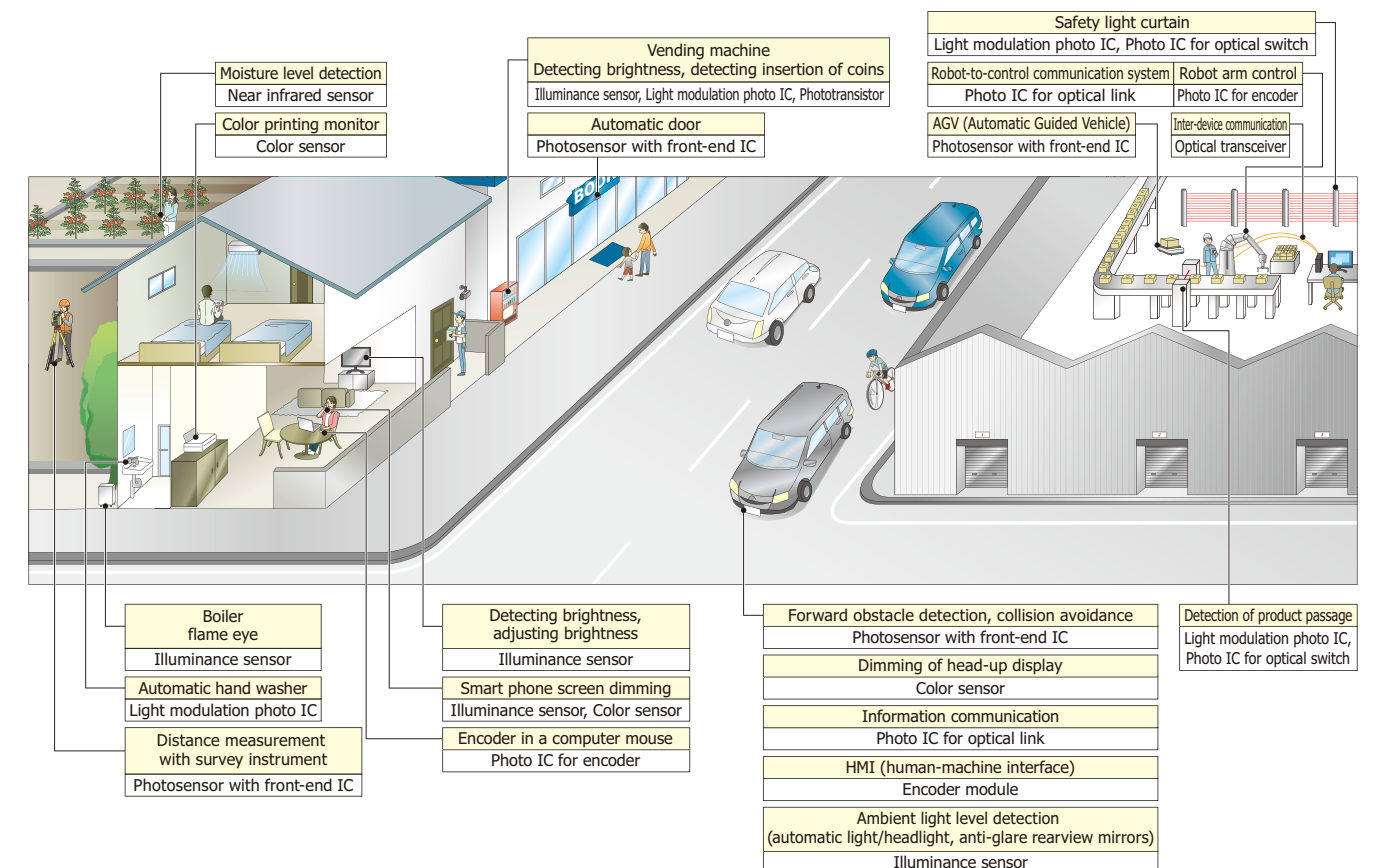
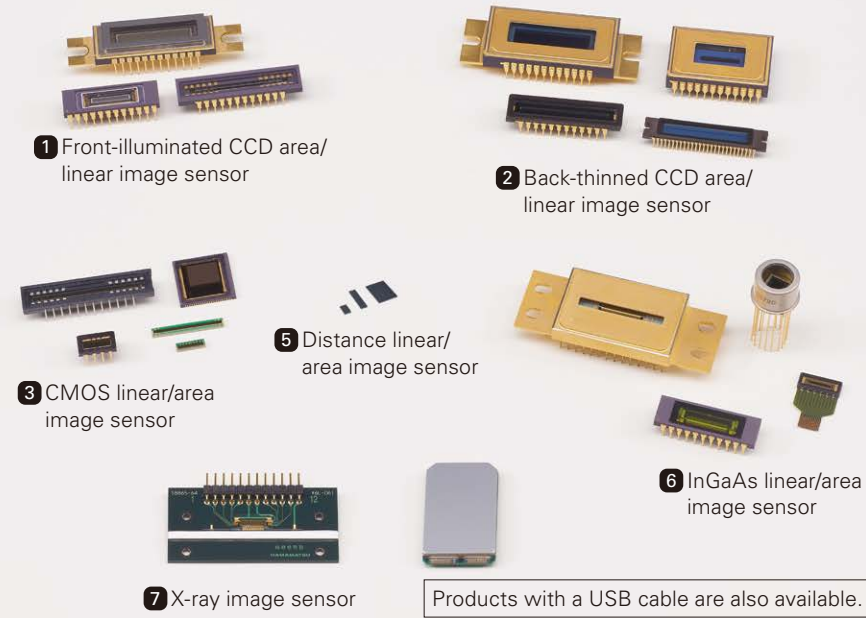


Image sensors

A wide lineup of image sensors suitable for spectroscopy and measurement applications

Hamamatsu provides various types of image sensors that cover a wide energy level and spectral response range from near infrared (NIR) at 2.6 μm through visible, ultraviolet, vacuum ultraviolet (VUV) down to soft X-rays and hard X-rays at several hundred keV.



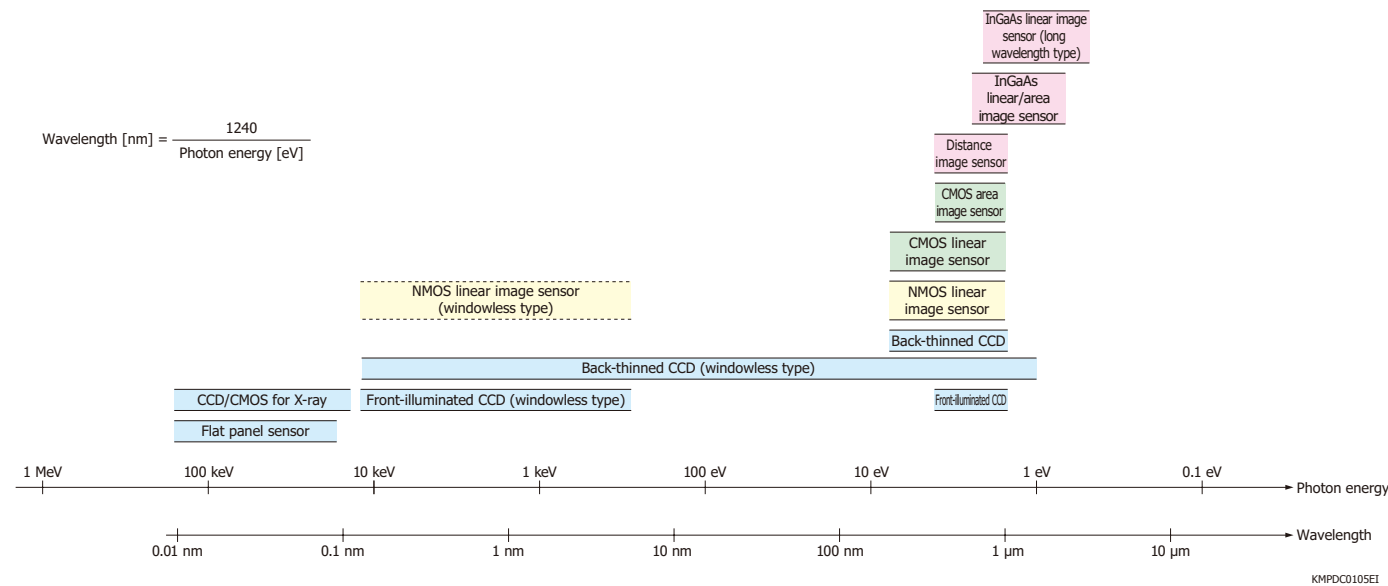
Features

- A wide lineup covering different wavelengths

Major applications

- Spectrophotometry
- Scientific measurement
- NIR spectrometry
- X-ray imaging
- Obstacle detection
- Security

Example of detectable energy level and spectral response range

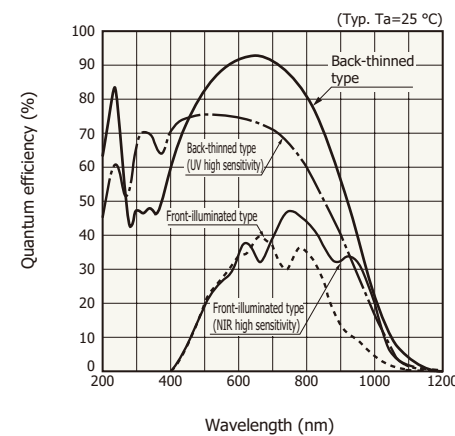


Product lineup

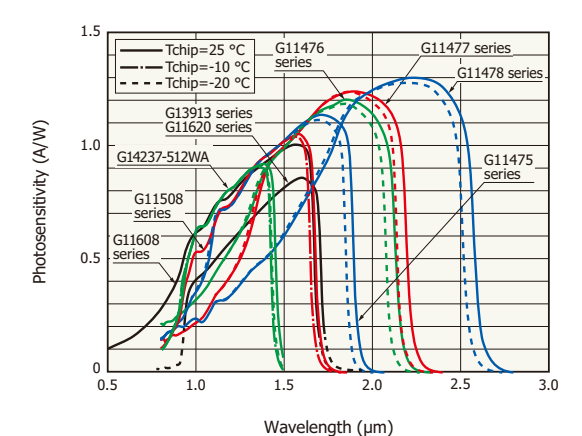
Product name	Features	Lineup
1 Front-illuminated CCD area/linear image sensor	Image sensors with low dark current and low noise	<ul style="list-style-type: none"> For spectrophotometry For scientific measurement
2 Back-thinned CCD area/linear image sensor	Image sensors delivering high quantum efficiency from visible to VUV region	<ul style="list-style-type: none"> For spectrophotometry (Standard type, UV enhanced type, NIR enhanced type, Large full well type, High resolution type, High-speed readout type, Built-in electronic shutter type) For scientific measurement TDI-CCD area image sensor For industrial equipment
3 CMOS linear image sensor	Image sensors integrated with signal processing circuits, making them suitable for applications where low power consumption and downsizing of the detector unit are essential	<ul style="list-style-type: none"> Standard type Variable integration time type High-speed readout type High sensitivity type Digital output type With RGB color filter
3 CMOS area image sensor	APS type CMOS area image sensors with high sensitivity in near infrared region	<ul style="list-style-type: none"> SXGA type VGA type Low pixel count type
4 NMOS linear image sensor	Image sensors with high UV-sensitivity and excellent output linearity, making them suitable for precision photometry	<ul style="list-style-type: none"> Current output type (standard type) Current output type (infrared-enhanced type) Voltage output type
5 Distance linear/area image sensor	Image sensors designed to measure the distance to an object by TOF method	<ul style="list-style-type: none"> Distance linear image sensor Distance area image sensor
6 InGaAs linear/area image sensor	Image sensors for near infrared region. Built-in CMOS IC allows easy operation.	<ul style="list-style-type: none"> For NIR spectrometry For DWDM monitor For near infrared image measurement
7 X-ray image sensor	Image sensors and photodiode arrays delivering high quality X-ray images by coupling FOS (FOP coated with X-ray scintillator) or phosphor sheet	<ul style="list-style-type: none"> CMOS area image sensors for radiography TDI-CCD area image sensors Photodiode arrays with amplifier for non-destructive inspection

Spectral response (typical example)

CCD area image sensor (without window)



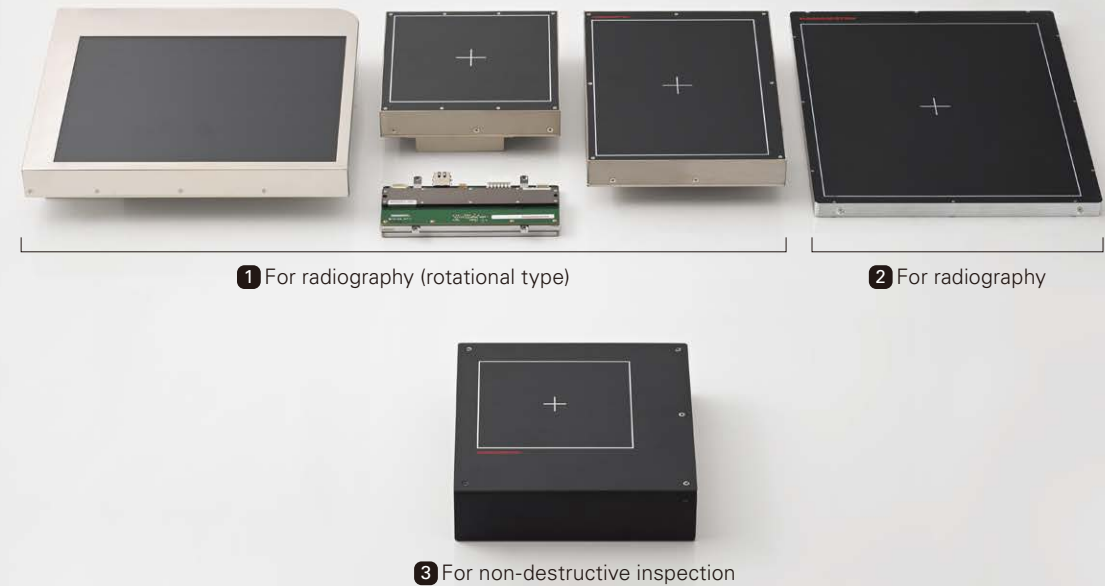
InGaAs linear image sensor



Flat panel sensors

Capturing high-resolution, high-quality X-ray images in real-time

Flat panel sensors are digital X-ray image sensors capable of acquiring high-resolution, high-quality X-ray images in real-time. They are made up of a sensor board and a control board, designed for a thin, compact configuration.



» Major applications

- CT imaging/panoramic imaging, biochemical imaging
- Radiography

» Product lineup

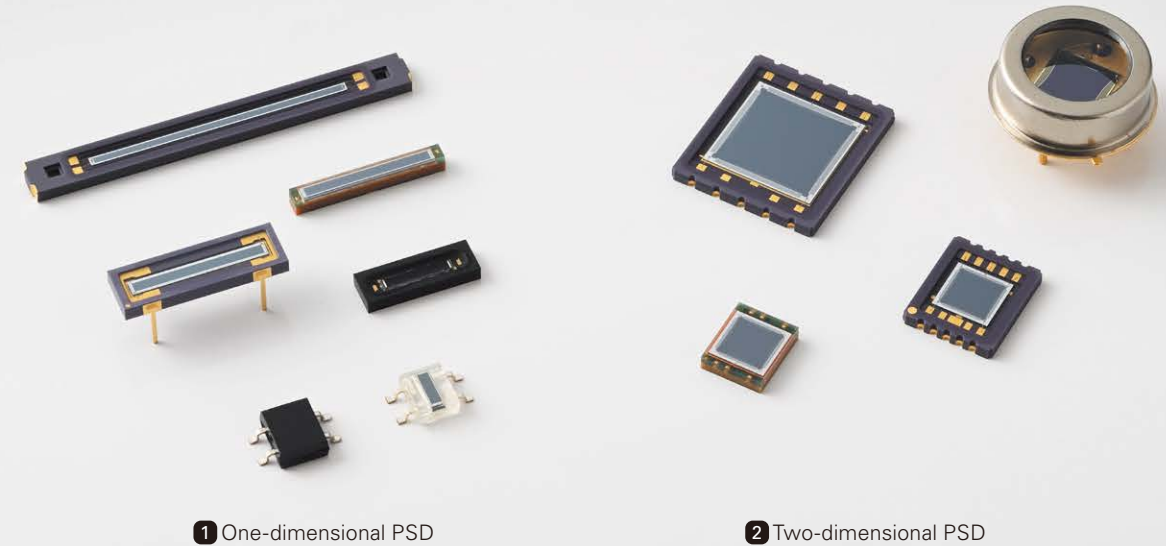
Type	Pixel size (μm)	Active area [(H) × (V) cm]	Frame rate* (frames/s)	Features
1 For radiography (rotational type)	100 × 100	15 × 0.6	310	High-speed, high-sensitivity type suitable for CT imaging and panoramic imaging For assembly into equipment
		14 × 12	19	
	120 × 120	15 × 12	30	
		16 × 16	30	
		24 × 17	20	
27 × 22	13			
2 For radiography	100 × 100	30 × 25	3	For still imaging
3 For non-destructive inspection	100 × 100	13 × 11	21	For in-line, high-speed imaging

* All pixels, 1 × 1 Mode readout

PSD (position sensitive detectors)

Light spot position sensors used for distance and angle measurements

A PSD is a non-discrete type position photosensor that makes use of photodiode surface resistance. It provides position data as a continuous electrical signal and offers high position resolution, high-speed response, and high reliability.



» Features

- Excellent position resolution
- Wide spectral response range
- High-speed response
- Simultaneously detects light intensity and center-of-gravity position of a light spot
- High reliability

» Major applications

- Position and angle sensing
- Distortion and vibration measurements
- Optical rangefinders
- Optical switches
- Precise position measurements such as laser displacement meters

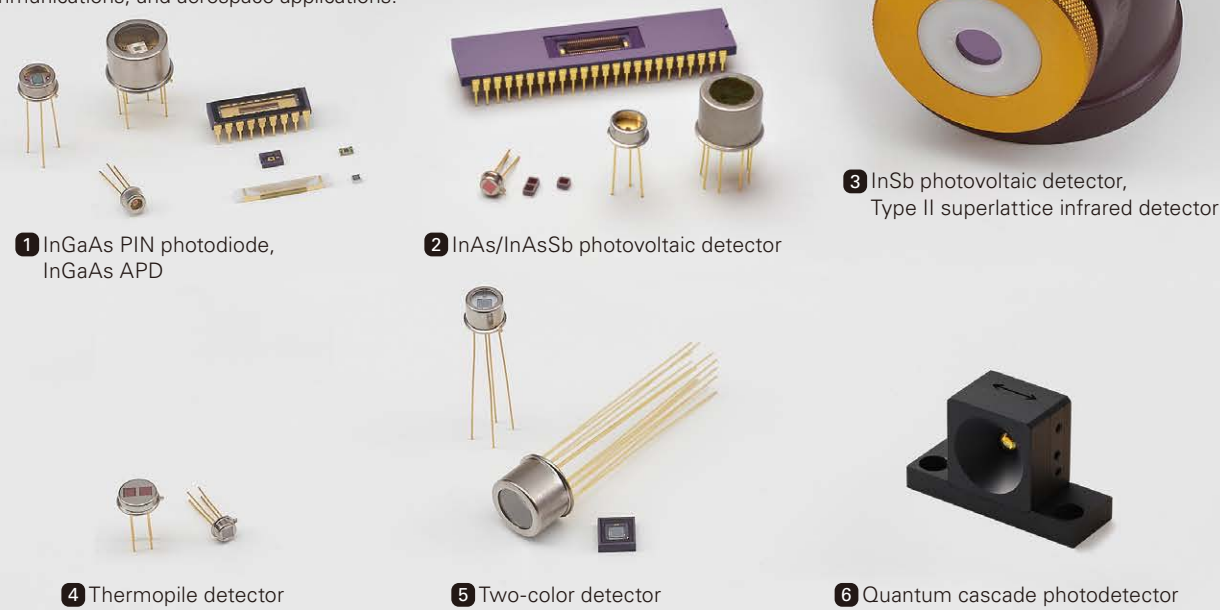
» Product lineup

Type	Lineup
1 One-dimensional PSD	Visible light cut-off type suitable for detection of near infrared light
	High IR-sensitivity
	Suitable for detection of microscopic light spot such as from a laser diode
2 Two-dimensional PSD	Long, narrow type with photosensitive area length of 20 mm or more
	High-speed response, low dark current, superior position-detection characteristic

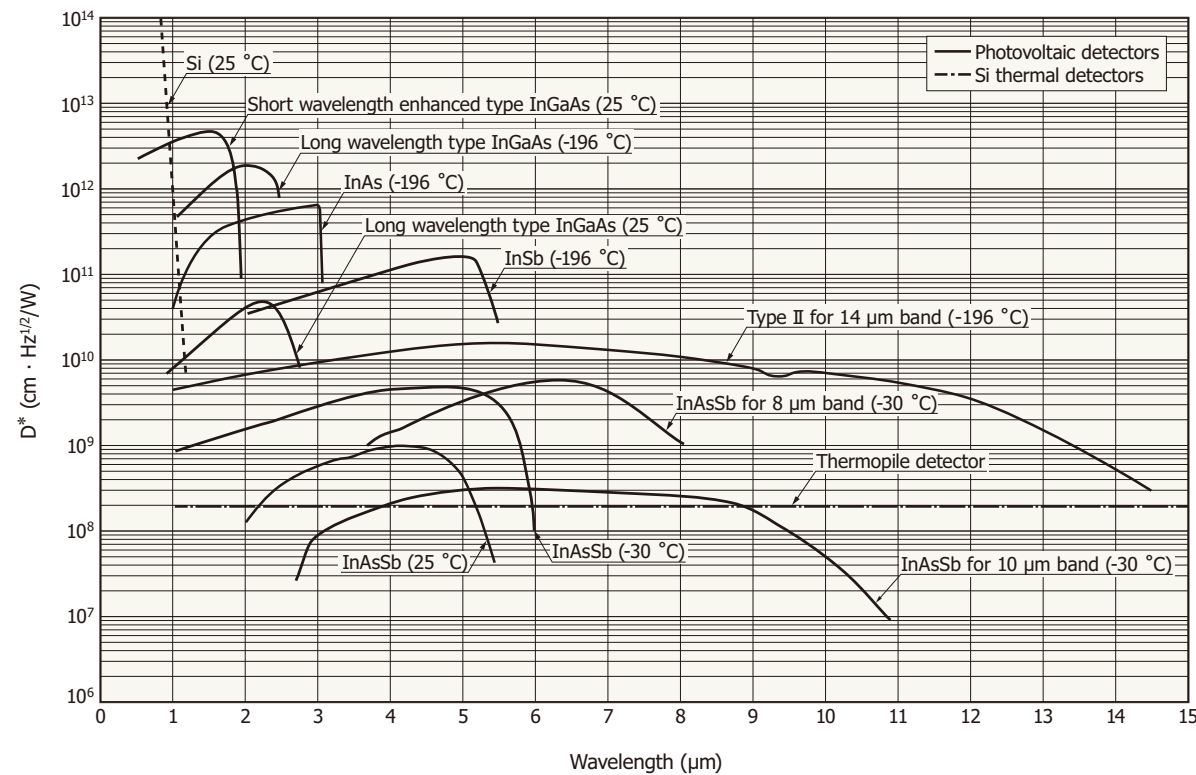
Infrared detectors

Product lineup to meet various needs for spectral response range

Infrared detectors are utilized in a wide range of fields such as measurement, chemical analysis, industry, agriculture, medicine, physics and chemistry, communications, and aerospace applications.



Spectral response (typical example)



Product lineup

Product name	Spectral response range	Features	Major applications	
1 InGaAs PIN photodiode	0.5 to 1.7 μm	<ul style="list-style-type: none"> High-speed response Various types of photosensitive areas, arrays, and packages available TE-cooled type available 	<ul style="list-style-type: none"> Optical fiber communications Optical power meter Gas analyzer Water content analyzer NIR (near infrared) photometry 	
	0.9 to 1.7 μm			
	0.9 to 1.9 μm			
	0.9 to 2.1 μm			
	0.9 to 2.6 μm			
1 InGaAs APD	0.9 to 1.7 μm	<ul style="list-style-type: none"> Low dark current Low capacitance High sensitivity 	<ul style="list-style-type: none"> Distance measurement LiDAR OTDR 	
2 InAs photovoltaic detector	1 to 3.8 μm	<ul style="list-style-type: none"> Covers a spectral response range close to PbS but offers higher response speed 	<ul style="list-style-type: none"> Gas measurement Infrared radiation measurement FTIR 	
2 InAsSb photovoltaic detector	1 to 11 μm	<ul style="list-style-type: none"> Infrared detector in the 5 μm, 8 μm, or 10 μm spectral band, with high sensitivity and high reliability Covers a spectral response range (5 μm band) close to PbSe but offers higher response speed 	<ul style="list-style-type: none"> Gas measurement FTIR Radiation thermometer Laser monitors 	
3 InSb photovoltaic detector	1 to 5.5 μm	<ul style="list-style-type: none"> Suitable for CO₂ and SO_x (SO, SO₂, SO₃) gas analysis due to high sensitivity in the 3 to 5 μm band 	<ul style="list-style-type: none"> FTIR Gas measurement Radiation thermometer 	
3 Type II superlattice infrared detector	1 to 14.5 μm	<ul style="list-style-type: none"> The sensor does not use mercury and cadmium, which are RoHS directive restricted substances, and it has expanded sensitivity up to the 14 μm band. 		
4 Thermopile detector	3 to 5 μm	<ul style="list-style-type: none"> Sensors that generate thermoelectromotive force in proportion to the energy level of incident light 	<ul style="list-style-type: none"> Radiation thermometer Flame detection CH₄, CO₂ concentration measurement 	
5 Two-color detector	Si + InGaAs	0.32 to 2.55 μm	<ul style="list-style-type: none"> Wide spectral response range from UV to IR Two-color detectors incorporate an infrared-transmitting Si photodiode mounted over an InGaAs PIN photodiode or an InAsSb photovoltaic detector. 	<ul style="list-style-type: none"> Spectrophotometers Laser monitors Flame monitors Radiation thermometer
	Si + InAsSb	0.32 to 5.3 μm		
	InGaAs + InGaAs	0.9 to 2.55 μm		
6 Quantum cascade photodetector	4.1 to 5.5 μm	<ul style="list-style-type: none"> Ultrafast mid-infrared photodetector with a response bandwidth of over 20 GHz. 	<ul style="list-style-type: none"> Heterodyne detection High frequency/high time resolved measurement 	

High-speed optical fiber communication devices

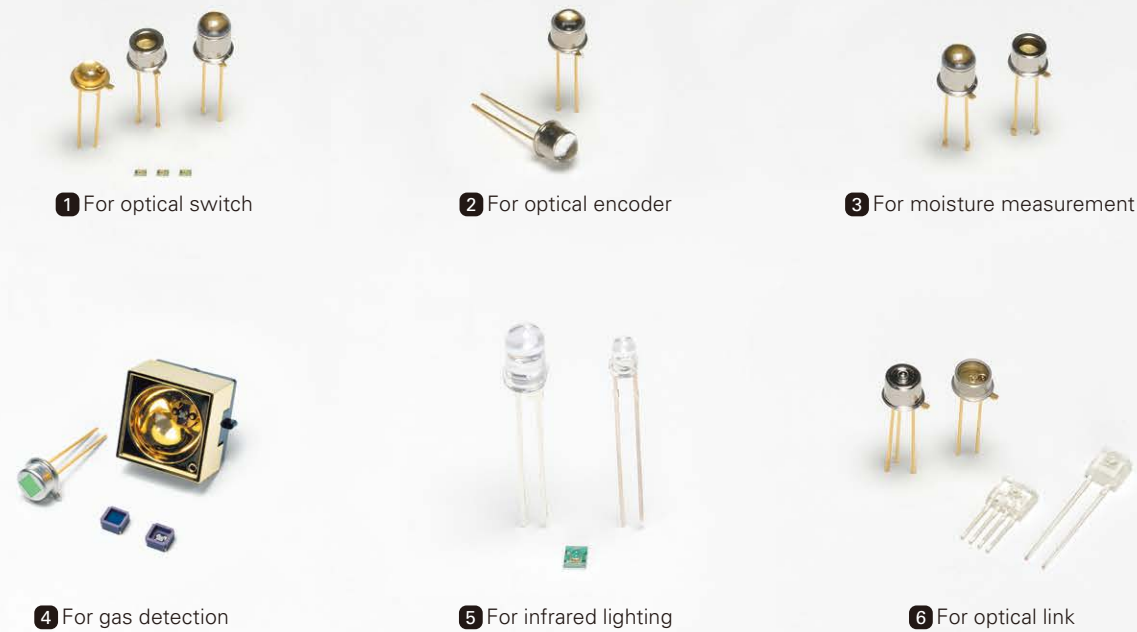
The high-speed photodiodes come in various packages (metal, receptacle, pigtail).



LED

Infrared LED and red LED with high output

Compared to laser diodes, LEDs offer advantages such as lower cost and longer life.



» Features

- High output
- Available in various types of packages

» Major applications

- Optical switches
- Encoders
- Light sources for moisture meter
- Optical rangefinders
- Optical fiber communications
- FSO

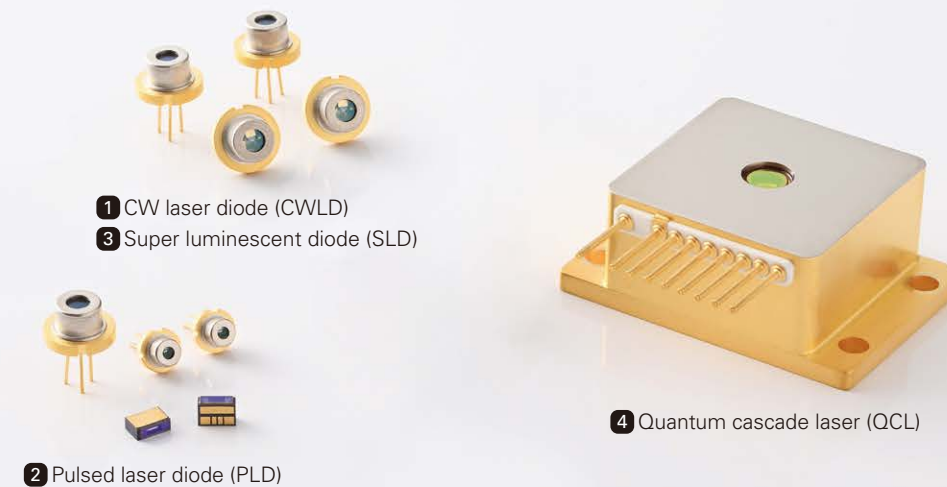
» Product lineup

Type	Features		
1 For optical switch	Near infrared	Reflector type	High output power
		Ball-lens type	Narrow directivity, uniform emission pattern
		Peripheral electrode type	Shadow of wire does not appear in emission pattern.
Red	Reflector type	High output power	
2 For optical encoder	Optimized lens shape allows these LEDs to emit highly collimated beams. High reliability is obtained since these LEDs do not use a current confinement structure chip.		
3 For moisture measurement	Long-wavelength LED with peak emission wavelength at 1.45 μm		
4 For gas detection	High output LED with peak emission wavelength in the mid infrared region		
5 For infrared lighting	Infrared camera lighting LED. Types with peak emission wavelength at 850 to 1550 nm are available.		
6 For optical link	These LEDs are suitable for 50 Mbps or 125 Mbps optical link.		

Semiconductor lasers

Semiconductor lasers used for a wide range of applications

Compact and highly robust semiconductor lasers are used in every aspect of our daily lives.



» Features

- Lineup covering variety of needs

» Product lineup

Product name	Features	Major applications
1 CW laser diode (CWLD)	Laser diodes designed to be driven in continuous wave (CW) mode. Output power from milliwatts to a few W.	<ul style="list-style-type: none"> ■ General measurement ■ Laser-driven light source ■ Infrared light source ■ Laser heating
2 Pulsed laser diode (PLD)	Laser diodes featuring high peak power under pulsed operation. Various peak output power and emission widths available.	<ul style="list-style-type: none"> ■ Rangefinder ■ LiDAR
3 Super luminescent diode (SLD)	SLDs combine the high brightness of laser diodes with the low coherence of LED and are used as a light source to compensate for the shortcomings of laser diodes, such as low speckle noise.	<ul style="list-style-type: none"> ■ Light source for OCT ■ Precision measurement ■ Interference microscope
4 Quantum cascade laser (QCL)	Quantum cascade lasers are semiconductor lasers that offer peak emission in the mid-IR range (4 to 10 μm). It operates on a completely different principle from previous laser diodes and is expected to become a new mid-infrared laser.	<ul style="list-style-type: none"> ■ Gas measurement ■ Quantum measurement

Mini-spectrometers

Integrating an optical system and image sensor, etc.

Hamamatsu offers a full line of mini-spectrometers that are integrated with an optical system and image sensor, etc. by fabricating the grating section using micromachining techniques.



Features

- High throughput due to transmission grating made of quartz (TG/TM series)
- Highly accurate optical characteristics
- No external power supply required:
 - Uses USB bus power (excluding CCD type, cooled type, and type for installation in devices)
- Low noise (cooled type)
- Compact design for easy assembly
- Contains a wavelength conversion factor (data supplied only with types for installation in devices)

Major applications

- Evaluation of light source characteristics
- Taste analyzers
- Water content measurement
- Film thickness measurement
- Semiconductor process control
- Low-light-level measurement such as fluorescence measurement
- Installation into measurement equipment



Spectroscopic module

Compact, lightweight Raman spectroscopic module capable of photometry in a wide spectral range

The ultra-compact Raman spectroscopic module incorporates a mini-spectrometer, excitation light source, filters, and other optical elements. The measurement range is 200 cm^{-1} to 2500 cm^{-1} , and the maximum output of the excitation light source is 50 mW. Because it has a temperature adjustment function for stabilizing the emission wavelength of the light source, it is capable of stable measurement even in environments with a fluctuating ambient temperature. It can be used for point-of-care testing (POCT) and other simple onsite screening tests.

Product lineup

Series	Type	Spectral response range (nm)	Spectral resolution max. (nm)	External power supply	Light input method	Built-in circuit	Internal image sensor
1 TG series	High sensitivity C9404CA	200 to 400	3	AC adapter	SMA connector	Yes	Back-thinned CCD image sensor
	High resolution C9404CAH		1*1				
	IR-enhanced C9405CC	500 to 1100	5 (550 to 900)	Not needed*2			IR-enhanced back-thinned CCD image sensor
	Near IR C11482GA	900 to 1700	7				+5 V, +12 V
	Near IR (cooled) C9913GC		7				
	Near IR (cooled) C9914GB	1100 to 2200	8	+5 V, +12 V			
	Near IR (cooled) C11118GA	900 to 2550	20				
2 TM series	High sensitivity C10082CA	200 to 800	6	AC adapter	SMA connector	Yes	Back-thinned CCD image sensor
	High resolution C10082CAH		1*1				
	Wide dynamic range C10082MD		6	Not needed*2			CMOS linear image sensor
	High sensitivity C10083CA	320 to 1000	8 (320 to 900)				AC adapter
	High resolution C10083CAH		1*1 (320 to 900)				
	Wide dynamic range C10083MD		8	Not needed*2			CMOS linear image sensor
	Trigger-compatible C11697MB		8				High-sensitivity CMOS linear image sensor
3 TF series	Compact, thin C13053MA	500 to 1100	3.5	Not needed*2	SMA connector	Yes	High-sensitivity CMOS linear image sensor
	Compact, thin C14214MA	790 to 1050	0.6				
	Compact, thin C13555MA	340 to 830	3				
	Compact, thin C14486GA	950 to 1700	5*1				
4 MS series	Ultra-compact (for installation in devices) C11708MA	640 to 1050	20	-	Input window	No	CMOS linear image sensor
5 Micro series	Ultra-compact (for installation in devices) C16767MA	190 to 440	8	-	Input window	No	High-sensitivity CMOS linear image sensor
	Ultra-compact (for installation in devices) C12666MA	340 to 780	15				CMOS linear image sensor
	Ultra-compact (for installation in devices) C12880MA	340 to 850			Input window*3	No*4	High-sensitivity CMOS linear image sensor

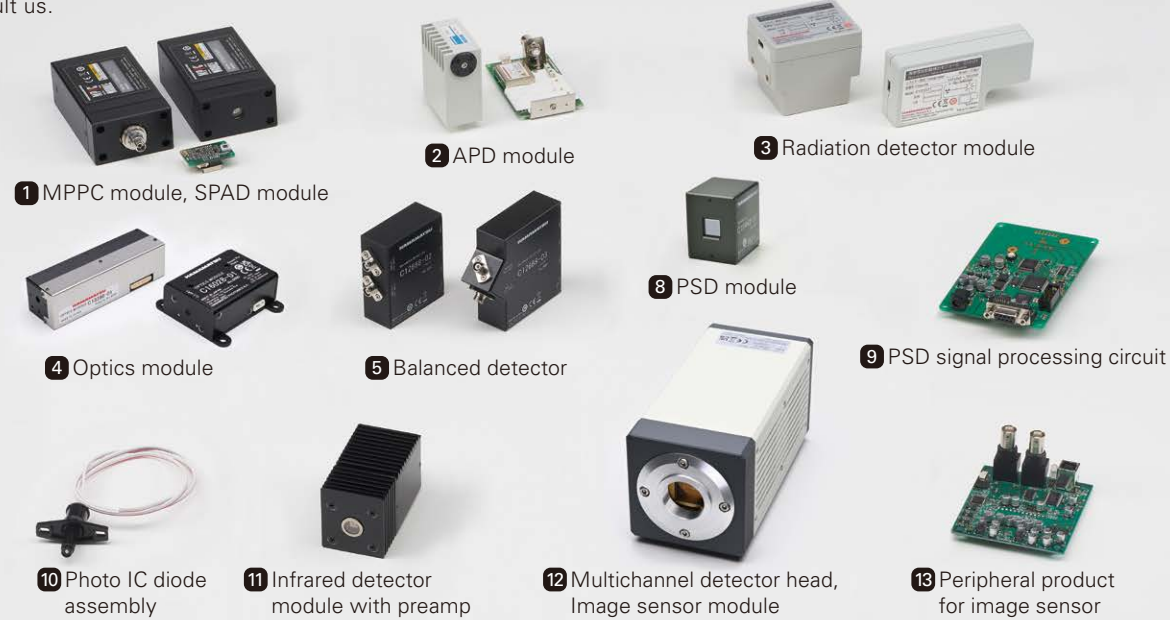
*1: Typical value *2: USB bus power only *3: The C12880MA-20 with an SMA connector is also available.

*4: We also offer the C13985 and C13985-20 (with SMA connector) with a built-in circuit.

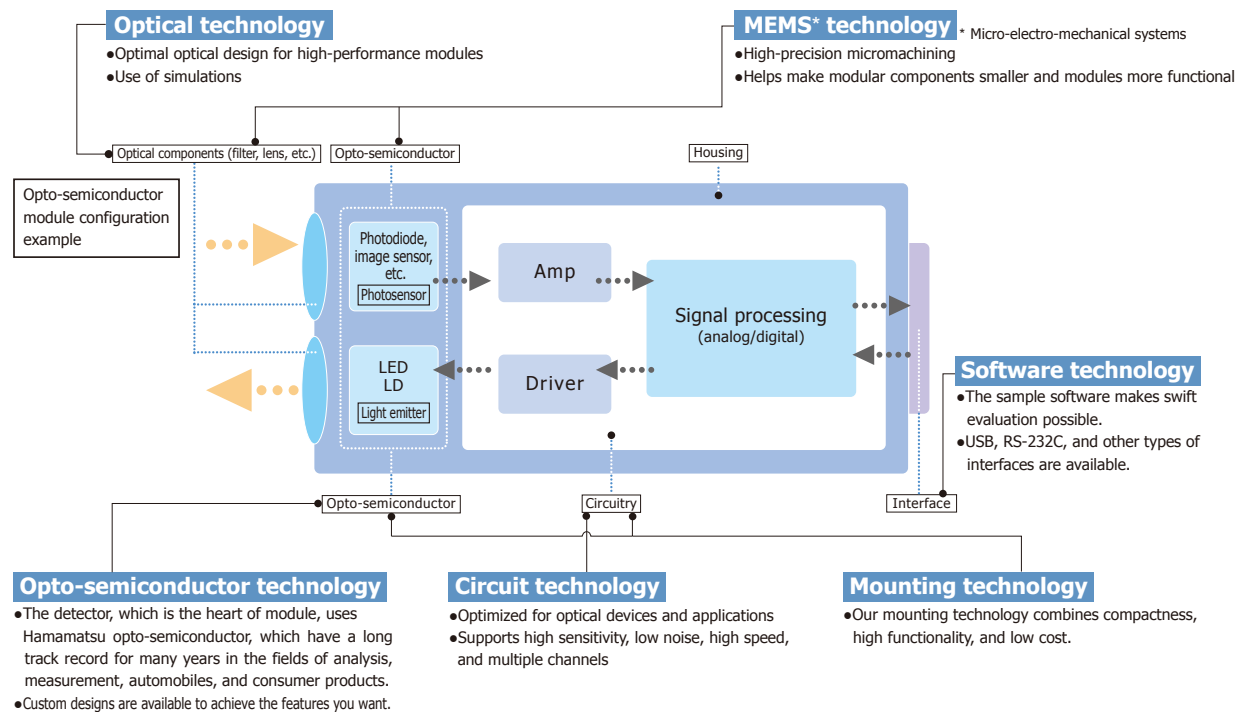
Opto-semiconductor modules

Modules using opto-semiconductors / Circuits for operating opto-semiconductors

Hamamatsu provides a wide variety of opto-semiconductor modules developed by our own module technology capable of extracting the maximum performance from opto-semiconductors. Custom products are also available by request. Please feel free to consult us.



Technologies that create opto-semiconductor modules



Product lineup

Products	Features	Application examples
1 MPPC module, SPAD module	MPPC modules are photon-counting modules that contain an MPPC capable of detecting extremely low-level light.	<ul style="list-style-type: none"> Fluorescence lifetime measurement Biological flow cytometry Bioluminescence analysis Low-light-level detection
2 APD module	APD modules are high-speed, high-sensitivity photodetectors using an APD (avalanche photodiode).	<ul style="list-style-type: none"> Low-light-level detection Optical power meters Laser monitors
3 Radiation detector module	These modules incorporate a scintillator and MPPC and are designed to detect gamma-rays.	<ul style="list-style-type: none"> Environmental monitoring and mapping Screening tasks
4 Optics module	Optics modules are spectroscopic modules featuring high blocking performance and low noise. A 10 ch module specifically designed for multi-wavelength detection and a 2 ch module with an excitation light source for fluorescence detection are available.	<ul style="list-style-type: none"> Blood analysis devices PCR inspection equipment
5 Balanced detector	These are differential amplification type photoelectric conversion modules containing two Hamamatsu photodiodes with balanced characteristics.	<ul style="list-style-type: none"> OCT Doppler LiDAR
6 Photodiode module	Photodiode modules are high-precision photodetectors combining a photodiode and current-to-voltage conversion amp.	<ul style="list-style-type: none"> Precision photometry Light source power monitors Illuminometers, color difference meters
7 Photosensor amplifier	These photosensor amplifiers are current-to-voltage conversion amplifiers for amplifying photocurrent with low noise.	<ul style="list-style-type: none"> Precision photometry Optical power meters Illuminometers
8 PSD module	PSD modules are high-precision position detectors combining a PSD and current-to-voltage conversion amp.	<ul style="list-style-type: none"> Optical axis alignment Rangefinders 3D measurement
9 PSD signal processing circuit	These are signal processing circuits for evaluation of PSDs.	<ul style="list-style-type: none"> Performance evaluation of PSD
10 Photo IC diode assembly	The flame eye is a sensor that monitors flames in oil boilers and heating equipment.	<ul style="list-style-type: none"> Flame detection in oil boilers and heaters
11 Infrared detector module with preamp	These modules integrate an infrared detector and a preamp.	<ul style="list-style-type: none"> Infrared detection
12 Multichannel detector head, Image sensor module	Multichannel detector heads incorporate a driver circuit designed for various types of image sensors (CCD area image sensors, InGaAs linear image sensors, NMOS linear image sensors).	<ul style="list-style-type: none"> Spectrophotometer Raman spectroscopy Semiconductor inspection Radiation thermometry
13 Peripheral product for image sensor	Driver circuits that are designed to match the CCD image sensor and CMOS/NMOS/InGaAs linear image sensor types are provided.	<ul style="list-style-type: none"> Multichannel spectrophotometry

MEMS devices

New devices using semiconductor micro-fabrication technology

They are compact, sophisticated devices that use MEMS (micro-electro-mechanical systems) technology.



Product lineup

Product name	Features	Applications
1 MEMS mirror	<ul style="list-style-type: none"> Miniature electromagnetic mirror The structure includes a magnet and a mirror chip consisting of mirror, coil, and torsion bar Low power consumption Wide optical deflection angle High mirror reflectivity One-dimensional type and two-dimensional type available 	<ul style="list-style-type: none"> Machine vision (shape recognition) Laser material processing Industrial LiDAR Laser measurement Laser scan unit Optical switches
2 Spectroscopic module	<ul style="list-style-type: none"> Compact module with built-in MEMS-FPI spectrum sensor, light source, and control circuit Spectrum and absorbance are measured by connecting a PC via USB. 	<ul style="list-style-type: none"> Material identification in solutions Plastic identification Textile identification Moisture detection Composition analysis in the agriculture and food sectors
3 FTIR engine (FT-NIR spectrometer)	<ul style="list-style-type: none"> Compact Fourier transform infrared spectrometer Built-in Michelson optical interferometer and control circuit Spectrum and absorbance can be measured by connecting a PC via USB. Optical fiber incident type 	<ul style="list-style-type: none"> Process analysis Material inspection Farm product inspection Plastic screening Concrete strength measurement Film thickness measurement Medical and health care equipment

Factory/Research laboratory/Domestic sales office

Factories

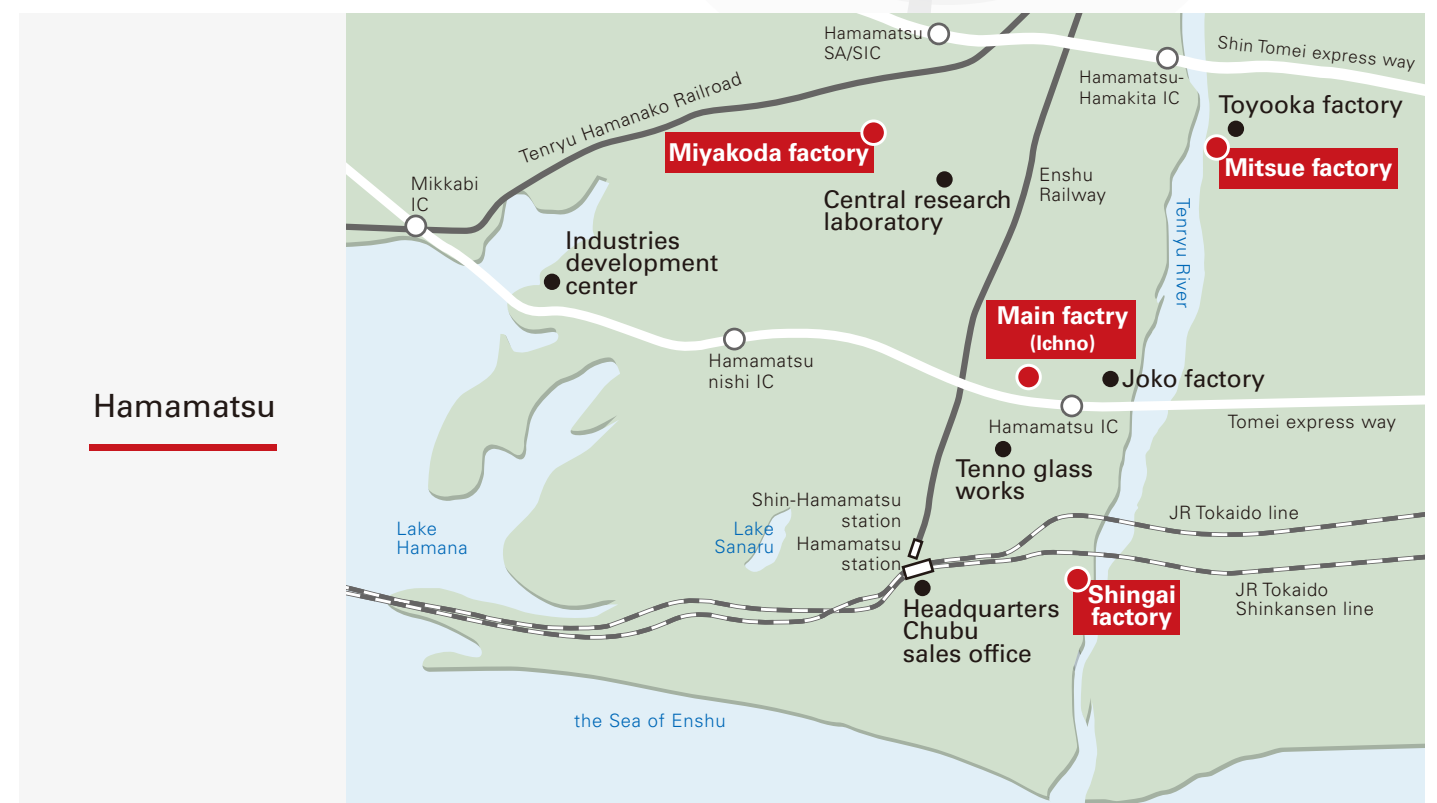
- Solid state division
 - Main factory (Ichino), Mitsue factory, Shingai factory, Miyakoda factory
- Electron tube division
 - Toyooka factory, Tenno glass works
- System division
 - Joko factory
- Laser division
 - Miyakoda factory

Laboratories

- Central research laboratory
- Tsukuba research center
- Industries development center
- Yokohama IT development office

Domestic sales offices

- Tokyo sales office
- Osaka sales office
- Chubu sales office
- Sendai sales office
- Nishinohon sales office



Main factory (Ichino)

Si/compound/MEMS process,
module manufacturing

1126-1, Ichino-cho, Chuo-ku, Hamamatsu City,
Shizuoka Pref., 435-8558, Japan



HAMAMATSU
PHOTON IS OUR BUSINESS

Date. _____

No. _____

Mitsue factory

Multi-kind low-volume production

768-8, Mitsue, Iwata City,
Shizuoka Pref., 438-0127, Japan



Shingai factory

Mass production,
multi-kind low-volume production

1128, Shingai-cho, Chuo-ku, Hamamatsu City,
Shizuoka Pref., 435-0023, Japan



Miyakoda factory

Compound process,
semiconductor laser manufacturing

1-8-3, Shinmiyakoda, Hamana-ku,
Hamamatsu City, Shizuoka Pref., 431-2103, Japan



Main Products

Opto-semiconductors

- Si photodiodes
- APD
- MPPC®
- Photo IC
- Image sensors
- PSD
- Infrared detectors
- LED
- Optical communication devices
- Automotive devices
- X-ray flat panel sensors
- MEMS devices
- Mini-spectrometers
- Opto-semiconductor modules

Electron Tubes

- Photomultiplier tubes
- Photomultiplier tube modules
- Microchannel plates
- Image intensifiers
- Xenon lamps / Mercury-xenon lamps
- Deuterium lamps
- Light source applied products
- Laser applied products
- Microfocus X-ray sources
- X-ray imaging devices

Imaging and Processing Systems

- Scientific cameras
- Spectroscopic and optical measurement systems
- Ultrafast photometry systems
- Life science systems
- Medical systems
- Non-destructive inspection products
- Semiconductor manufacturing support systems
- Material research systems

Laser Products

- Single chip laser diodes
- Laser diode bar modules
- Quantum cascade lasers
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