

November 2023

**HAMAMATSU**  
PHOTON IS OUR BUSINESS

# X-ray Non-destructive Inspection Products

Essential components for high-speed, high-precision inspection and analysis



# X-ray Non-destructive Inspection Products

Recent years have seen a sharp rise in demand for high-speed, high-precision inspection and analysis in a broad spectrum of industries. Automotive electronics continue to evolve at a dizzying pace. Lithium-ion batteries spurred by the adoption of hybrid vehicles (HVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs) are seeing rapidly growing demand. The world's food, infrastructure and security systems continue to need enhanced safety and security. X-ray non-destructive inspection is the focus of much attention in all of these industries due to its capability for non-contact, non-destructive and real-time inspection and analysis of the structure and properties of objects.

High performance X-ray sources and detectors (sensors/cameras) are the fundamental components for non-destructive X-ray inspection systems. These sources and detectors enable the acquisition of sharp and clear X-ray images so system manufacturers can meet the increasingly demanding requirements of non-destructive X-ray inspection. We combine the latest technologies with our experience accumulated over many years to provide a wide range of X-ray sources and detectors that are backed by unique application knowledge and technical support.



## INDEX

Applications

In-line Inspection (Automotive/Electronics) P04

In-line Inspection (Lithium-ion battery) P06

In-line Inspection (Food and Packaging) P08

Structural Analysis P10

Infrastructure Inspection P12

Security Inspection P13

Product Introduction

X-ray Source P14

Microfocus X-ray source

Soft X-ray source

X-ray 1D Camera P16

X-ray line scan camera

X-ray TDI camera

Dual energy X-ray line scan camera

X-ray 2D Camera P17

X-ray sCMOS camera

X-ray image intensifier camera unit

X-ray flat panel sensor

X-ray Sensor / X-ray Lens P18

CCD / CMOS area image sensor

16-element Si photodiode array

Photodiode array with amplifier

64-element Si photodiode array

128-element Si photodiode array module

16 x 16-element Si photodiode array module

Radiation line sensor for corrosion inspection

X-ray capillary lens

FAQ P20

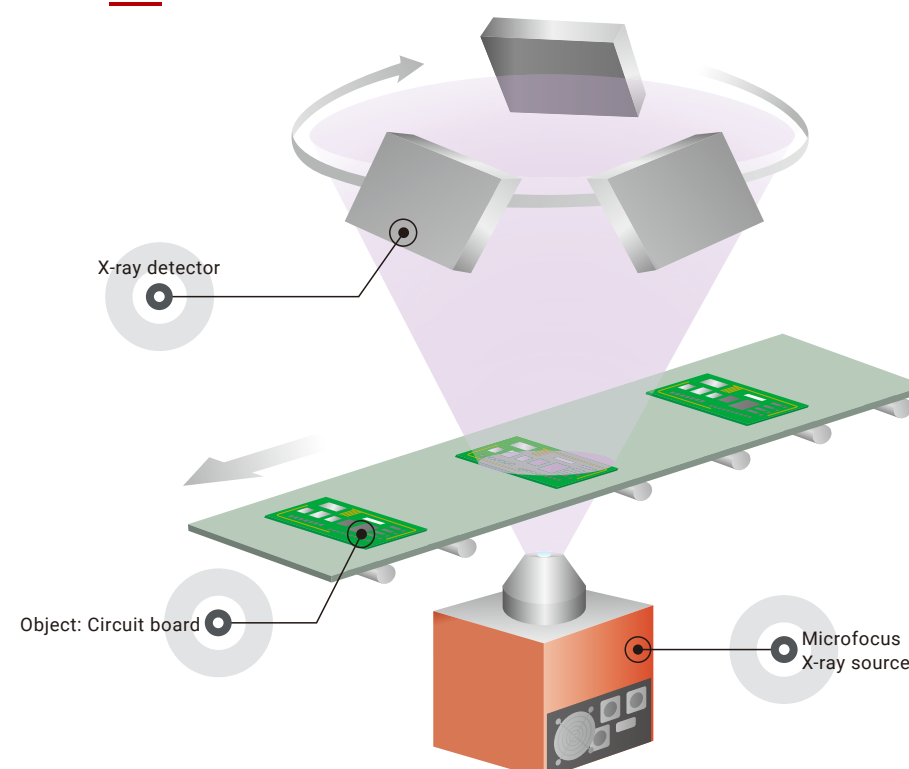
Guide to test imaging P22

# In-line Inspection (Automotive/Electronics)

## High-precision full inspection that contributes to ensuring reliability

In the advancement of the automotive/electronics field, ensuring safety and security through full inspection is required, ranging from quality control of parts to inspection of new materials for weight reduction. In addition, small and high-performance electronic devices such as smartphones, which have rapidly become widespread in recent years, and wireless devices such as drones are also required to ensure not only performance but also reliability. Given this background, non-destructive X-ray inspection is becoming even more important.

### Configuration example



## Hamamatsu Photonics solutions

1. Provide a wide selection of X-ray source, sensors/cameras, and proposes the optimal combination for the customer
2. Work with customers to propose the appropriate inspection method at the optimum conditions
3. X-ray technology that enables highly accurate inspection of small to large parts across a broad range of energy levels

### ■ Applicable products

**Microfocus X-ray source**  
L14351-02



This microfocus X-ray source operates at high energy 180 kV allowing for penetration through power electronic boards with thin heat sinks. Sealed design and integrated HVPS is ideal for factory production applications.

**X-ray TDI camera**  
C12300 series



This X-ray TDI camera is high-resolution and high-speed for in-line inspection with models capable of up to 180 kV of X-ray energy imaging.

**X-ray flat panel sensor**  
C16401SK-51



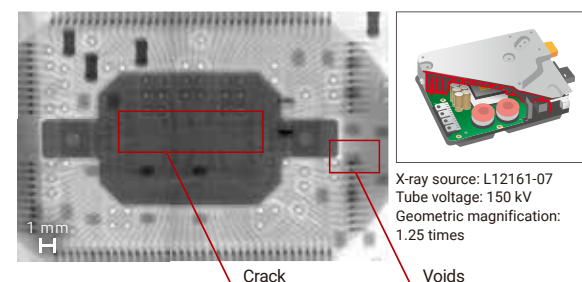
This X-ray flat panel sensor uses a CMOS area image sensor to capture vivid high-quality digital images.

For other products, please refer to the product introduction on pages 14 - 19.

## Imaging examples

### ECU: Engine Control Unit

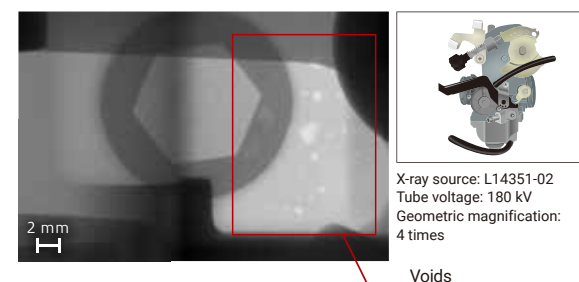
Cracks and voids (bubbles) can be observed.



X-ray source: L12161-07  
Tube voltage: 150 kV  
Geometric magnification: 1.25 times

### Engine parts (die casting)

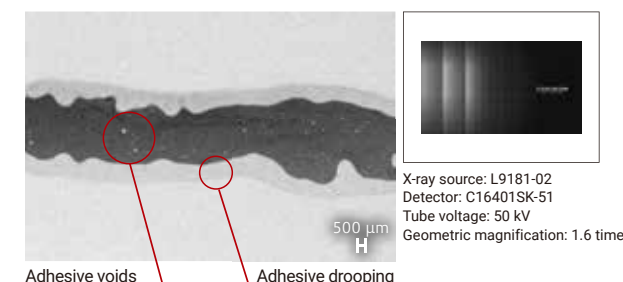
The abnormal occurrence of voids (bubbles) can be observed.



X-ray source: L14351-02  
Tube voltage: 180 kV  
Geometric magnification: 4 times

### CFRP bonding

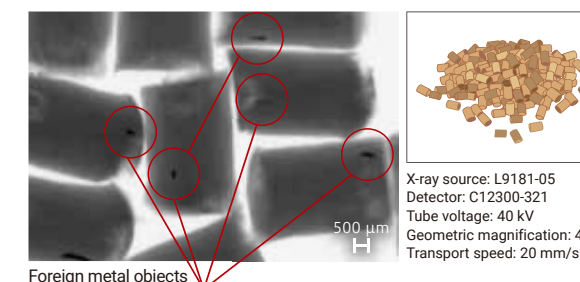
Voids and drooping can be seen in adhesive.



X-ray source: L9181-02  
Detector: C16401SK-51  
Tube voltage: 50 kV  
Geometric magnification: 1.6 times

### Resin pellet material

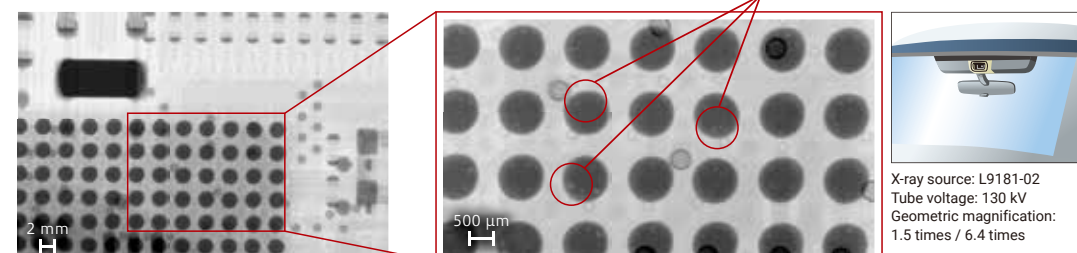
Foreign metal pieces in the resin pellet material can be observed.



X-ray source: L9181-05  
Detector: C12300-321  
Tube voltage: 40 kV  
Geometric magnification: 4.6 times  
Transport speed: 20 mm/s

### Driving support system (camera unit)

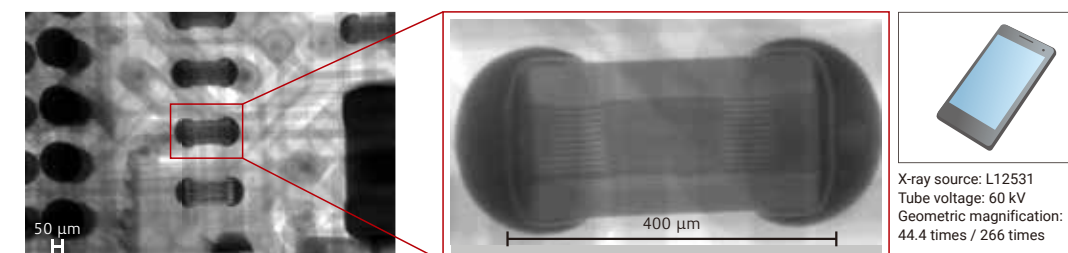
Multiple voids (bubbles) can be observed.



X-ray source: L9181-02  
Tube voltage: 130 kV  
Geometric magnification: 1.5 times / 6.4 times

### Smartphone circuit board

Internal structure of a multilayer ceramic capacitor (0402 size) can be observed.



X-ray source: L12531  
Tube voltage: 60 kV  
Geometric magnification: 44.4 times / 266 times



# In-line Inspection (Lithium-ion Battery)

## High-precision X-ray inspection that confirms the quality of lithium-ion battery

Recent years have brought a huge spike in demand for lithium-ion batteries (LiB) due to the rapid adoption of HVs, PHEVs and BEVs spurred by a drive to achieve carbon neutrality to meet environmental concerns. However, the LiB is a precision component in which even tiny foreign matters or slight defects may lead to heat generation and ignition. Efforts are being made to improve the safety of LiB not only by conducting final product inspections, but also by inspecting the quality of raw materials and checking for foreign matter and defects during the manufacturing process.

## Hamamatsu Photonics solutions

1. Provide a wide selection of X-ray source, sensors/cameras, and proposes the optimal combination for the customer
2. Propose the best inspection method and conditions according to the type of battery
3. Provide technical support for making inspections that detect tiny foreign matter in materials

## Applicable products

**Microfocus X-ray source**  
L9181-05



This is a compact microfocus X-ray source with well-balanced performance and high versatility, making it useful for inspection of a vast range of objects.

**X-ray TDI camera**  
C12300 series



This X-ray TDI camera is high-resolution and high-speed for in-line inspection with models capable of up to 180 kV of X-ray energy imaging.

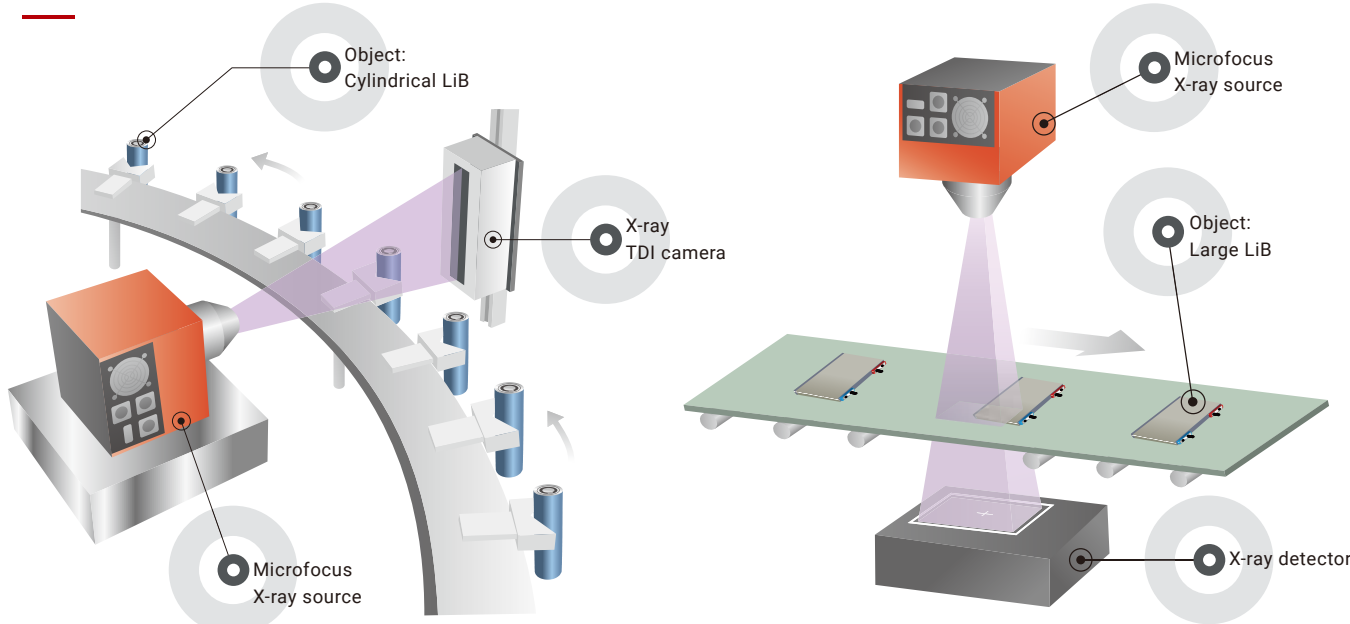
**X-ray flat panel sensor**  
C16401SK-51



This X-ray flat panel sensor uses a CMOS area image sensor to capture vivid high-quality digital images.

For other products, please refer to the product introduction on pages 14 - 19.

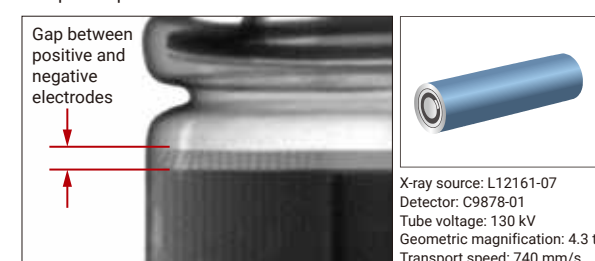
## Configuration example



## Imaging examples

### In-vehicle cylindrical LiB (Detector: X-ray image intensifier camera unit)

Inspects the gap between the positive and negative electrodes at a rate of over 500 pieces per minute.



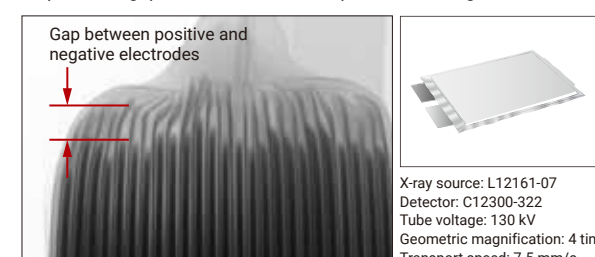
### In-vehicle cylindrical LiB (Detector: X-ray flat panel sensor)

Inspects the gaps between the positive and negative electrodes.



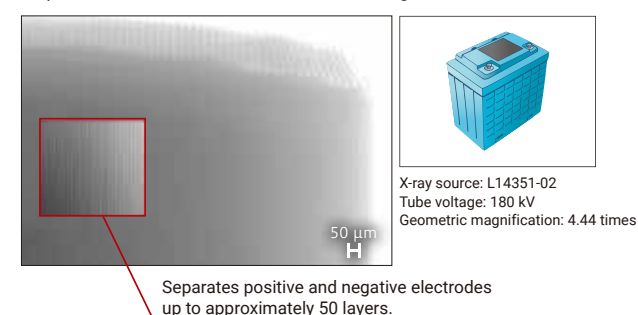
### In-vehicle large LiB (Pouch type: Stacked layer, Detector: X-ray TDI camera)

Inspects the gap between the stacked positive and negative electrodes.



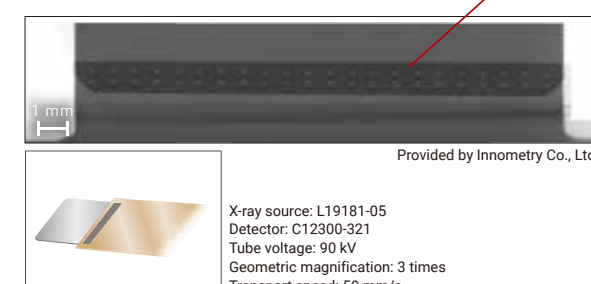
### In-vehicle large LiB (Prismatic type: Stacked layer)

Inspects the internal structure of in-vehicle large LiB.



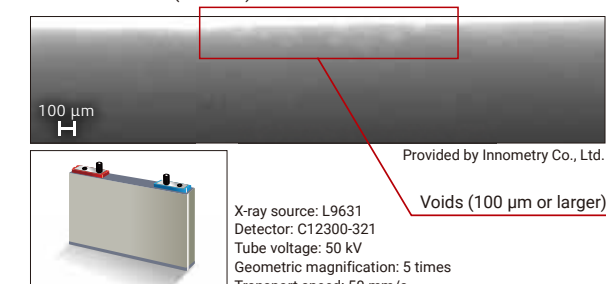
### Component material (Electrode tabs and welds)

Checks the weld state down to the fine details.



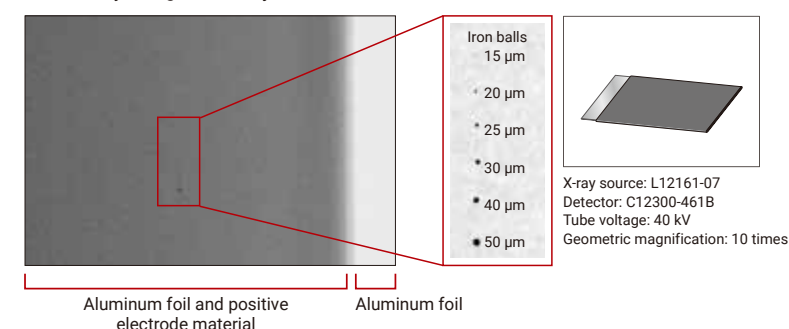
### Component material (Aluminum case)

Checks for voids (bubbles) in the aluminum case weld.



### Component material (Electrode sheet)

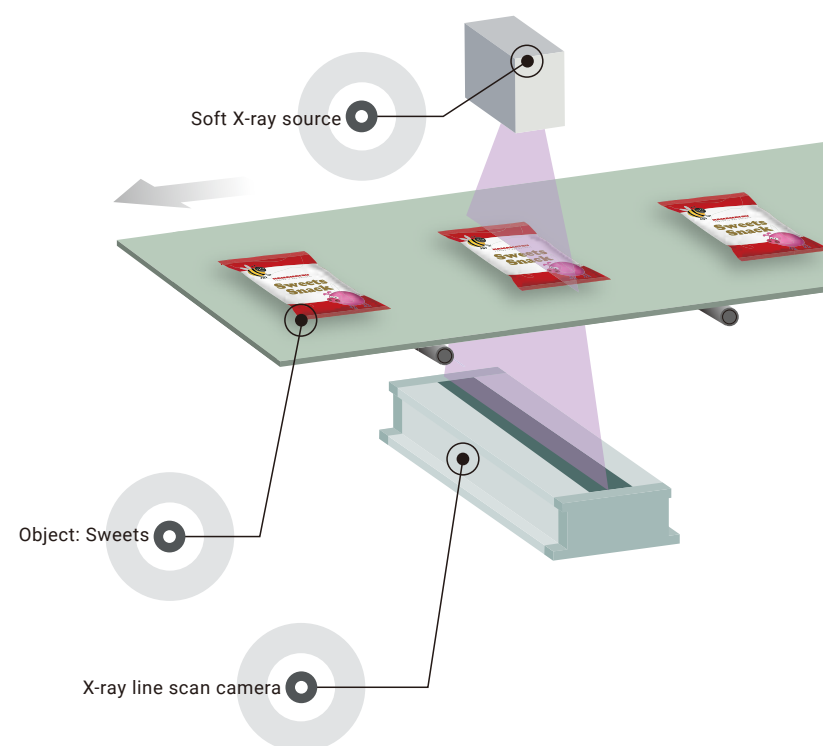
Detects tiny foreign metal objects.



## High-precision X-ray inspection components for the demanding requirements of the food industry

X-ray non-destructive inspection is used throughout the food formation process from field bulk separation to final quality check and package seal inspection. From dairy products and meat as well as frozen foods like dumplings and individually packaged confectionery products are X-ray inspected during processing and packaging. These non-destructive X-ray inspections in this way ensure that food products are safe and of high quality. Hamamatsu Photonics offers the best in class solutions for highly accurate in-line detection of low-density foreign matter, tiny contaminants, and packaged product integrity.

### Configuration example



## Hamamatsu Photonics solutions

1. Provide a wide range of X-ray sources and sensors/cameras that can be combined into an optimum pairing
2. X-ray technology that enables highly accurate inspection of both thick and thin materials such as package sealing defects
3. Provide software for image acquisition and dual-energy computation

### Applicable products

**X-ray line scan camera**  
C14300



This X-ray line scan camera is high-sensitivity and wide-dynamic range for in-line inspection which supports a wide range of objects, from thin to thick.

**Dual energy X-ray line scan camera**  
C11800



It is possible to inspect foreign matters that cannot be detected by a single energy, by acquiring and processing images acquired at 2 energy levels, low and high.

**Soft X-ray source**  
L11754-01W



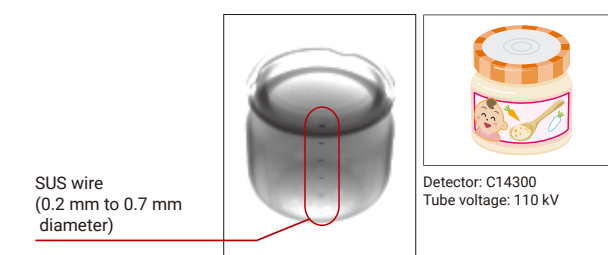
Low X-ray energy can detect low-density foreign matters, which was difficult in the past.

For other products, please refer to the product introduction on pages 14 - 19.

## Imaging examples

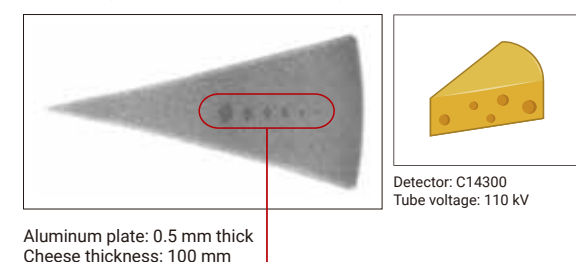
### Baby food

Metal foreign matter overlapping onto the metal lid can be detected.



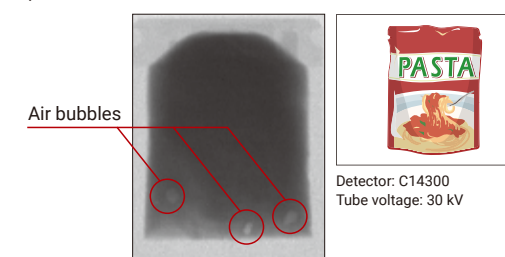
### Cheese

Foreign objects mixed into high-density and thick cheese can be checked.



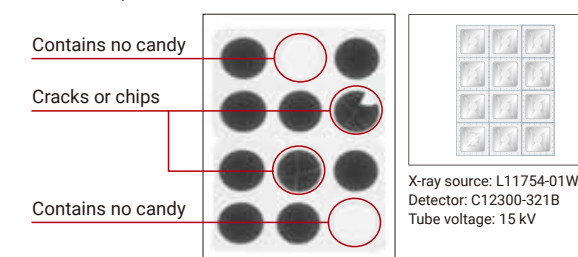
### Pasta sauce

Easily finds air bubbles and foreign matter inside a retort-packaged products.



### Tablet candy

Easily checks for cracks, chipped candies, and the number of candies in a blister pack.



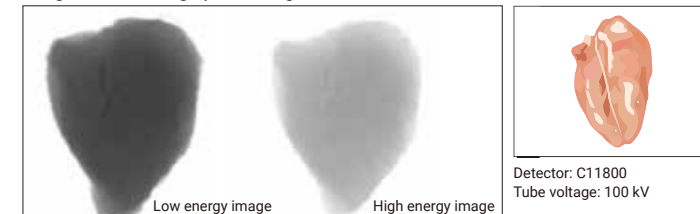
### Chicken breast meat

Bone fragments and residual bones that are difficult to show in images due to low contrast with chicken meat are now detectable by dual-energy imaging and image processing.

Image after auto processing by  
DUAL XTRAX™

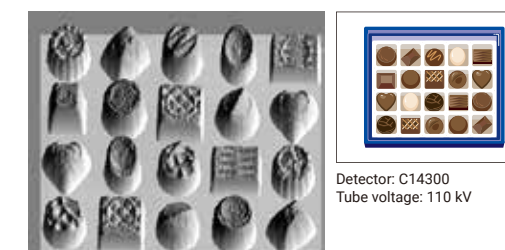


Images before image processing



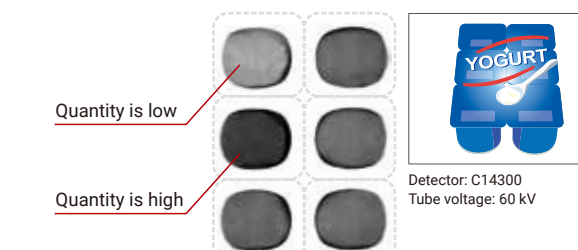
### Chocolate

In addition to inspecting shapes, the weight of each piece of chocolate can also be found based on the shading of the image.



### Yogurt

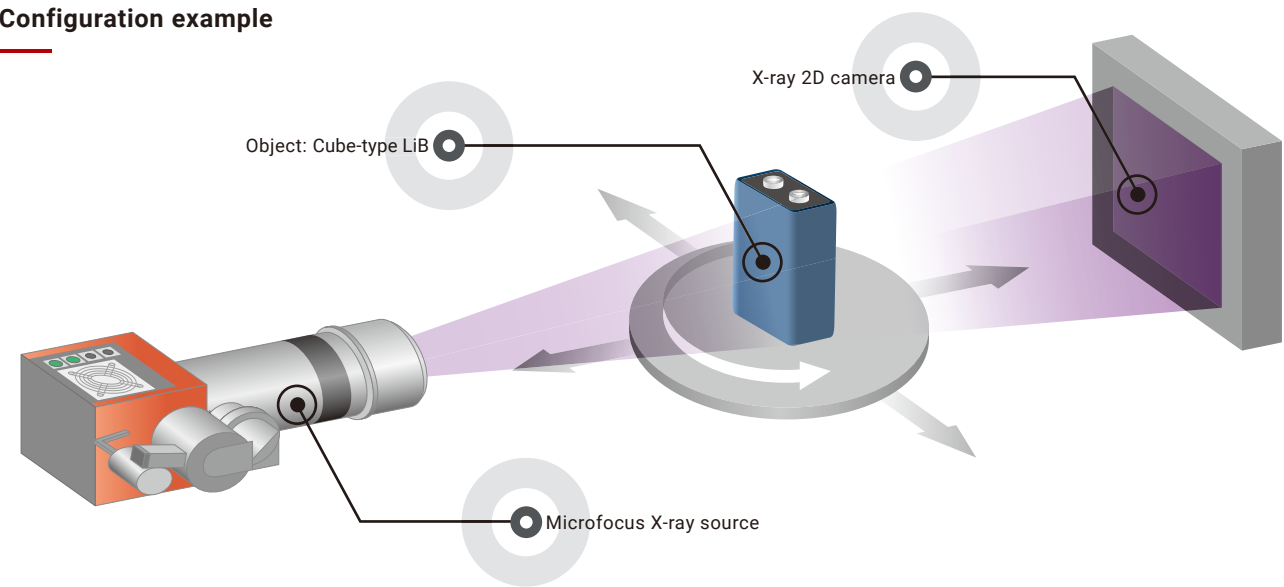
The quantity in each pack can be inspected based on the shading of the image.



Nano-level X-ray CT in quality control and R&D

The need for nano-level structural analysis by X-ray CT has been increasing along with the demand for stricter quality control and R&D that requires high resolution. X-ray CT enables the observation of internal defects and the dimensional measurement of objects, and it contributes to a wide range of applications from accuracy assurance/quality assurance to reverse engineering. In addition, the microfocus X-ray source is usable for 3D analysis of material structure and the status of particles/fibers. X-ray CT structural analysis is expected to find further applications due to its high accuracy and versatility.

Configuration example



Hamamatsu Photonics solutions

- 1. Propose products with high performance and high stability
- 2. Propose products designed with easy maintenance
- 3. X-ray technology that enables highly accurate analysis of complex micro structures as well as large / high-density parts

Applicable products

Microfocus X-ray source  
L12721



Its high tube voltage (300 kV max.) enables imaging of large parts such as aluminum die casting and battery systems.

Microfocus X-ray source  
L10711-03



With the world's highest level of resolution (0.25 μm), high-definition structural analysis at the nano level is possible.

X-ray flat panel sensor  
C16401SK-51



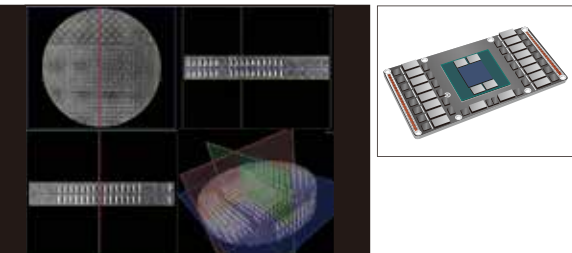
This X-ray flat panel sensor uses a CMOS area image sensor to capture vivid high-quality digital images.

For other products, please refer to the product introduction on pages 14 - 19.

Imaging examples

GPU: Graphics Processing Unit

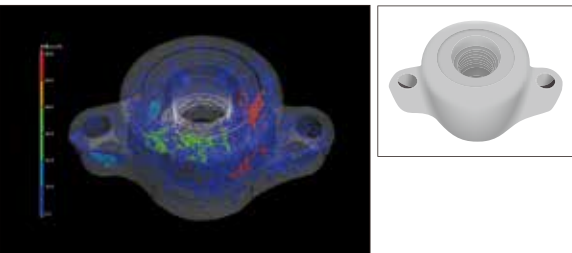
Internal defect observation and dimensional measurement are possible.



Provided by UNI-HITE System Corporation

Aluminum die casting

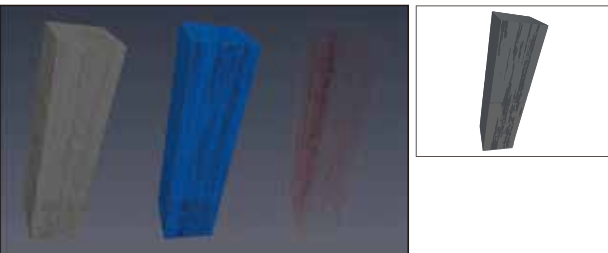
Detailed volume information of the cavities (cavities inside the casting) can be obtained.



Provided by Toshiba IT & Control System Corporation

CFRP: Carbon Fiber Reinforced Plastic

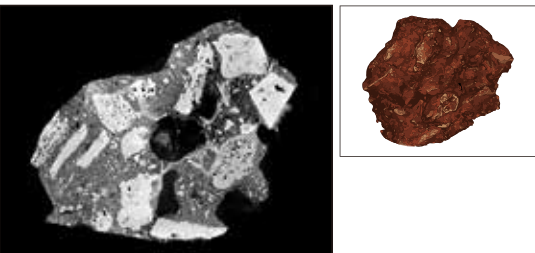
The orientation of fibers can be determined, and material porosity can be obtained.



Provided by Thermo Fisher Scientific Inc.  
Analysis equipment: HeliScan™ high-resolution microCT system

Rocks and minerals

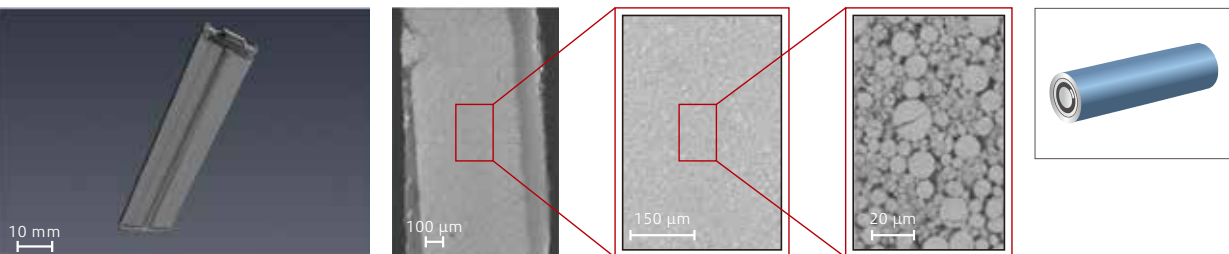
Analysis of the materials and structures of rocks and minerals will lead to more efficient mining.



Provided by RX SOLUTIONS SAS

Lithium-ion battery

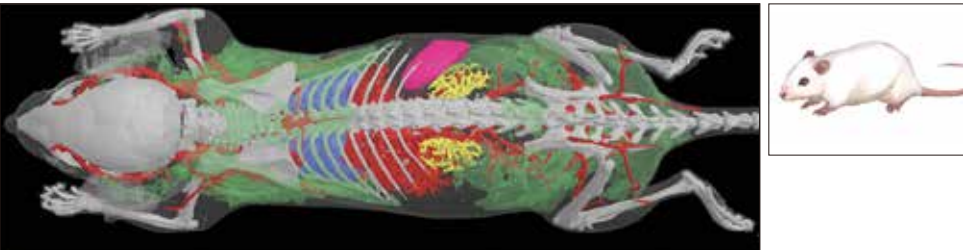
High-definition structural analysis is possible, by CT technology.



Provided by Thermo Fisher Scientific Inc.  
Analysis equipment: HeliScan™ high-resolution microCT system

Mouse

Changes in biological information of small experimental animals are being investigated. Green parts indicate fat, and the amount and percentage of body fat can be calculated.



Provided by BRUKER CORPORATION  
Analysis equipment: SkyScan systems produced by BRUKER BELGIUM NV

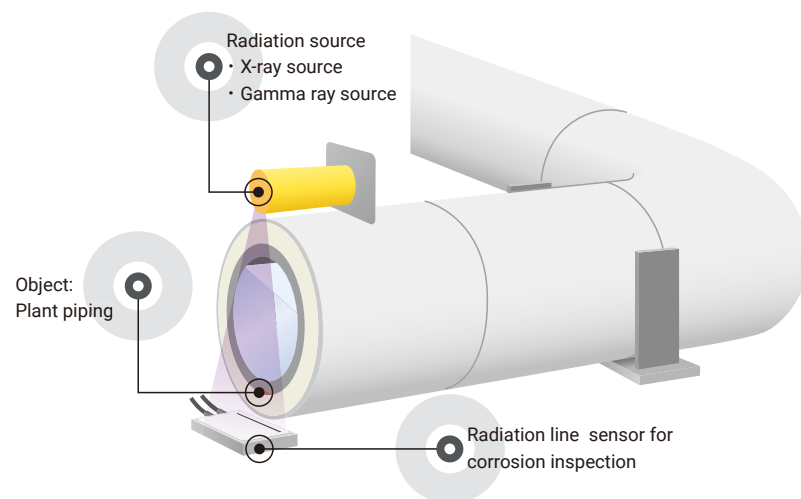


# Infrastructure Inspection

## Radiation inspection that contributes to planned maintenance

In recent years, there have been growing concerns of the aging of infrastructure equipment. In particular, troubles caused by corrosion of pipes at oil, gas and chemical plants have become a problem. Among various inspection methods such as visual inspection and ultrasonic inspection, highly efficient and highly accurate radiation inspection is attracting attention. It contributes to early detection of deterioration and planned maintenance, which is important in the maintenance of infrastructure equipment such as plant piping.

### Configuration examples



### Hamamatsu Photonics solutions

1. Propose products that make full use of advanced technology cultivated in academic research
2. X-ray technology that enables highly accurate inspection from small-diameter pipes to large-diameter pipes
3. Work with customers to propose the appropriate inspection method at the optimum conditions
4. X-ray technology that enables not only pipe corrosion inspection but also thickness and level measurements

### ■ Applicable products



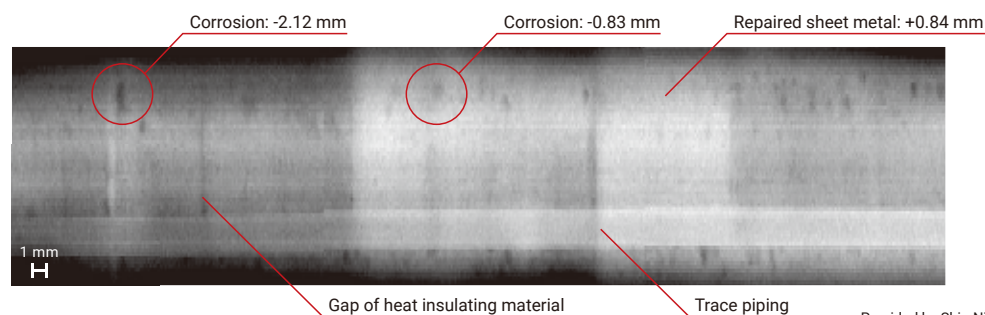
**Radiation line sensor for corrosion inspection**  
C13247

It enables efficient and quantitative corrosion inspection of pipes without the need to remove the heat insulating material and without stopping the operation of the pipes. This will lead to a significant reduction in time and cost.

For other products, please refer to the product introduction on pages 14 - 19.

### Imaging examples

#### 6-inch piping with heat insulating material (with trace piping / with contents)



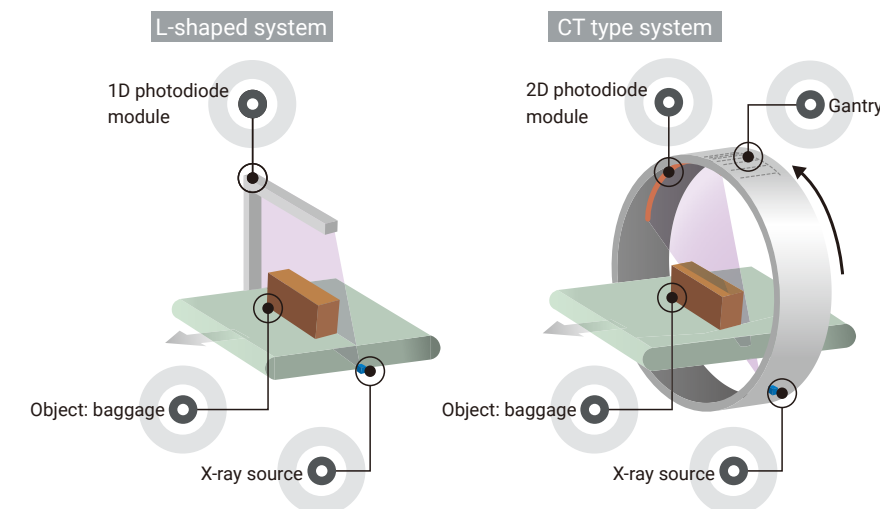
Provided by Shin-Nippon Nondestructive Inspection Co., Ltd.

# Security Inspection

## Easy baggage inspection for a wide range of applications

Interest in personal safety and security is increasing. In addition to security inspections at airports, baggage inspections are now being seen on ships, land transportation and event venues, and X-ray non-destructive inspection, which allows inspections without opening the baggage, is used as an effective means. In the past, L-shaped systems were the mainstream, but in recent years, CT-type systems that can obtain more detailed X-ray images are increasing.

### Configuration examples



### Hamamatsu Photonics solutions

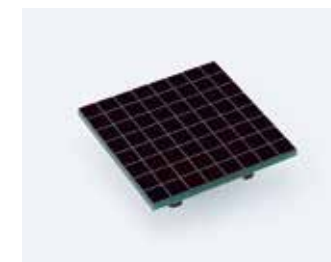
1. Have various types of sensors such as single element, linear array and area array, and can propose suitable products
2. Propose products that use scintillators suitable for each type of energy
3. Propose a module with a built-in dedicated driver circuit
4. Propose a configuration that fits the equipment design

### ■ Applicable products



**16-element Si photodiode array**  
S11212 series

The S11212 series is a 16-element photodiode array with a back-illuminated structure. It can be used as a line sensor by arraying multiple units.

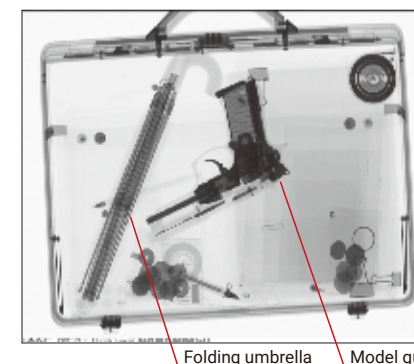


**64-element Si photodiode array**  
S13620-02

This is an 8 x 8-element photodiode array with a back-illuminated structure. By arraying multiple units, it can be used as an area sensor.

For other products, please refer to the product introduction on pages 14 - 19.

### Imaging examples



#### Attaché case

By detecting differences in quality such as metal, it is possible to accurately identify the objects in the attaché case.

# X-ray Source

## Microfocus X-ray source

This is the X-ray source that enables acquisition of X-ray images with high definition and little blur even at high geometric magnification rate by setting the focal spot size at the micron scale. The high voltage power supply is integrated inside the body of the X-ray source, making it free of high-voltage cables. We have a wide lineup, and you can choose the product that suits your application and conditions.



Microfocus X-ray sources are categorized into sealed type and open type according to the structure. The sealed type has a small body and is easy to incorporate into the system. The open type requires ancillary equipment such as a vacuum pump, but it has high tube voltage and high-resolution characteristics that cannot be achieved with the sealed type.

	Type no.	Tube voltage	Tube current	Maximum output	Focal spot size (Min.) *1	X-ray radiation angle	FOD (Min.) *2
Sealed type	L9421-02	20 kV to 90 kV	10 μA to 200 μA	8 W	5 μm	Approx. 39°	Approx. 9.5 mm
	L10101	40 kV to 100 kV	10 μA to 200 μA	20 W	5 μm	Approx. 42°	Approx. 6.8 mm
	L10321	40 kV to 100 kV	10 μA to 200 μA	20 W	7 μm	Approx. 118°	Approx. 7.3 mm
	L9631	40 kV to 110 kV	10 μA to 800 μA	50 W	15 μm	Approx. 62°	Approx. 16.8 mm
	L12531	40 kV to 110 kV	10 μA to 200 μA	16 W	2 μm *3	Approx. 120°	Approx. 1.0 mm
	L9181-02	40 kV to 130 kV	10 μA to 300 μA	39 W	5 μm	Approx. 45°	Approx. 13.0 mm
	L9181-05	40 kV to 130 kV	10 μA to 300 μA	39 W	16 μm	Approx. 100°	Approx. 13.0 mm
	L12161-07	40 kV to 150 kV	10 μA to 500 μA	75 W	5 μm	Approx. 43°	Approx. 17.0 mm
Open type	L14351-02	40 kV to 180 kV	10 μA to 500 μA	90 W	20 μm	Approx. 62°	Approx. 19.8 mm
	L10711-03	20 kV to 160 kV	5 μA to 200 μA	16 W *4	0.25 μm *3 *5	Approx. 140°	Approx. 0.3 mm
	L10801	20 kV to 230 kV	10 μA to 1000 μA	200 W	4 μm *3	40° to 60°	Approx. 4.6 mm
	L12721	20 kV to 300 kV	10 μA to 1000 μA	200 W	4 μm *3	40° to 60°	Approx. 4.6 mm

\*1: This is the nominal value. \*2: This is the distance from the X-ray focus to the output window. \*3: This is the minimum resolution when using an X-ray chart.  
\*4: When the optional diamond window is selected (sold separately) \*5: The value is based on the optimum measurement conditions including the measurement environment and measurement equipment.

## Soft X-ray source

This is the X-ray source that makes it possible to image low-density materials using low energy X-rays, which was difficult in the past. It is small (palm-sized) and lightweight at about 1.7 kg, and by shortening the irradiation distance to the object with a wide radiation angle, you can easily install it in a compact inspection facility. In addition, the lower voltage eliminates the need for lead shielding, which contributes to total cost reduction in shielding equipment.



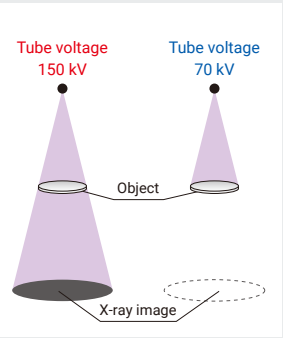
Model name	Tube voltage	Tube current	Maximum output	Focal spot size (Max.) *1	X-ray radiation angle	FOD (Min.) *2
L11754-01W	15 kV	1 mA	15 W	0.8 mm	Approx. 150°	Approx. 3.2 mm

\*1: This is the nominal value. \*2: This is the distance from the X-ray focus to the output window.

### Tube voltage

#### X-ray transmission

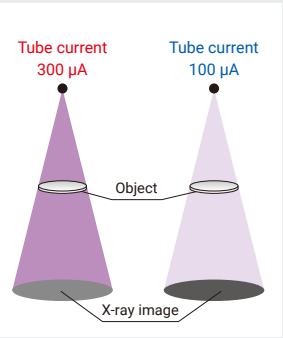
As the X-ray energy increases with the increase in tube voltage, the X-ray transmission to the object also increases. A high-contrast X-ray image can be obtained by setting a tube voltage value suitable for the object.



### Tube current / output

#### X-ray image brightness

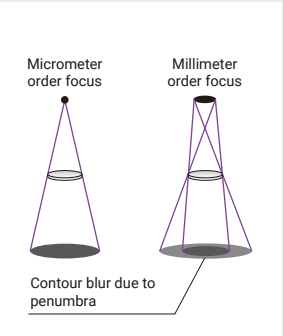
With the tube current value increased, the X-ray dose also increases, and a brighter X-ray image can be obtained. When you inspect an object, the higher the tube current and output are, the shorter the imaging time and the faster the inspection throughput become.



### Focal spot size

#### X-ray image resolution

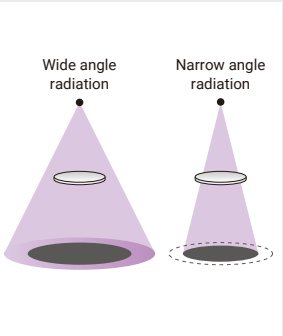
The focal spot size is directly related to the resolution of images. The larger the focal spot size is, the larger the blurry area in images (penumbra) becomes at high magnification imaging. In contrast, the smaller focal spot size enables less blurry X-ray images.



### X-ray radiation angle

#### Imaging area

The wide radiation angle reduces the irradiation distance and enables imaging of large objects. It also enables 3D shape observation by imaging from an oblique direction. Select the optimum X-ray radiation angle according to your application and object.

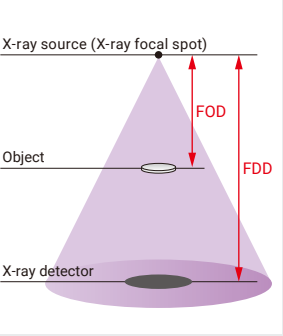


### Geometric magnification

#### X-ray image magnification

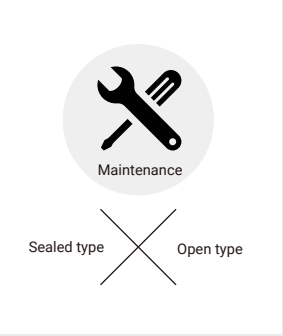
When FDD is set to a constant value, the shorter the FOD is, the higher the geometric magnification calculated by FDD/FOD becomes.

**FOD (focus to object distance):**  
Distance from X-ray focal spot to object  
**FDD (focus to detector distance):**  
Distance from X-ray focal spot to X-ray detector



### Maintainability

The sealed type is designed so that the X-ray generator is sealed in a vacuum tube. There is no need for periodic maintenance by the customer. The open type requires the customer to replace the cathode/target during periodic maintenance; however, it can be used continuously for a long period of time and contributes to the reduction of downtime (unusable time).



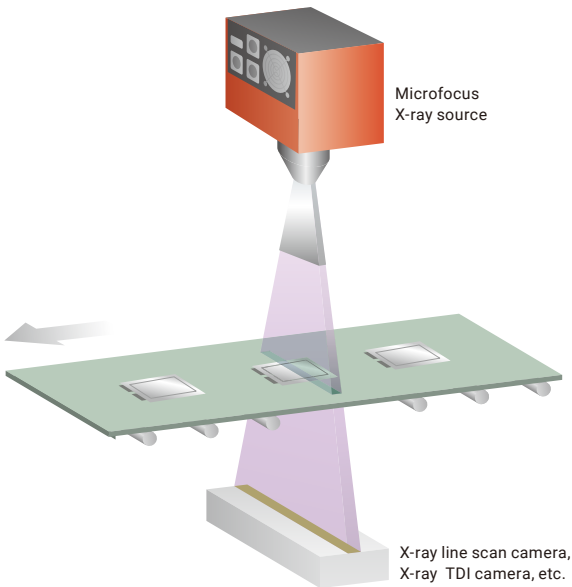


# X-ray 1D Camera

This camera is widely used in in-line inspection because it can continuously acquire high-resolution X-ray images.

## Product lineup

Product name	Features	Resolution	Frame rate	Detection width	Detection power
X-ray line scan camera	High speed, wide field of view	☆☆	☆☆☆	☆☆☆	☆
X-ray TDI camera	High resolution	☆☆☆	☆☆	☆	☆☆
Dual energy X-ray line scan camera	High detection power (corresponds to low-density foreign matter and thin foreign matter)	☆	☆☆	☆☆	☆☆☆



### X-ray line scan camera C14300/C14960 series

The C14300 and C14960 series are X-ray line scan cameras ideal for high-speed in-line inspections. Features including high sensitivity and low noise ensure these cameras capture clear images with high S/N ratio even at low dose levels. A single unit can handle both thick and thin materials and the detection width is selectable according to the inspection conditions and available space.

- High-speed readout
- High dynamic range
- Wide field of view
- High sensitivity and low noise

Type no.	Detection width	Pixel pitch	Corresponding line speed	Digital output
C14300 series	153.6 mm to 614.4 mm	0.4 mm	4 m/min to 200 m/min	14 bit
C14960 series	716.8 mm to 921.6 mm	0.4 mm	4 m/min to 100 m/min	14 bit



### X-ray TDI camera C10650/C12300 series

An X-ray TDI camera that enables highly accurate in-line inspection. By using TDI (time delay integration) technology, it has four benefits: high resolution, high-speed readout, wide field of view, and high sensitivity.

- High resolution
- High sensitivity and low noise
- Bidirectional readout (C12300 series)

Type no.	Sensor placement *1	Detection width	Pixel size	Corresponding line speed	Number of integrated stages	Digital output
C10650 series	Straight	145.9 mm, 221.1 mm	48 μm	0.178 m/min to 6.073 m/min	128	12 bit
	Overlapped	146.9 mm to 586.4 mm				16 bit
C12300 series	Straight	73.728 mm, 221.1 mm	48 μm	0.576 m/min to 144.0 m/min	150	12 bit
	Overlapped	293.4 mm				16 bit

\*1: There are 2 types of sensor placement: a normal straight type and a overlapped type with no dead zones.  
NOTE: Corresponding tube voltage is approx. 25 kV to 90 kV for C10650 series, approx. 10 kV to 180 kV for C12300 series.



### Dual energy X-ray line scan camera C11800 series

The "Dual XTRAX®," which combines the next-generation X-ray detector with improved performance compared to our conventional products and the new next-generation computing technology, enables detection of low-density foreign matter and thin foreign matter, which was difficult until now.

- Different materials can be separated
- High dynamic range
- High-speed readout
- Wide field of view

Type no.	Detection width	Pixel pitch	Corresponding line speed	Digital output
C11800 series	409.6 mm	0.4 mm	4 m/min to 100 m/min	14 bit
	460.8 mm			

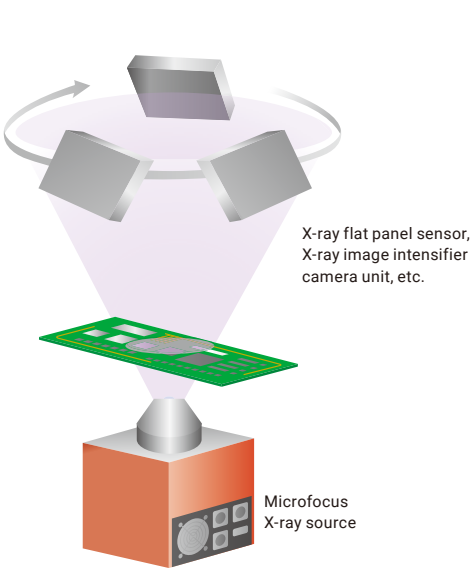


# X-ray 2D Camera

It is widely used in 3D inspection and structural analysis because it irradiates an object with X-rays all at once.

## Product lineup

Product name	Features	Energy range	Resolution	Frame rate	Field of view	Miniaturization
X-ray sCMOS camera	High sensitivity and high resolution	Low	☆☆☆	☆☆	☆	☆☆☆
X-ray image intensifier camera unit	High sensitivity and high speed	Medium to high	☆☆	☆☆☆	☆☆	☆
X-ray flat panel sensor	High resolution and wide field of view	Medium	☆☆	☆	☆☆☆	☆☆

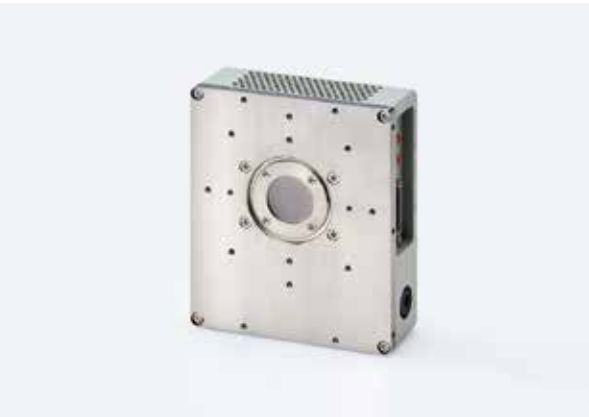


### X-ray sCMOS camera C12849-111U

A high-resolution X-ray sCMOS camera that enables highly accurate inspection and analysis of minute objects. Due to its small size, it is also suitable for incorporation into devices such as micro X-ray CT devices.

- High resolution
- Low noise
- Low energy and high sensitivity characteristics
- Small size

Type no.	Number of pixels	Field of view	Scintillator	Resolution	Frame rate
C12849-111U	4 megapixels	13.3 mm × 13.3 mm	GOS (10 μm)	33 lp/mm	30 fps

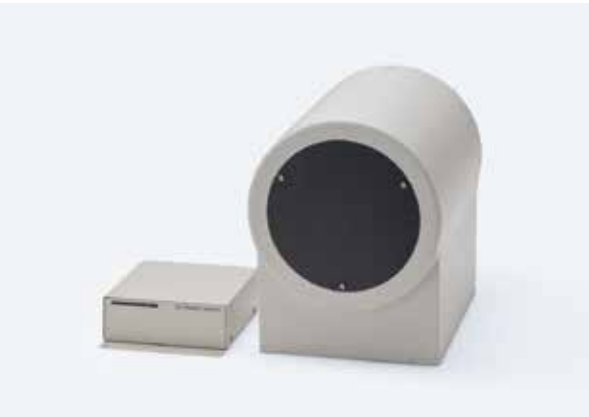


### X-ray image intensifier camera unit C7336-06/-07

X-ray image intensifier camera unit that enables high-speed inspection and analysis with high sensitivity. It has a magnification function and can acquire X-ray images in a short time with high resolution and high contrast.

- High-speed readout
- High resolution
- High sensitivity and low noise
- High contrast

Type no.	Number of pixels	Field of view	Scintillator	Resolution	Frame rate
C7336-06	2.35 megapixels	75 mm × 48 mm	CsI	8 lp/mm	165 fps
C7336-07	3 megapixels	72 mm × 54 mm	CsI	8 lp/mm	65 fps



### X-ray flat panel sensor C16401SK-51

The C16401SK-51 is a high-speed imaging X-ray flat panel sensor with a pixel size of 100 μm × 100 μm for in-line use.

- Large area (wide field of view)
- High-resolution
- Low noise

Type no.	Number of pixels	Field of view	Scintillator	Resolution	Frame rate
C16401SK-51	1.40 megapixels	127.2 mm × 110.4 mm	GOS	4.5 lp/mm	21 fps *1

\*1: When reading 1 × 1. Reading speed varies during binning and partial reading.



# X-ray Sensor / X-ray Lens

## CMOS area image sensor S15683-13

The S15683-13 is a CMOS area image sensor with a pixel size of 20 μm × 20 μm optimized for X-ray imaging. Coupling a fiber optic plate (FOP) to the image sensor reduces noise and damage caused by transmitted X-rays, and so extends the product lifetime. Its thin design helps you downsize the inspection device.

- High resolution
- Small
- USB interface

Type no.	Number of pixels	Field of view	Scintillator	Resolution	Frame rate
S15683-13	2.21 megapixels	26 mm × 34 mm	CsI(Tl)	20 lp/mm	0.46 fps

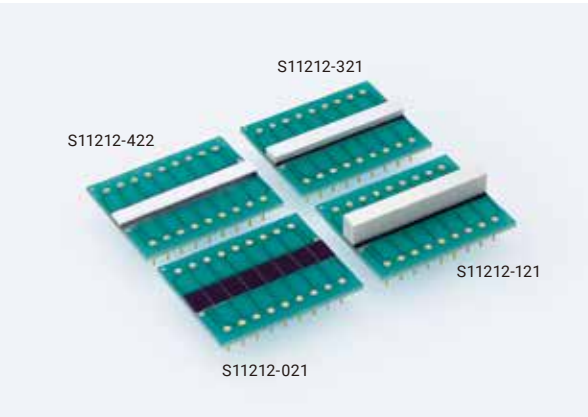


## 16-element Si photodiode array S11212 series

The S11212 series is a 16-element photodiode array with a back-illuminated structure. It can be used as a line sensor by arraying multiple units. There are also types without scintillators. Since there is no wire bonding on the incident surface side, the scintillator required by the customer can be easily mounted.

- Can be lengthened by multiple arrays
- Supports dual energy imaging

Type no.	Element size	Element pitch	Number of elements	Scintillator
S11212-021	1.175 mm × 2.0 mm	1.575 mm	16	—
S11212-121				CsI(Tl)
S11212-321				GOS ceramic
S11212-422				Phosphor sheet



## Photodiode array with amplifier S11865/S11866 series

These are photodiode arrays with an amplifier for X-ray detection ,with phosphor sheet attached on the photosensitive area. It is possible to configure a long image sensor by arraying multiple units.

- 5 V drive
- Low noise, wide dynamic range
- Detectable energy range: 30 keV to 100 keV

Type no.	Element size	Element pitch	Number of elements	Line rate
S11865-64G	0.7 mm × 0.8 mm	0.8 mm	64	14678 lines/s
S11865-128G	0.3 mm × 0.6 mm	0.4 mm	128	7568 lines/s
S11865-256G	0.1 mm × 0.3 mm	0.2 mm	256	3844 lines/s
S11866-64G-02	1.5 mm × 1.6 mm	1.6 mm	64	14678 lines/s
S11866-128G-02	0.7 mm × 0.8 mm	0.8 mm	128	7568 lines/s

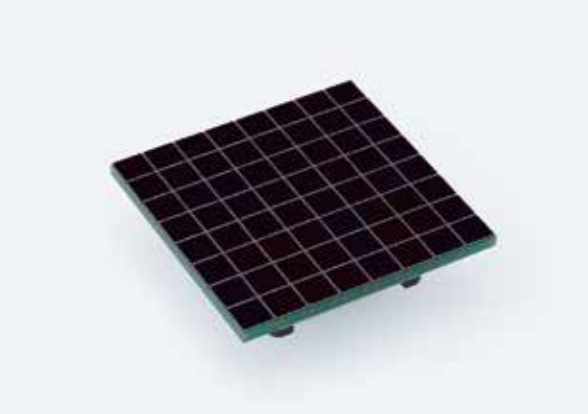


## 64-element Si photodiode array S13620-02

This is an 8 × 8-element Si photodiode array that uses a back-illuminated structure. By arraying multiple units, it can be used as an area sensor. There are also types without scintillators. Since there is no wire bonding on the incident surface side, the scintillator required by the customer can be easily mounted.

- Tiling with multiple arrays is possible
- No crosstalk between channels

Type no.	Photosensitive area	Element pitch	Number of elements
S13620-02	2.5 mm × 2.5 mm / element	3.0 mm	64(8 × 8)



## 128-element Si photodiode array module C14560 series

This is a digital output Si photodiode array module that combines an ASIC with a 1D photodiode array that uses a back-illuminated structure. The photodiode array is mounted on both sides of the board, and supports dual energy imaging.

- Can be lengthened by multiple arrays
- Supports dual energy imaging
- 16-bit LVDS output

Type no.	Element size	Element pitch	Number of elements	Scintillator
C14560 series	1.3 mm × 2.0 mm	1.575 mm	128(64 × 2)	—
				CsI(Tl)
				GOS ceramic Phosphor sheet

NOTE: The thickness of the scintillator can be customized (customization example: CsI(Tl) 4 mm / phosphor sheet)



## 16 × 16-element Si photodiode array module C14604 series

This is a digital output photodiode array module that combines a 16 × 16-element photodiode array with a back-illuminated structure and an ASIC. By arraying multiple units, it can be integrated into CT type scanning equipment.

- Supports CT type scanning equipment
- 16-bit LVDS output

Type no.	Photosensitive area	Element pitch	Number of elements	Scintillator
C14604 series	2.5 mm x 2.5 mm / element	3 mm	256(16 × 16)	—
				CsI(Tl)
				GOS ceramic Phosphor sheet

NOTE: The thickness of the scintillator can be customized (customization example: GOS ceramic 1.5 mm).



## Radiation line sensor for corrosion inspection C13247

This is a radiation line sensor specialized for inspection of infrastructure equipment such as pipe corrosion in oil, gas and chemical plants. It is more accurate and efficient than the conventional visual inspection, ultrasonic inspection, radiation inspection and neutron moisture inspection, and enables real-time image inspection.

- No need to remove the heat insulating material
- Inspection during piping operation is possible
- Significant reduction in time and cost through automation
- Quantitative measurement of thickness is possible
- Scattered rays can be removed

Type no.	Detection width	Number of pixels	Pixel pitch	Energy measurement range	1 line accumulation time
C13247	211 mm	64	3.3 mm	50 keV to 500 keV	50 ms to 4095 ms



## X-ray capillary lens J12432-01, J12818-01

This is an X-ray optical device made by bundling a large number of hollow glass capillaries and processing them to a gently tapered shape. Utilizing total reflection at the wall surface inside the capillaries, it enables parallelization of X-rays and focusing on minute spots.

- Collimate X-ray for parallel beam
- Focus X-rays to micro spot



**Q** Do X-rays remain?

**A** X-rays do not remain.  
Once you stop the X-ray irradiation, the X-rays will disappear immediately.

**Q** What steps should we take if we want to install an X-ray inspection system?

**A** We manufacture the critical imaging components for a precision X-ray systems.  
We do not manufacture the complete X-ray inspection system.

**Q** Which X-ray source, sensor/camera etc. should we use?

**A** Please contact us, as we will propose the optimum combination of X-ray source and sensor/camera according to your application and conditions.  
For the purpose of prior evaluation, we can offer demonstrations at our facility by using various X-ray sources, sensors/cameras etc. or loan our demo units to a customer for evaluation. Please feel free to contact us.

**Q** Can you take "test imaging" for customers?

**A** Yes, we can do that. See pages 22 and 23 for detailed information on what we can do for taking test images for customers.

**Q** What kind of design is needed to shield out X-rays?

**A** X-rays should be shielded so that the effective dose outside the equipment is within the value specified by regulations on preventing of ionizing radiation hazards in your own country. To protect operators or other personnel from accidental exposure to X-rays, be sure to install a safety interlock device so that X-ray generation immediately stops when the shielding equipment is opened.

**Q** Do you comply with environmental measure standards?

**A** We are complying with various environmental measure standards.  
Please contact us for detailed information on each product.

**Q** Are imports and exports of your products allowed?

**A** Our products listed in this catalog are not subject to the Japanese Export Trade Control Order, Foreign Exchange and Foreign Trade Act. However, when importing or exporting our products, please comply with the applicable laws and regulations in your country or state.

**Q** Do X-ray sources, sensors/cameras have a limited life span?

**A** Some parts need to be replaced depending on the frequency of use. Please contact us for details.

**Q** What should we do to dispose of a product?

**A** If you want to dispose of our products, please comply with the waste management law or regulation in your country or state, and do it by yourselves or outsource to an appropriate licensed industrial disposal company. When disposing of waste abroad, dispose of it properly in accordance with the waste disposal laws and regulations of each country and state.



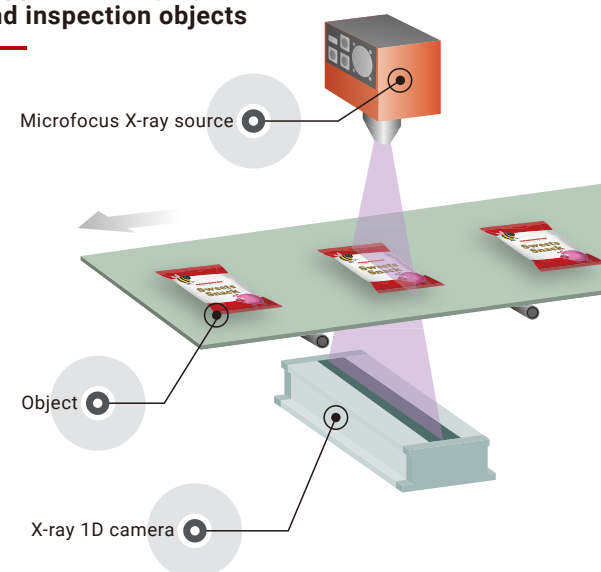
# Guide to test imaging

## Hamamatsu Photonics will propose optimal solutions for your X-ray non-destructive inspection needs through test imaging.

Hamamatsu Photonics performs preliminary evaluations of customer requests for X-ray non-destructive inspections by taking test images using various X-ray sources, sensors/cameras.

Based on our long years of experience in the X-ray business, we will not only introduce you to the most optimal devices, but also propose the best possible solutions including tips and know-how on X-ray imaging.

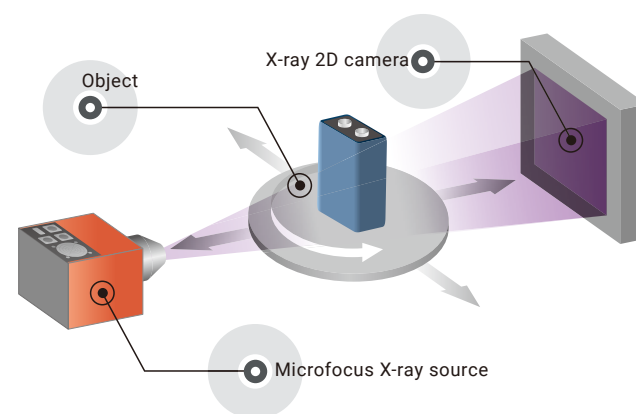
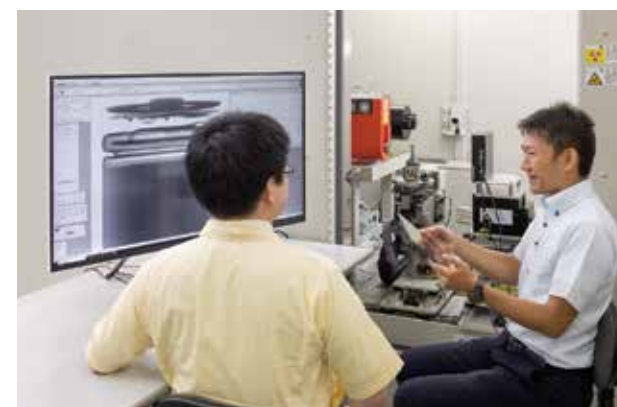
### Supported imaging methods and inspection objects



### Imaging of moving objects by X-ray 1D camera

A microfocus X-ray source and a X-ray 1D camera (line sensor camera or TDI camera) are mounted above and below a belt conveyor. The camera captures X-ray images of samples flowing on the conveyor at any desired speed.

Size of inspection object (maximum): 1000 mm (W) × 300 mm (H) × 600 mm (D)  
Weight of inspection object (distributed weight on tray): 10 kg  
Transport speed: Up to 100 m/min



### Imaging of objects by X-ray 2D camera

This setup consists of a microfocus X-ray source, a sample stage and a 2D X-ray camera (flat panel sensor or X-ray image intensifier camera) that are arrayed in a straight line. X-ray images of the entire sample or a portion of the sample area are captured by moving the sample stage to any desired position.

Size of inspection object (maximum): 500 mm (W) × 500 mm (H)  
Weight of inspection object (distributed weight on stage): 9 kg

### Example for test imaging

#### LiB, Automotive parts



- Inspection for wire breakage and defects in tires
- Inspection for LiB electrode misalignment and foreign matter
- Inspection of foreign matter in LiB electrode sheets and separators
- Inspection for voids in aluminum die castings
- Quality inspection of other parts (brake pedals, door panels, bearing, etc.)

#### Food, Pharmaceuticals



- Inspection for foreign matter, contents and sealing integrity of processed food products
- Inspection for worm-eaten vegetables and fruits
- Inspection for foreign matter and contents in vial bottles
- Needle shape and quality inspection

#### Clothing, etc.



- Detection of pins or needles in clothing
- Inspection for underwear adhesion defects
- Inspection for defective nails inside shoes
- Inspection for golf ball eccentricity

#### Electronic parts



- Inspection for power device defects
- Inspection of BGA for voids, cracks and bonding failures
- Inspection for bonding wire failures
- Inspection for ceramic capacitor cracks

#### Materials



- Material sorting/screening of metals and resins
- Inspection of fibers and bonding condition of CFRP
- Inspection of metal welds
- Inspection of wood knots

If you would like us to take X-ray images for proof of concept, or if you would like to use our lending unit for evaluation, please contact us by scanning the QR code or accessing the URL shown below.



<https://www.hamamatsu.com/all/en/support/inquiry.html>

## 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
- 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
- Applied products of semiconductor lasers
- Solid state lasers
- Laser related products

## Sales Offices

### Japan:

**HAMAMATSU PHOTONICS K.K.**  
325-6, Sunayama-cho, Naka-ku,  
Hamamatsu City, Shizuoka Pref. 430-8587, Japan  
Telephone: (81)53-452-2141, Fax: (81)53-456-7889  
E-mail: intl-div@hq.hpk.co.jp

### China:

#### HAMAMATSU PHOTONICS (CHINA) CO., LTD.

##### Main Office

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

##### Shanghai Branch

4905 Wheelock Square, 1717 Nanjing Road West,  
Jingan District, 200040 Shanghai, P.R. China  
Telephone: (86)21-6089-7018, Fax: (86)21-6089-7017  
E-mail: hpcsh@hamamatsu.com.cn

##### Shenzhen Branch

14F China Merchants Tower 1#, No. 1166 Wanghai Road,  
Shekou, Nanshan District, Shenzhen, P.R. China  
Telephone: (86)755-2165-9058, Fax: (86)755-2165-9056  
E-mail: hpcsz@hamamatsu.com.cn

##### Wuhan Branch

Room 1005 Fanyue City T2 Building, No. 19 Guanshan  
Avenue, East Lake High-tech District, Wuhan 430075,  
Hubei, P.R. China  
Telephone: (86)27-5953-8219  
E-mail: hpcwh@hamamatsu.com.cn

### Taiwan:

#### HAMAMATSU PHOTONICS TAIWAN CO., LTD.

##### Main Office

13F-1, No.101, Section 2, Gongdao 5th Road,  
East Dist., Hsinchu City 300046, Taiwan (R.O.C.)  
Telephone: (886)3-659-0080, Fax: (886)3-659-0081  
E-mail: info@hamamatsu.com.tw

### U.S.A.:

#### HAMAMATSU CORPORATION

##### Main Office

360 Foothill Road, Bridgewater, NJ 08807, U.S.A.  
Telephone: (1)908-231-0960, Fax: (1)908-231-1218

##### California Office

2875 Moorpark Ave., San Jose, CA 95128, U.S.A.  
Telephone: (1)408-261-2022, Fax: (1)408-261-2522

### Germany, The Netherlands, Poland, Denmark, Israel:

#### HAMAMATSU PHOTONICS DEUTSCHLAND GMBH

##### Main Office

Arzbergerstr. 10, 82211 Herrsching am Ammersee,  
Germany  
Telephone: (49)8152-375-0, Fax: (49)8152-265-8  
E-mail: info@hamamatsu.de

##### Netherlands Office

Transistorstraat 7, 1322 CJ Almere, The Netherlands  
Telephone: (31)36-5405384, Fax: (31)36-5244948  
E-mail: info@hamamatsu.nl

##### Poland Office

10 Ciolka Street, 126-127 01-402 Warsaw, Poland  
Telephone: (48)22-646-0016, Fax: (48)22-646-0018  
E-mail: poland@hamamatsu.de

##### Danish Office

Lautrupvej 1-3, 2750 Ballerup, Denmark  
Telephone: (45)88-74-53-10  
Email: info@hamamatsu.dk

### Israel Office (HAMAMATSU PHOTONICS ISRAEL LTD.)

Ha-Menofim 10 st., third floor, 4672561 Herzliya, Israel  
E-mail: Info@hamamatsu.co.il

### France, Switzerland, Belgium, Spain:

#### HAMAMATSU PHOTONICS FRANCE S.A.R.L.

##### Main Office

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

##### Swiss Office

Dornacherplatz 7, 4500 Solothurn, Switzerland  
Telephone: (41)32 625 60 60, Fax: (41)32 625 60 61  
E-mail: swiss@hamamatsu.ch

##### Belgian Office

Axisparc Technology, Rue André Dumont 7,  
1435 Mont-Saint-Guibert, Belgium  
Telephone: (32)10 45 63 34, Fax: (32)10 45 63 67  
E-mail: info@hamamatsu.be

##### Spanish Office

C. Argenters 4, edif 2, Parque Tecnológico del Vallés,  
08290 Cerdanyola, (Barcelona), Spain  
Telephone: (34)93 582 44 30  
E-mail: infospain@hamamatsu.es

### North Europe and CIS:

#### HAMAMATSU PHOTONICS NORDEN AB

##### Main Office

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.

##### Main Office

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

##### Rome Office

Viale Cesare Pavese, 435, 00144 Roma, Italy  
Telephone: (39)06-50 51 34 54  
E-mail: inforoma@hamamatsu.it

### United Kingdom:

#### HAMAMATSU PHOTONICS UK LIMITED

##### Main Office

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

### South Africa Contact:

9 Beukes Avenue, Highway Gardens, Edenvale,  
1609, South Africa  
Telephone/Fax: (27)11-609-0367

\* DualXTRAX and MPPC are registered trademarks of Hamamatsu Photonics K.K.

\* Information in this catalog is believed to be reliable. However, no responsibility is assumed for possible inaccuracies or omission. Specifications are subject to change without notice. No patent rights are granted to any of the circuits described herein. © 2023 Hamamatsu Photonics K.K.

\* Please thoroughly read the precautions and the prohibited uses included in the user manual before installation and use.