Oct. 2023

HAMAMATSU
PHOTON IS OUR BUSINESS

Technologies and Products for Plastic Sorting Equipment

Contribute to Realizing a Sustainable Society with Light

Technologies and Products for Plastic Sorting Equipment

Plastics are used in various scenes in our daily lives. Yet, many environmental problems have been caused by plastics in recent years. For example, greenhouse gases emitted during combustion are a cause of global warming. Also, a huge amount of microplastics flow into the sea, leading to marine pollution. In order to solve these environmental problems, it is important to reduce the production and consumption of plastics, and also recycle them.

Recycling of plastics starts with removal of foreign objects and sorting by type. For many years, Hamamatsu Photonics has been developing and manufacturing optical devices such as optical sensors, light sources, and cameras used in plastic sorting equipment.
High sorting accuracy can be achieved and high-quality recycling can be enabled by incorporating a key device suitable for plastic sorting applications into equipment.

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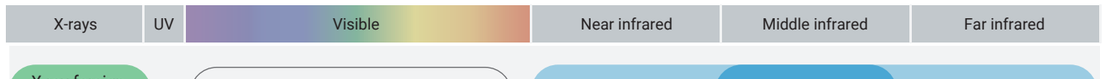
Optical Identification of Plastics

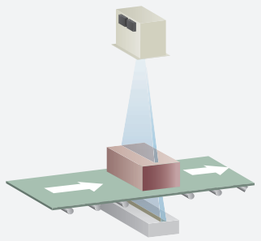
There are many types of plastics, ranging from single material plastics to mixed material plastics. Also, many plastics contain additives such as flame retardants. When recycling these plastics, it is necessary to choose the appropriate identification method according to the type.

With optical identification using our optical devices, the plastic is sorted by the type of plastic based on the spectrum of the reflected or transmitted light which is irradiated on the plastic. This catalog introduces plastic sorting methods using near-infrared spectroscopy and X-ray imaging, and devices that can be applied to these methods.



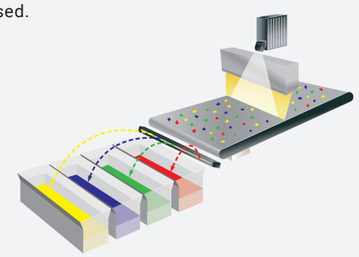
[X-ray imaging]

This method of sorting materials uses X-ray images.
By doing arithmetic processing of images acquired using two X-ray energies (high/low), it is possible to do advanced detection of metal scraps, bromine, and composite plastics containing glass fibers that get mixed in as foreign objects.

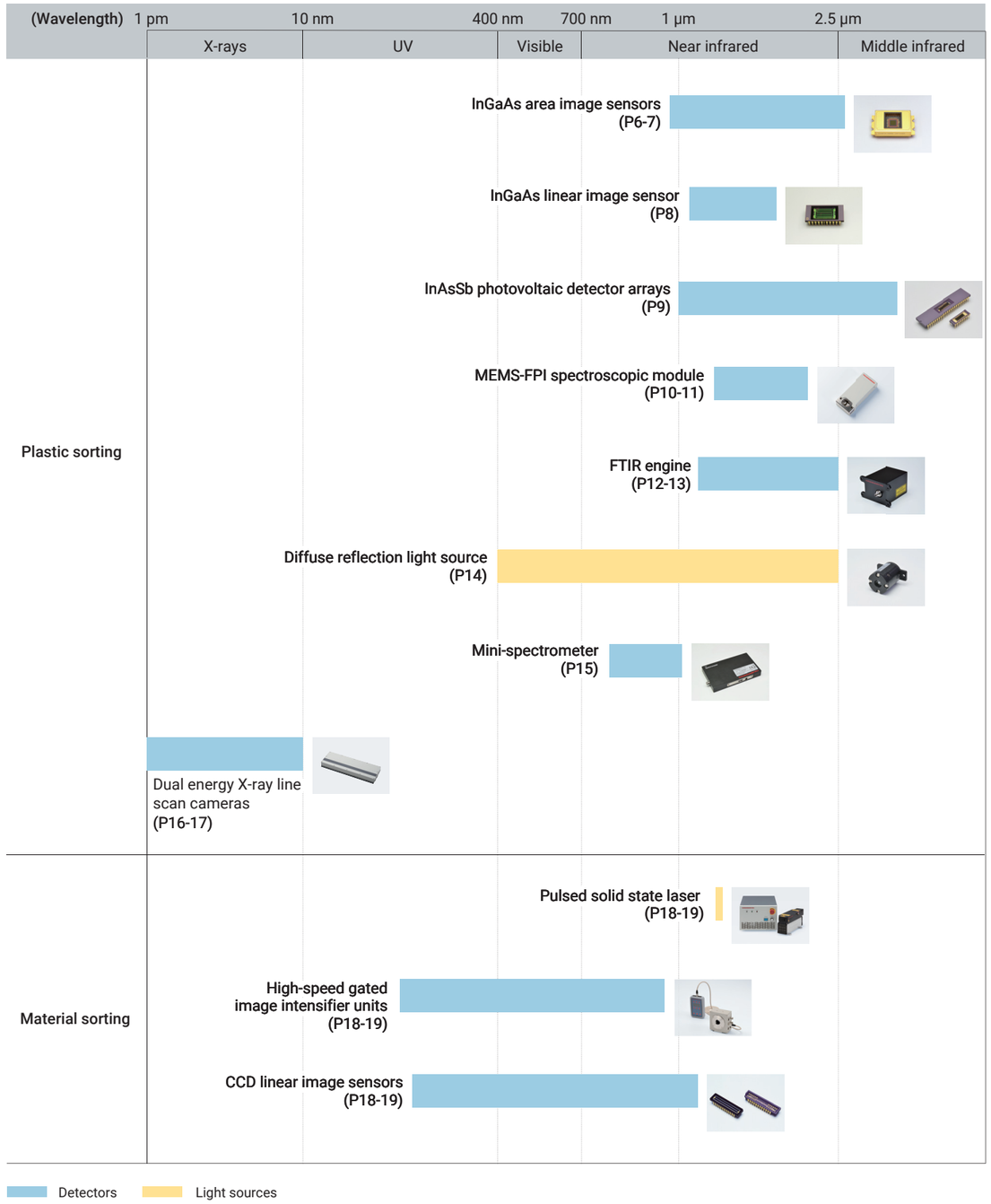


[Near infrared spectroscopy]

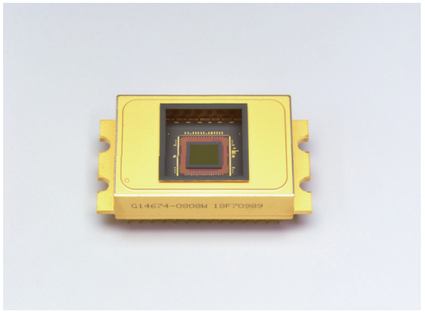
This is the most common method of plastic sorting. Using the difference in near-infrared light absorption rate, types of plastic are sorted mainly from the spectrum around 1.9 µm.
However, some types of plastic cannot be analyzed in the spectrum around 1.9 µm. For example, plastics with additives such as flame retardants or toughers have spectral features around 2.4 µm. Since black plastic absorbs near-infrared light, middle infrared light up to 5 µm is used.



Product Lineup



InGaAs area image sensors G14671 to G14674-0808W



Near-infrared image sensors capable of sorting multiple types of plastics

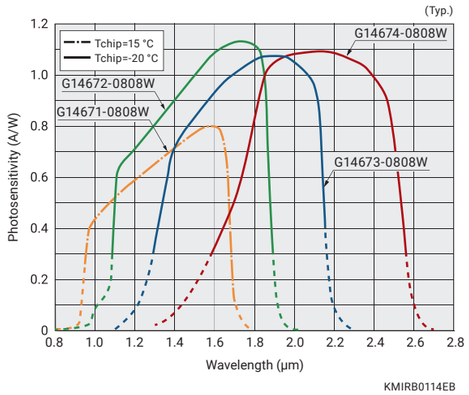
These are the InGaAs area image sensors supporting 0.95 µm to 2.55 µm. It is possible to sort plastics that are difficult with visible light images by equipping these sensors in a hyperspectral camera and analyzing near-infrared images.

Type no.	G14671-0808W	G14672-0808W	G14673-0808W	G14674-0808W	Unit
Spectral response range	0.95 to 1.69	1.12 to 1.85	1.3 to 2.15	1.7 to 2.55	µm
Pixel pitch	20				µm
Total number of pixels	320 × 256				pixels
Dark current	0.03 typ.	0.3 typ.	3 typ.	30 typ.	pA
Frame rate	509 max.				fps

Main features

Lineup of products with wide spectral response ranges

The product lineup includes 1.69/1.85/2.15/2.55 µm cutoff wavelength types.



KMIRB0114EB

High-speed readout

The frame rate of 509 fps max., which is more than double that of the previous product, was achieved. Also, further speeding up is enable by using the partial readout function.

Previous product:
G13393-0808W
228 fps max.

G14674-0808W
509 fps max.

InGaAs area sensor modules C16090 series

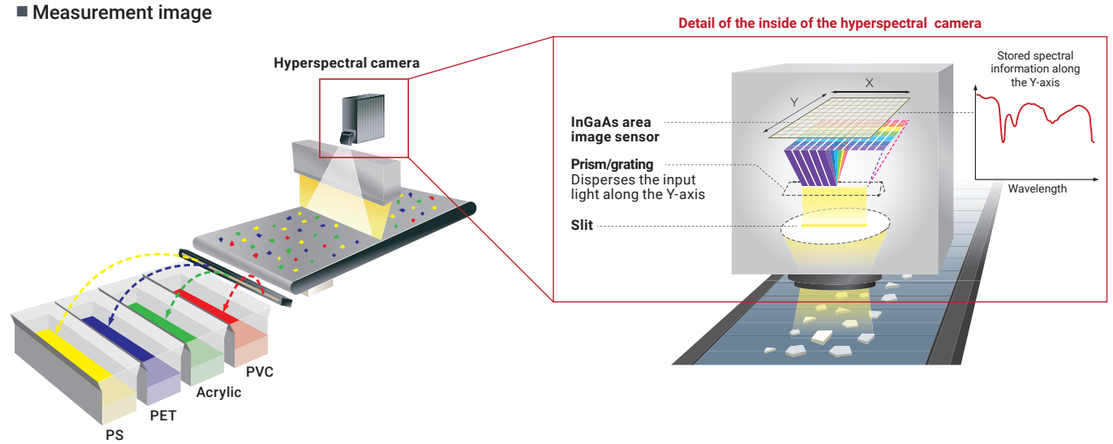
This module is equipped with an InGaAs area image sensor. It consists of a driver circuit, temperature controller, and high-speed communication controller, etc. It outputs analog video signals from an InGaAs area image sensor as digital output.

Application examples

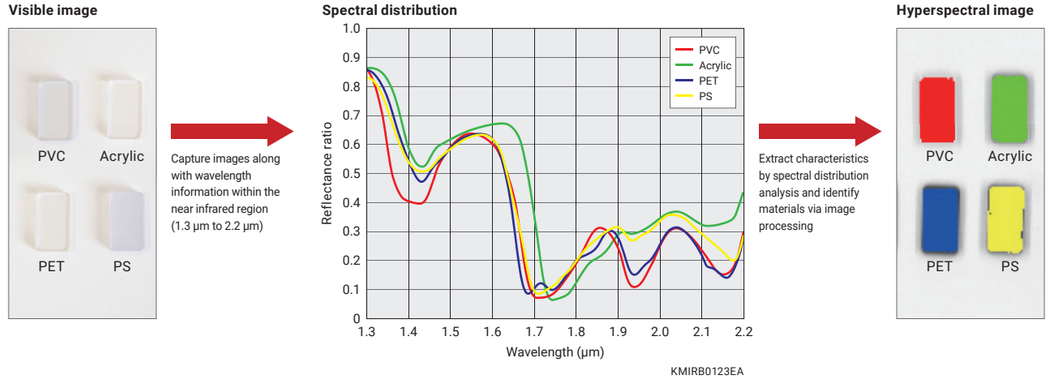
Plastic sorting using hyperspectral imaging

Hyperspectral imaging is a method by which pixel-level spectrum information is acquired simultaneously with the shooting of the target object. It is a useful method to identify and classify materials that are difficult to distinguish by eyesight.
A hyperspectral camera is used to acquire hyperspectral images. Like normal line cameras, scanning is performed by moving the target object (or camera). The input light passes through a slit, is dispersed into the Y-axis direction by a prism, grating, and is measured by an area image sensor. Plastics can be obtained in the infrared wavelength range depending on the plastic material, using a hyperspectral camera with a built-in infrared area image sensor allows highly accurate identification.

■ Measurement image



■ Measurement result (measurement comparison of 4 types of plastics)



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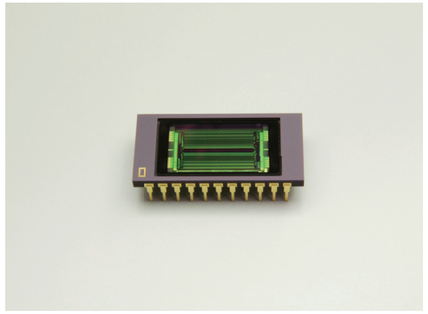
Near Infrared Spectroscopy

InGaAs linear image sensor G14006-512DE



Near-infrared image sensors capable of sorting single plastics

These are near infrared image sensors that realize high sensitivity and high-speed readout in the near infrared region of 1.12 µm to 1.9 µm. They are capable of sorting single plastics by removing different plastics, namely plastics other than specific plastics from multiple types of plastics mixed together.

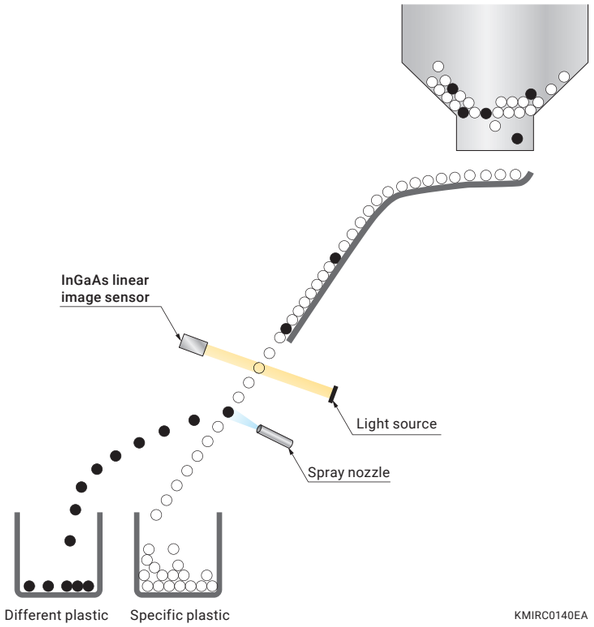
Parameter	Specification	Unit
Spectral response range	1.12 to 1.9	µm
Pixel pitch	25	µm
Total number of pixels	512	pixels
Dark current	10 max.	pA
Line rate	8150 max.	lps

Application example

Sorting different plastics with near-infrared spectroscopy

Light is irradiated on plastic and identify foreign objects from the transmitted light, and identified foreign objects are then removed with a jet of high-pressure air.

■ Measurement image



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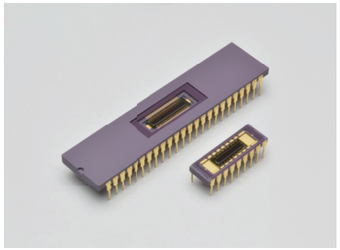
Related information

Mid Infrared Spectroscopy

InAsSb photovoltaic detector arrays P15742-016DS, P15742-046DS



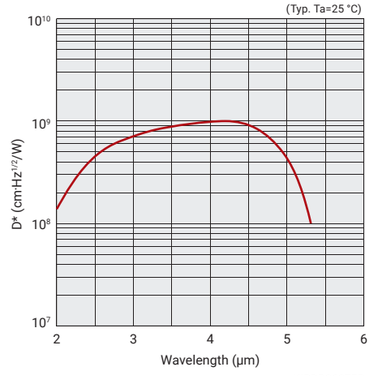
Middle infrared photosensors capable of sorting black plastic

Since the pigment carbon black contained in black plastic absorbs near-infrared light, it is possible to sort black plastic by using light in the middle infrared region up to 5 µm.

Type no.	P15742-016DS	P15742-046DS	Unit
Number of elements	16	46	—
Element size	0.45 × 0.7	0.2 × 0.7	mm
Package	18-pin ceramic DIP	48-pin ceramic DIP	—
Cutoff wavelength	5.3 typ.		µm

■ Spectral response

High sensitivity in the middle infrared region



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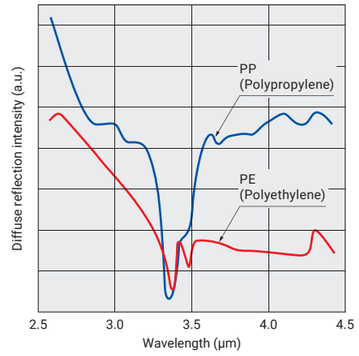
■ Measurement example

Absorbance spectra of black plastic (PP, PE)



Data provided by Professor Hirofumi Kawazumi
Research Fellow,
Institute of Systems, Information Technologies and Nanotechnologies (ISIT)

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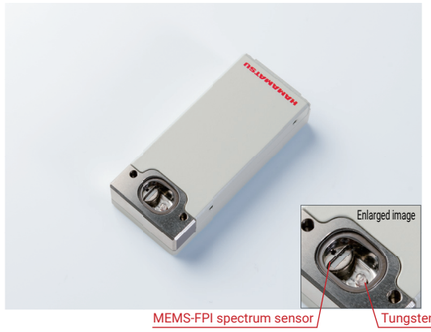
Near Infrared Spectroscopy

MEMS-FPI spectroscopic module C15713



Compact spectrocopic module capable of simple plastic sorting

This compact spectroscopic module has a built-in light source, control circuit, and MEMS-FPI* spectrum sensor consisting of an MEMS-FPI tunable filter and an InGaAs PIN photodiode. This technology is expected to be incorporated into portable equipment that makes it possible to do on-the-spot confirmation of whether food trays and PET bottles in collection boxes have been correctly collected for each type of plastic.

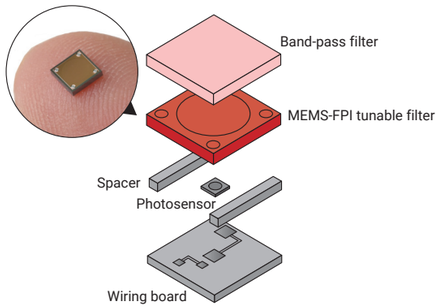
* Fabry-Perot Interferometer

Parameter	Specification	Unit
Built-in sensor (MEMS-FPI spectrum sensor)	C13272-03	—
Spectral response range	1.55 to 1.85	μm
Spectral resolution (FWHM)	20 max.	nm

Structure (MEMS-FPI spectrum sensor)

Despite a spectrum sensor, the MEMS-FPI spectrum sensor employs a single-element photodetector and does not use an expensive multichannel photodetector (photodiode array or image sensor). The MEMS-FPI tunable filter and the photodetector are arranged on the same axis as the direction of incident light, to make it a simple configuration. Another advantage is high optical throughput because aperture can be made larger.

■ Internal structure



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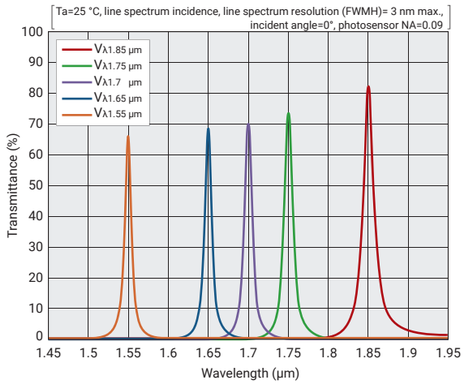
■ Transmittance vs. wavelength of MEMS-FPI tunable filter (C13272-02/-03)



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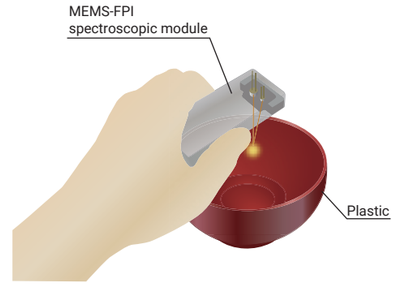
Application examples

A tungsten lamp is irradiated on the plastic and reflected light is detected by the MEMS-FPI spectroscopic module (C15713).

■ Measurement image



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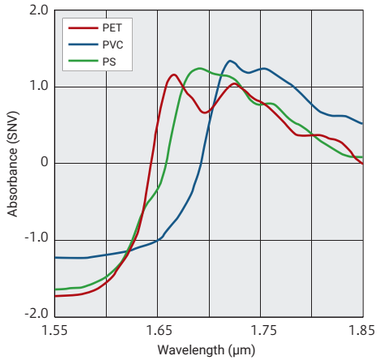
■ Measurement of white plastic (PET, PVC, PS)

This is an measurement example of different types of white plastic (PET: polyethylene terephthalate, PVC: polyvinyl chloride, PS: Polystyrene).



Measurement cooperated by: Hamamatsu Central Research Laboratory

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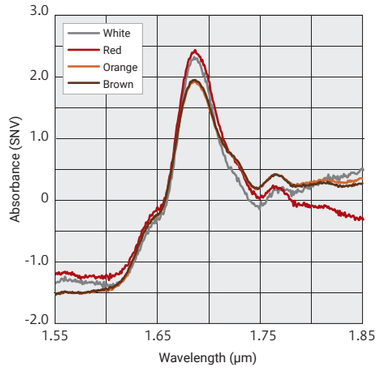
■ Measurement of colored plastic for food (PS)

This is an example of measurement of the same plastic (PS) with different measurement coloring (white, red, orange, brown) of plastic (PS) for food.



Measurement cooperated by: Hamamatsu Central Research Laboratory

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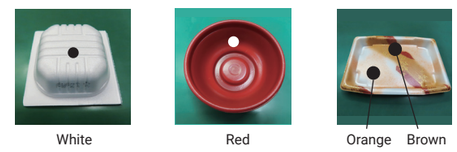
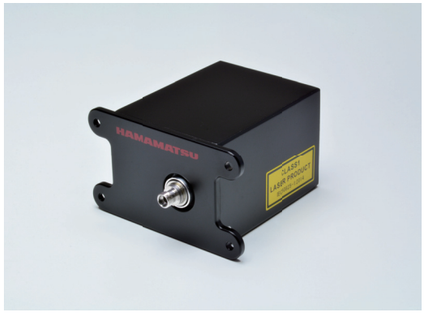


FTIR engine C15511-01



Near-infrared spectrometer capable of sorting out plastics containing additive compounds

Many plastics contain flame retardants and toughers to prevent ignition and increase strength, and they are widely used in consumer electronics.
The FTIR*1 engine C15511-01 is a palm-sized Fourier transform spectrometer which covers the near-infrared region up to 2.5 µm. Since it can detect up to around 2.4 µm, where the spectra differ depending on the presence or absence of flame retardants, it can be used to sort plastics containing flame retardants.

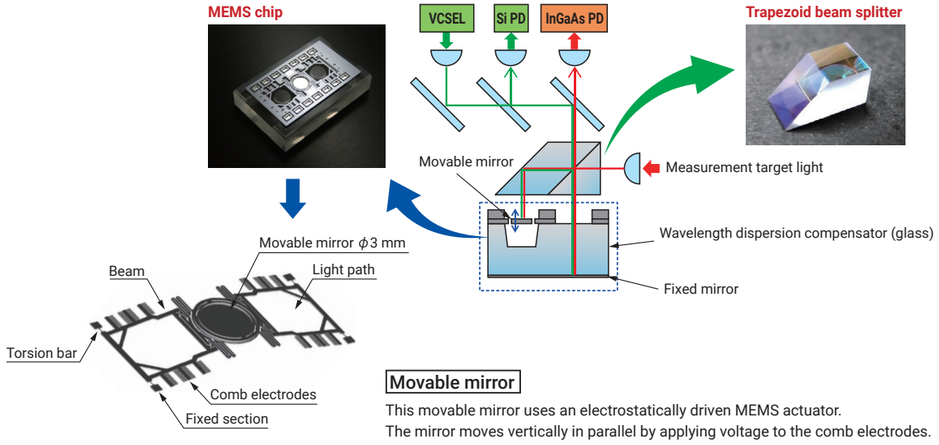
*1: Fourier Transform Infrared Spectrometer

Parameter	Specification	Unit
Spectral response range	1.1 to 2.5	µm
Optical interferometer	Michelson interferometer (ϕ3 mm movable mirror installed)	—
Photodetector	InGaAs PIN photodiode	—
Light input method*2	Optical fiber incident type (with SMA connector)	—
Interface	USB 2.0	—
Dimensions (W × H × D)	57 × 49 × 76 (excluding protrusions)	mm
Spectral resolution (FWHM)*3	5.7 typ.	nm
Signal-to-noise ratio	10000:1	—
Weight	Approx. 300	g

*2: Recommended optical fiber (core diameter 600 µm, NA 0.22)
*3: λ=1.533 µm

Structure

Interference light occurs when light being measured (incident light) is split by a beam splitter, then reflected by the movable mirror and the fixed mirror, and finally recombined. Interference light intensity changes depending on the position of the movable mirror. This intensity is detected by a photodetector (InGaAs PIN photodiode), then the signal is subjected to arithmetic processing (Fourier transform) to obtain an optical spectrum. By measuring the position of the movable mirror inside the interferometer using a photodetector (Si PIN photodiode) and semiconductor laser (VCSEL), it is possible to obtain an optical spectrum with high wavelength reproducibility.



Movable mirror

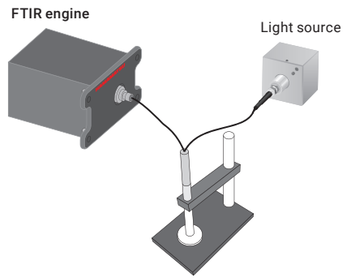
This movable mirror uses an electrostatically driven MEMS actuator.
The mirror moves vertically in parallel by applying voltage to the comb electrodes.

Measurement examples

Sorting of plastic that includes flame retardant

Flame retardants contained in plastics can be sorted out by identifying spectra in the 2 to 2.5 µm band.

■ Measurement system



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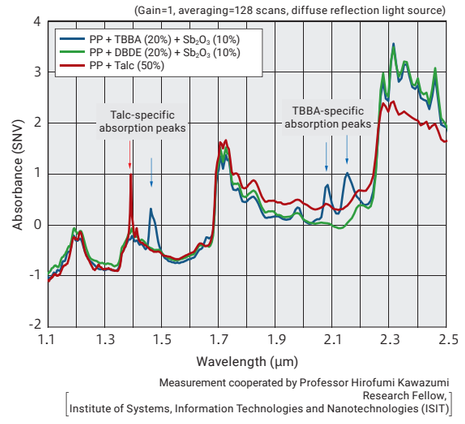
[Contents measurement of white polypropylene]

The figure below shows absorbance spectra of additives such as TBBA (tetrabromobisphenol A), DBDE (decabromodiphenyl ether) and Talc. From the absorption peak at around 1.4 µm, the graph shown in red is possible to infer a talc-specific component. Although TBBA and DBDE have relatively similar spectra, they can be distinguished from each other by the difference in the absorption peak at around 2.1 µm.

■ Near infrared absorption spectra



Measurement cooperated by Professor Hirofumi Kawazumi Research Fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT)

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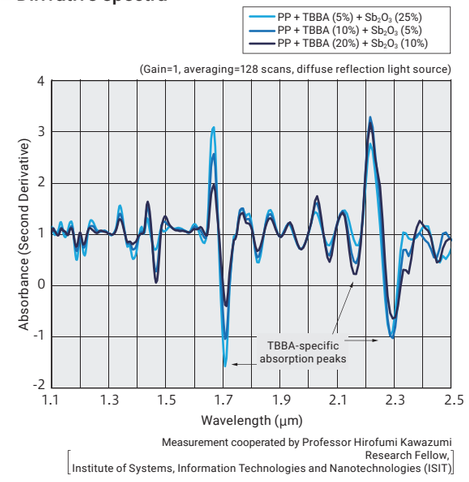
[Estimation of concentration level]

The figure below shows absorbance spectra of white polypropylene integrating different concentration additives of TBBA and Sb_2O_3 (antimony oxide). The concentration of TBBA additives can be estimated from the difference in absorption intensities at 1.7 µm, 2.2 µm and 2.3 µm.

■ Dirivative spectra



Measurement cooperated by Professor Hirofumi Kawazumi Research Fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT)

KACCB0699EA

Near Infrared Spectroscopy

Diffuse reflection light source L16462-01

Light source for near-infrared spectroscopic analysis that can be used for sorting bioplastics

Diffuse reflection light source L16462-01 is a compact light source used in a pair with a near-infrared spectrometer. Light emitted from the sample can be efficiently detected thanks to the integrated structure of the tungsten lamps for irradiation and the fiber for guiding light. It can be used for sorting bioplastics.

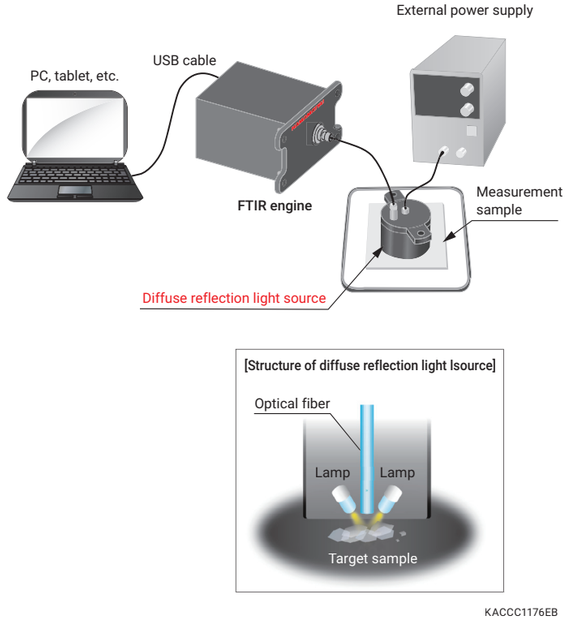
Parameter		Specification	Unit
Dimensions (excluding protrusions)		ϕ28 × 35.5	mm
Built-in lamp (Tungsten lamp)	Quantity	4	pcs
	Recommended supply voltage	+5	V
	Average lifetime	7000	hr

Measurement example

Sorting of biodegradable bioplastics

Biodegradable bioplastics have attracted attention as materials that can significantly reduce the burden on the global environment.
The sorting of non-biodegradable and biodegradable plastics allows for effective recycling and is expected to reduce the amount of plastic waste that is disposed of.

■ Measurement system



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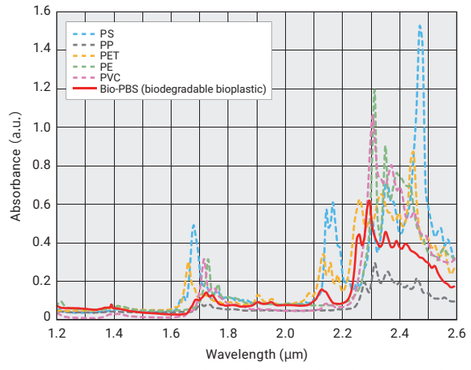
■ Measurement result



Measurement cooperated by: Hamamatsu Central Research Laboratory

KACCB0730EC

Near Infrared Spectroscopy

Mini-spectrometer C14214MA

Mini-spectrometer for raman spectroscopy capable of sorting dark-colored plastics

Raman spectroscopic analysis is not as greatly affected by the pigment carbon black contained in dark-colored plastics as near-infrared light, making it possible to analyze the components of dark-colored plastics. Since the peaks of the absorption spectrum are clearly visible, it is possible to sort with high precision, and is being considered for use in sorting high-performance resins used in lenses.

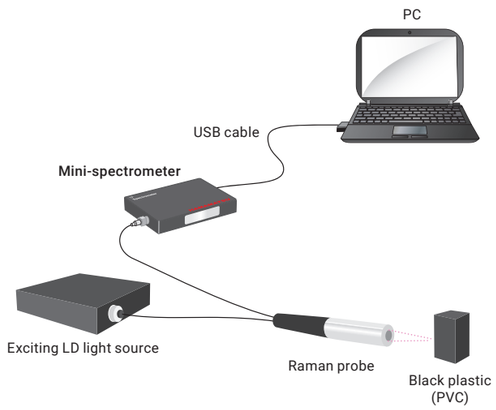
Parameter	Specification	Unit
Spectral response range	790 to 1050	nm
Spectral resolution (FWHM)	0.4 typ.	nm
Dimensions (W × H × D)	100 × 12 × 60	mm

Measurement example

Measurement of black plastic (PVC)

This is an example of measuring the Raman scattered light spectrum of black plastic (PVC: polyvinyl chloride) with the C14214MA mini-spectrometer. Laser light is irradiated to a black plastic sample, then Raman scattered light is detected by a mini-spectrometer.

■ Measurement system



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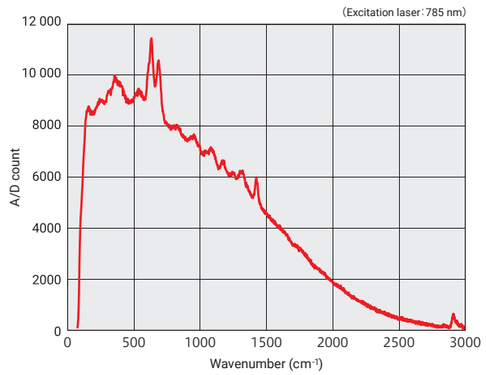
■ Measurement result



Measurement cooperated by Professor Hirofumi Kawazumi Research Fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT)

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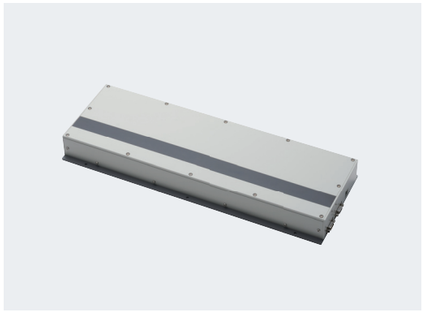
X-ray Imaging

Dual energy X-ray line scan cameras C11800-08U/-09U



X-ray line scan camera suitable for removing foreign objects contained in plastics

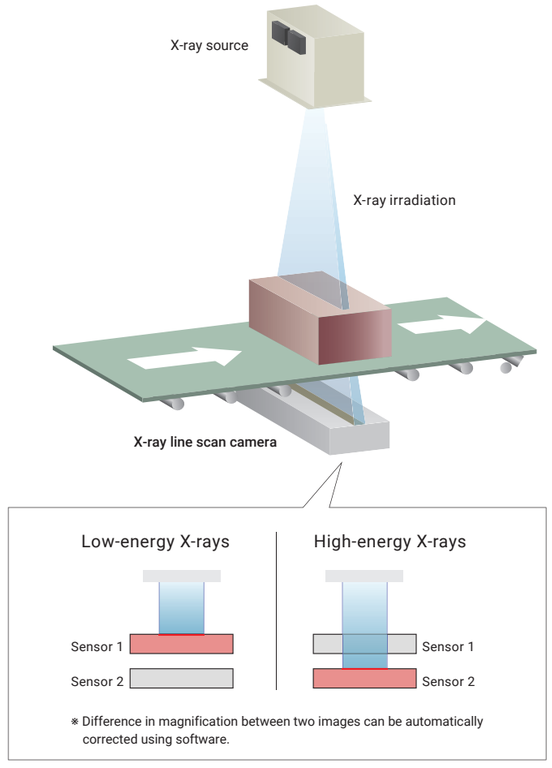
This dual energy X-ray line scan camera enables the separation of different materials and measures the X-ray absorption of two energies, high and low, thereby enhancing the contrast due to differences in objects. In plastic sorting, it is ideal for detecting metal scraps, bromine, and composite plastics containing glass fibers that get mixed in as foreign objects.

Type no.	C11800-08U	C11800-09U	Unit
Camera type	Dual energy X-ray line scan camera		—
Recommended use (X-ray sensitivity) range	Approx. 25 to 160		kV
Detection element pitch	0.4		mm
Detection width	409.6	460.8	mm
Corresponding line speed	4 to 100		m/minute
A/D converter	14		bit
Control interface	USB 3.0		—
Power supply	DC +15 to +24		V

Main features

Technology that increases detection ability
Next-generation X-ray detector equipped with DUALXTRAX™

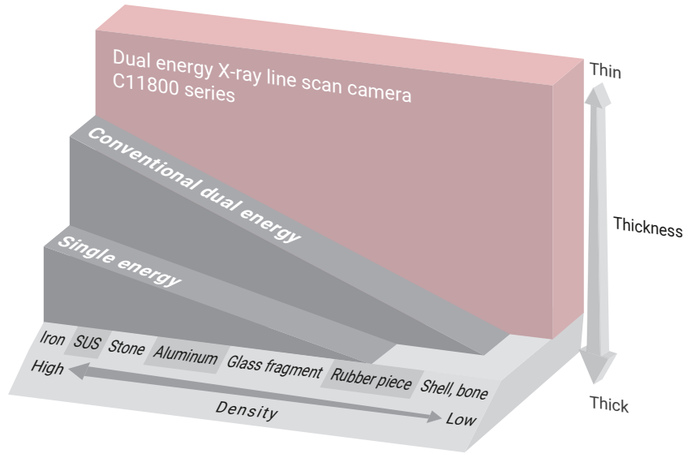
With normal in-line X-ray non-destructive inspection, materials and contaminant are detected by the difference in the shading of the X-ray transmission image. However, in some cases, it is difficult to distinguish materials and foreign substances only by shading due to non-uniform X-ray transmittance caused by complex shapes and a mixture of various substances in the actual object.
This product is equipped with "DualXTRAX®," a technology that combines a high sensitivity X-ray detector with next-generation computing technology.
Computational technology using high hardware performance has greatly improved detection capability with high and low energy images. Furthermore, unnecessary information such as the background can be removed, improving distinction ability substantially.
This enables advanced distinction ability for low density and thin objects, which was difficult in the past.



※ Difference in magnification between two images can be automatically corrected using software.

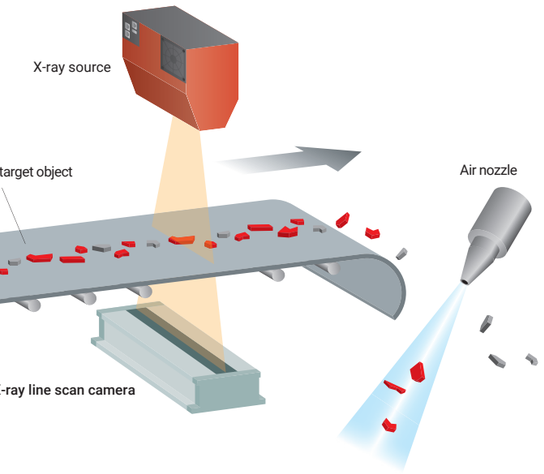
Corresponding contaminant Comparison Diagram

It enables to distinguish materials in various states, from high to low density, and from thin to thick samples.

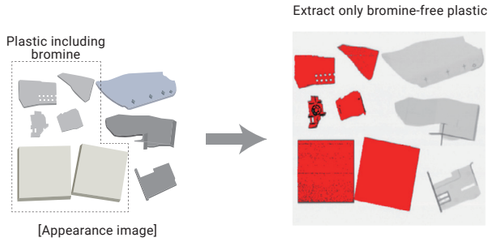


Imaging examples

Plastics that cannot be distinguished with visible light images can be selected by their material content and displayed in pseudo colors.

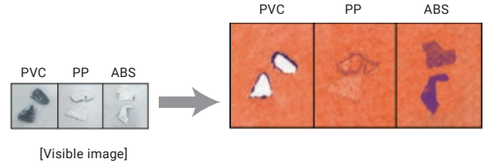


Captured image: Flame-retardant plastic



Captured image: PVC (polyvinyl chloride)

PVC and ABS judgement by pseudo color.
PP is out of judgement.

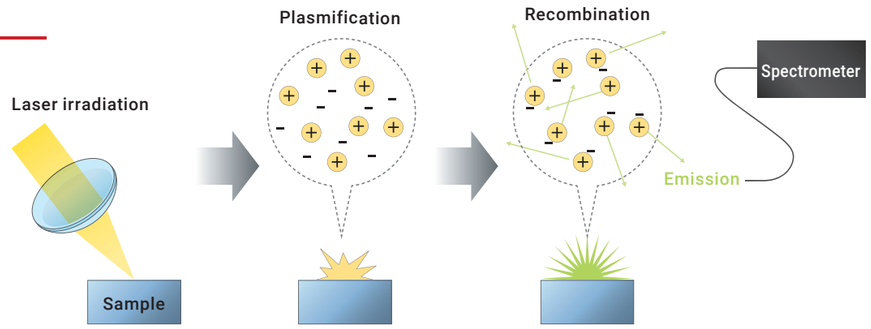


LIBS

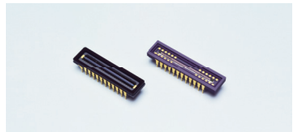
Light source/photosensors for LIBS

LIBS is a spectroscopic system that analyzes elements in a sample at high speed. High energy laser light is irradiated on a sample to turn part of the sample into plasma, then measurement is done on the intrinsic spectrum of contained elements generated during the subsequent plasma recombination. Since no pretreatment is required regardless of the sample state (gas, liquid, solid), it is possible to sort a wide range of substances, such as plastic (including black), metal and glass.

Principle



Product lineup

Parameter	Light source	Photosensors	
Product name	Pulsed solid state laser	High-speed gated image intensifier units	CCD linear image sensor
Type no.	L11038-11	C14245 series	S15254-2048 S15351-2048
Products			
Usage environment	Inline	Inline	Inline/handheld
Measurement distance*1	Up to approx. 1 m	Approx. 4 m to 8 m	Up to approx. 1 m
Features	● Laser oscillator integrated type ● Compact and lightweight ● Single shot possible ● Air-cooled type	● Enables high-speed phenomenon observation with gate operation ● Low-level light imaging enabled ● Supports from UV region to near-IR region ● Can be used as an I-CMOS camera by combining it with a CMOS camera	● High sensitivity from the UV region ● Image lag: 0.1% typ. ● Reset time of charge in pixels: 1 µs min. ● Driver circuit C15361 series (sold separately) is also available 

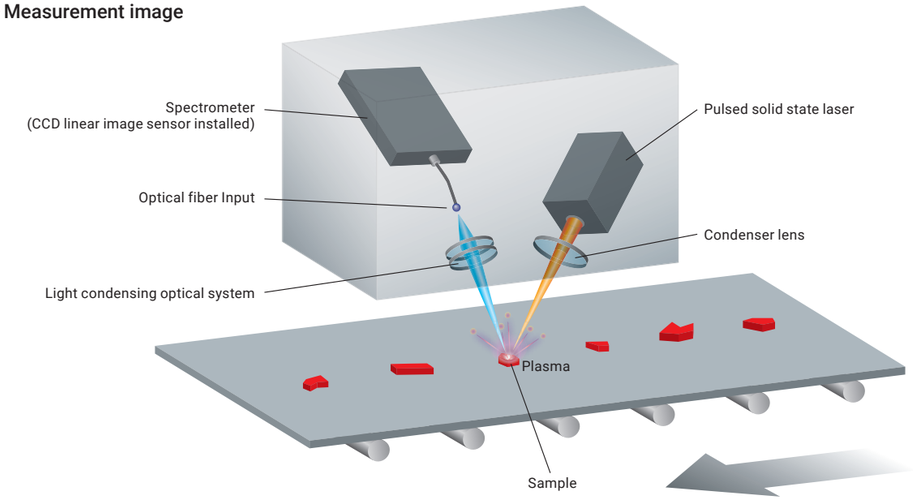
*1: Distance between the measurement unit and sample

Application examples

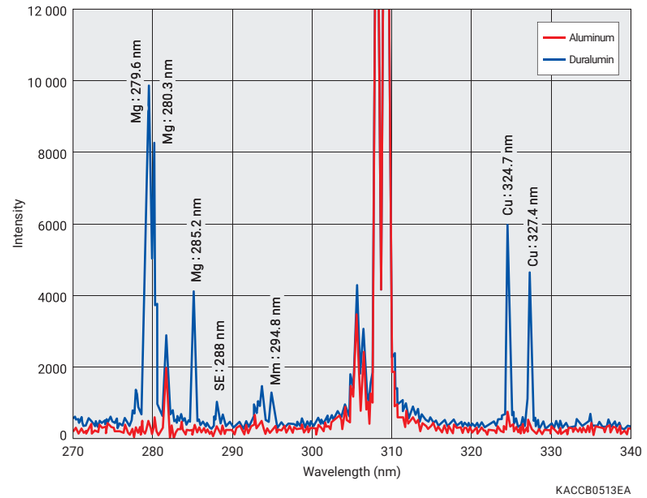
Metal sorting

A sorting system using LIBS technology allows for elemental analysis of objects. By focusing on differences in composition, it is also possible to sort alloys such as aluminum (pure aluminum) and duralumin (aluminum alloy).

● Measurement image



● Measurement result



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U.S.A. : HAMAMATSU COROPORATION: 360 Foothill Road, Bridgewater, NJ 08807, U.S.A., Telephone: (1)908-231-0960, Fax: (1)908-231-1218
Germany : HAMAMATSU PHOTONICS DEUTSCHLAND GMBH: Arzbergerstr. 10, 82211 Herrsching am Ammersee, Germany, Telephone: (49)8152-375-0, Fax: (49)8152-265-8 E-mail: info@hamamatsu.de
France : HAMAMATSU PHOTONICS FRANCE S.A.R.L.: 19 Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10 E-mail: infos@hamamatsu.fr
United Kingdom : HAMAMATSU PHOTONICS UK LIMITED: 2 Howard Court,10 Tewin Road, Welwyn Garden City, Hertfordshire, AL7 1BW, UK, Telephone: (44)1707-294888, Fax: (44)1707-325777 E-mail: info@hamamatsu.co.uk
North Europe : HAMAMATSU PHOTONICS NORDEN AB: Torshamnsgatan 35, 16440 Kista, Sweden, Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01 E-mail: info@hamamatsu.se
Italy : HAMAMATSU PHOTONICS ITALIA S.R.L.: Strada della Moia, 1 int. 6 20044 Arese (Milano), Italy, Telephone: (39)02-93 58 17 33, Fax: (39)02-93 58 17 41 E-mail: info@hamamatsu.it
China : HAMAMATSU PHOTONICS (CHINA) CO., LTD.: 1201, Tower B, Jiaming Center, 27 Dongsanhuan Beilu, Chaoyang District, 100020 Beijing, P.R. China, Telephone: (86)10-6586-6006, Fax: (86)10-6586-2866 E-mail: hpc@hamamatsu.com.cn
Taiwan : HAMAMATSU PHOTONICS TAIWAN CO., LTD.: 13F-1, No.101, Section 2, Gongdao 5th Road, East Dist., Hsinchu City 3000406, Taiwan (R.O.C.) Telephone: (886)3-659-0080, Fax: (886)3-659-0081 E-mail: info@hamamatsu.com.tw

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