New Inspection Unit Optically Detects Tiny Pinhole Defects as Small as 1 μm Diameter in Plate/Sheet Workpieces
Cover Story

3 Optical Pinhole Inspection Unit C15477
   Quickly Finds Tiny Pinholes, Even as Small as 1 μm in Diameter,
   by Applying Low-light Detection Technology! Reduces the Takt Time
   (Production) for Manufacturing In-vehicle Batteries.

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   Enables Infrared Spectroscopic Analysis on the Spot.
   Palm Size Fourier Transform Spectrometer.

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www.hamamatsu-news.com
Technical designs and innovations aimed at reducing environmental impact are appearing at a rapid pace. Typical examples of these innovations are next-generation vehicles such as EV, HV and FCA. Such technological innovations continue to achieve higher performance, lower cost and more efficient mass production. It is therefore essential to deliver high-accuracy and high-speed quality control in the manufacture of batteries and power supplies as they are core parts in next-generation vehicles. Our advanced photonics technology for the detection of low-light levels, will give the vital support needed in the manufacturing process.
Optical pinhole inspection unit gives the support you need for producing core parts in this new age of EV and FCV.

Lithium-ion batteries offer large power capacity in a compact, lightweight unit and they can be recharged multiple times. These features have led to their widespread use in a variety of mobile devices. Although they are widely used, they still require extremely sophisticated manufacturing technology. This is especially true in the “cell” section that stores energy. The cell contains a flammable electrolyte that easily reacts with oxygen, making hermetic sealing essential to prevent even just gas vapors from leaking out. To ensure the sealing is complete, lithium-ion batteries and other fuel cells with similar structures must undergo 100% inspection. This factor significantly increases production costs compared to conventional rechargeable batteries such as nickel and cadmium.

Our “optical pinhole inspection unit” is a powerful tool for solving this production cost issue. It finds pinhole defects by detecting light coming through the pinholes as electrical signals using a high-sensitivity photodetector, namely a “photomultiplier tube”.

Compared to conventional methods used to identify pinholes such as a camera, our optical pinhole inspection unit offers high-speed and high-accuracy pinhole inspection. In the field of in-vehicle battery manufacturing, there is an increasing need for detecting even tinier pinhole defects, in larger and wider area workpieces. To meet these needs, our new optical pinhole inspection unit type “C15477” delivers higher sensitivity, and can inspect larger-size workpieces.

Use of a wide effective area photomultiplier tube, together with new signal processing technology, delivers high-speed detection of pinhole defects as tiny as 1 μm in diameter!

The C15477 is specifically designed for more advanced signal processing applications. It offers all the best features of our optical pinhole inspection unit, such as high accuracy, high-speed response and error monitoring function. These features, together with a wide effective area photomultiplier tube and new signal processing technology has allowed us to shrink the pinhole defect detection limit to 1 μm (one 1000th of a millimeter) in diameter. This means it can detect light from pinholes that are only one-fourth the size of pinholes detectable up to now. The C15477 is also designed to inspect large workpieces with just a single C15477 unit, therefore drastically cutting production takt time.
Main features

**Detects pinholes down to 1 μm in diameter with high accuracy!**

A light source unit periodically irradiates pulsed light onto the workpiece. Light passing through pinhole defects are detected as electrical signals. These are separated from the constant ongoing signal (noise signal) by the use of a lock-in amplifier to enhance detection accuracy. This allows accurate detection of pinhole defects as tiny as 1 μm in diameter. Therefore, the C15477 can find light leaks, even from pinholes that are only one-fourth the area of pinholes detectable up to now.

**Supports large workpieces up to 480 mm × 180 mm**

The light source unit and light collector unit are designed to process large workpieces up to 480 mm width by 180 mm depth. We also welcome requests for custom shapes and sizes.

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**Easier to use**

The amount of detectable light varies depending on the pinhole location. To minimize this variation, light passing through the pinhole is extracted from the four corners of the light collector unit. In our conventional products, four inspection units are required to detect each light signal. However, the C15477 uses a large-area photomultiplier tube that detects all light signals with just a single inspection unit. This enables easy and efficient pinhole inspections, while drastically reducing the installation space and cost.

A workpiece is sandwiched between the light source unit and light collector unit. Light passing through a pinhole defect is detected as an electrical signal. Unlike inspection methods using gases or fluids, this optical method applies no actual physical pressure to the workpiece during inspection.

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**Optical pinhole inspection setup**

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**Principle of optical pinhole inspection**

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**See page 19 to find out more about the new optical pinhole inspection unit C15477.**

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Our optical pinhole inspection units contribute to various industries and fields by utilizing features including high accuracy, high speed and no actual physical contact.

In addition to the inspection of materials in lithium-ion batteries and fuel cells, our optical pinhole inspection units are used in a broad spectrum of fields. They support a wide range of materials including metal and non-metal, transparent and non-transparent, thin and thick film. Our line-up, including custom products, will expand optical pinhole inspection applications further to include materials and parts for cans and molded packaging products. These advances in inspection technology will boost product quality to even higher levels.
FTIR Engine C15511-01


Molecules each have unique vibrations, thereby absorbing infrared light of a specific wavelength. Infrared spectroscopic analysis, which utilizes this characteristic to analyze the components contained in substances, is used in a variety of fields from scientific research to industry. FTIR, which uses infrared spectroscopic analysis, is normally the stationary type, which requires analysis to be done by bringing samples to a laboratory or specialized institution. For this reason, Hamamatsu Photonics has developed “C15511-01”, a palm-sized FTIR engine that supports near infrared light with a wavelength from 1.1 μm to 2.5 μm.

Features

To eliminate the decrease in incident light level caused by miniaturization, we used our unique MEMS technology to develop a movable mirror with a diameter of 3 mm that composes the MEMS actuator, then improved it so that the reflected light can be used efficiently.

Using our mounting technology cultivated over many years, we have integrated the movable mirror and the fixed mirror as a MEMS chip, thereby making it compact and reducing error in the relative angle between the mirrors to about 1/100.

By optimizing the structure and drive method of the MEMS actuator and eliminating shaking when in operation, we have suppressed the spread of infrared light inside the optical interferometer and reduced loss. By doing this, we have achieved detection performance comparable to previous stationary type devices.

Compactness and high accuracy achieved with MEMS technology

The “FTIR engine C15511-01” is a compact Fourier transform infrared spectroscopic module with high sensitivity to near infrared light in the range of 1.1 μm to 2.5 μm. A Michelson optical interferometer and control circuit are integrated into a palm-sized housing.

Generally FTIR features high resolution and high-speed measurement. We have made our FTIR engine more compact while retaining the features of the Fourier transform type by applying our unique MEMS technology and mounting technology to the optical interferometer.
High wavelength reproducibility

Optical interference occurs when the light being measured (incident light) is split by a beam splitter, reflected by a movable mirror and a fixed mirror, and combined again. Interference light intensity, which changes depending on the position of the movable mirror, 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 in the interferometer using a photodetector (Si PIN photodiode) and semiconductor laser (VCSEL), it is possible to obtain a optical spectrum with high wavelength reproducibility.

Measurement examples

Using FTIR engine

In the near infrared region of 1.1 μm to 2.5 μm, many substances have unique absorption spectra, and these are applied to infrared spectroscopic analysis in various fields. There are two measurement methods for infrared spectroscopic analysis using FTIR engines:

1. Reflection measurement
2. Transmission measurement

Using these measurement methods, we measured the spectra of sugar (glucose, sucrose) and alcoholic beverages (beer, sake, brandy).

Absorbance comparison of sugar

Comparing the reflection measurement results of sugar powder samples (glucose, sucrose) from the FTIR engine and from the stationary spectrometer, we found it was possible to accurately measure even minute peak patterns with the FTIR engine, similar to spectra obtained with the stationary spectrometer.

Get more information about the FTIR Engine C15511-01 on www.hamamatsu.com

* SNV (Standard Normal Variate)
Comparison of absorbance of alcoholic beverages and estimation of alcohol concentration

In the near infrared region of 1.1 μm to 2.5 μm, there is absorption by the OH group of water (1.45 μm band, 1.9 μm band) and absorption by the CH group of alcoholic beverages (2.1 μm to 2.5 μm).

With transmission measurement results, we were able to obtain characteristic spectra in the absorption bands of water and alcoholic beverages. In addition, with the results of estimating the alcohol concentration from absorbance in the 2.3 μm band, we confirmed that the estimated values and numerical values of components contained in the beverage matched, and that high accuracy measurement is possible with the stationary spectrometer.

**FTIR engines that greatly expand the potential of spectroscopic analysis**

We expect to find many applications for FTIR engines in a wide range of situations where it was difficult to make measurements in a timely manner, including pre-harvest inspection of agricultural products, soil analysis, and plastic sorting, etc. Hamamatsu Photonics will further expand the potential of infrared spectroscopic analysis through this product.

**Applications**
- Process analysis
- Material inspection
- Farm production inspection
- Plastic screening
- Concrete strength measurement
- Film thickness measurement
- Medical and healthcare equipment
Compact Near-infrared Spectroscopy Module Which Can be Installed in Portable Analysis Instruments

The C15511-01 is a compact fourier transform infrared spectrometer (FTIR) engine that integrates a Michelson optical interferometer and control circuit into a palm-sized enclosure. Spectrum and absorbance can be measured by connecting a PC via USB. It can be applied to real-time measurement performed on site without bringing the measurement sample into the analysis room. In addition, it can also be used for continuous monitoring.

**Features**
- Compact: palm size
- Optical fiber input type
- High Signal-to-Noise making it suitable for diffuse reflection, and absorbance measurements

**Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical interferometer</td>
<td>Michelson interferometer (with a built-in φ3 mm movable mirror)</td>
<td>–</td>
</tr>
<tr>
<td>Photodetector</td>
<td>InGaAs PIN photodiode</td>
<td>–</td>
</tr>
<tr>
<td>Light input method</td>
<td>Optical fiber input type** (with SMA connector)</td>
<td>–</td>
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<tr>
<td>Interface</td>
<td>USB 2.0</td>
<td>–</td>
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<tr>
<td>Dimensions (W × D × H)</td>
<td>57 × 76 × 49 (excluding protrusions)</td>
<td>mm</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>1100 to 2500 nm</td>
<td>nm</td>
</tr>
<tr>
<td>Spectral resolution (FWHM)**</td>
<td>5.7 nm</td>
<td>nm</td>
</tr>
<tr>
<td>Wavelength reproducibility</td>
<td>±0.5 nm</td>
<td>nm</td>
</tr>
<tr>
<td>Wavelength temperature dependence</td>
<td>±0.06 nm/deg. C.</td>
<td>nm/deg. C.</td>
</tr>
<tr>
<td>Signal-to-noise-ratio**</td>
<td>1000 min.</td>
<td>–</td>
</tr>
</tbody>
</table>

*1 Optical fiber A15363-01 (core diameter = φ600 µm, NA = 0.22)
*2 Equivalent to 25 cm⁻¹
*3 Ratio of the peak value of the spectrum data when light is incident to the root mean square (rms) of noise in the dark state
*4 Incident light level = 40000 counts p-p min., integration count = 512, gain setting = 1 to 4
Spectroscopic Module C15712, C15713, C15714

Compact Spectroscopic Module with MEMS-FPI Spectrum Sensor and Light Source

This compact module has a built-in light source, control circuit, and MEMS-FPI spectrum sensor consisting of an InGaAs PIN photodiode and MEMS-FPI (Fabry-Perot Interferometer) tunable filter which can vary its transmission wavelength by changing the applied voltage. Spectrum and absorbance can be measured by connecting a PC via USB.

Features
- Compact and thin: 32 (W) x 74 (D) x 16 (H) mm
- MEMS-FPI spectrum sensor and light source are installed
- External power supply not necessary: USB 2.0 bus powered
- Transmission wavelength shift due to the ambient temperature change is corrected
- High speed measurement

Applications
- Moisture detection
- Food inspection
- Farm product inspection
- Plastic screening
- Fiber identification, etc.

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>C15712</th>
<th>C15713</th>
<th>C15714</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Sensor</td>
<td>MEMS-FPI spectrum sensor</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Spectral response range</td>
<td>1350 to 1650</td>
<td>1550 to 1850</td>
<td>1750 to 2150</td>
<td>nm</td>
</tr>
<tr>
<td>Spectral resolution (FWHM)*1</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>nm</td>
</tr>
<tr>
<td>Wavelength reproducibility*2</td>
<td>±2</td>
<td>±2</td>
<td>±2</td>
<td>nm</td>
</tr>
<tr>
<td>Wavelength temperature dependence*3</td>
<td>±0.1</td>
<td>nm/deg. C.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1 When light with a line spectrum resolution (FWHM) of 3 nm max. is incident using an optical fiber (core diameter= 600 µm, NA = 0.22) and fiber adapter A15719
*2 Measured under constant light input and use conditions
*3 Topr = -5 to +50 deg. C.
C15712: λ = 1500 nm, C15713: λ = 1700 nm, C15714: λ = 1950 nm
This module detects weak Raman scattered light. It uses a mini-spectrometer equipped with a high sensitivity CMOS image sensor as the base, consists of a 785 nm semiconductor laser suitable for generation of Raman scattered light, a filter and beam splitter for separating laser light and Raman scattered light, a driver circuit, and a signal processing circuit.

**Raman Spectroscopy Module Capable of Photometry in a Wide Spectral Range**

**Differences from the previous product**

It features a temperature compensation function to stabilize the laser while maintaining the palm size of the conventional product C13560. Stable Raman measurement is possible with fewer calibrations in an outdoor environment where the ambient temperature changes significantly.

**Features**

- Built-in laser, spectrometer and driver circuit
- Compact and lightweight

**Applications**

- Environment (water quality inspection, agricultural and toxic substance inspection)
- Safety control (foreign matter checking in foods and medicine)
An electromagnetically driven mirror that incorporates our unique MEMS technology. The device was made smaller by arranging the magnet beneath the mirror and achieves two-dimensional scanning in linear mode. Electrical current flowing in the coil surrounding the mirror produces a Lorentz force based on Fleming’s rule that drives the mirror. Hamamatsu MEMS mirrors offer a wide optical deflection angle and high mirror reflectivity.

**Differences from the previous product**
With drive current, the optical deflection angle of the mirror can be accurately controlled two-dimensionally in linear mode.

**Features**
- Two-dimensional scanning in linear mode: Capable of vector scanning and step operation
- Compact, low voltage operation: Suitable for installation into devices
- Equipped with window material: Prevents foreign matter contamination
- Evaluation circuit is available: C15087 (sold separately)

**Applications**
- Machine vision
- Laser measurement
- Laser material processing
- Various laser scanning unit
These sensors measure the distance to an object by TOF (time-of-flight) method. When used in combination with a pulse modulated light source, these sensors output phase difference information on the timing that light is emitted and received. Distance data can be obtained by performing calculations on the output signal with an external signal processing circuit or on a PC.

**High Near Infrared Sensitivity Measures the Distance to an Object by TOF Method**

**Differences from the previous product**
By using a backside-illuminated structure, higher sensitivity is achieved in the near infrared region than previous products (S11961-01CR, S11962-01CR, S11963-01CR, S12973-01CT).

**Features**
- High sensitivity in the near IR region
- Improved tolerance to background light
- Small WLP* type

**Applications**
- Obstacle detection
- Security
- Shape recognition
- Motion capture
- Touchless interface

* Wafer level package

---

**Specifications**

<table>
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<tr>
<th>Parameter</th>
<th>S15452-01WT</th>
<th>S15453-01WT</th>
<th>S15454-01WT</th>
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<tr>
<td>Type</td>
<td>Linear</td>
<td>Area</td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Number of effective pixels</td>
<td>64</td>
<td>256</td>
<td>96 x 72</td>
<td>Pixels</td>
</tr>
<tr>
<td>Pixel size (H x V)</td>
<td>20 x 50</td>
<td>50 x 50</td>
<td></td>
<td>μm</td>
</tr>
<tr>
<td>Pixel pitch</td>
<td>20</td>
<td>50</td>
<td></td>
<td>μm</td>
</tr>
</tbody>
</table>

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**Spectral response**

(Ta = 25 deg. C.)
CMOS Area Image Sensor
S15683-12

This product has an APS (active pixel sensor) type CMOS area image sensor and USB interface, built into a compact housing. The fiber optic plate (FOP) covering the image sensor provides 1 million Gy of radiation resistance, in order to protect the image sensor from X-rays.

### Features
- High resolution
- Compact
- Low cost
- USB interface

### Applications
- Non-destructive inspection
- X-ray focal point observation

### Specifications

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<tr>
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<th>Specification</th>
<th>Unit</th>
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<tr>
<td>Photosensitive area (H x V)</td>
<td>26 x 34</td>
<td>mm</td>
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<tr>
<td>Pixel size (H x V)</td>
<td>20 x 20</td>
<td>µm</td>
</tr>
<tr>
<td>Number of effective pixels (H x V)</td>
<td>1300 x 1700</td>
<td>Pixels</td>
</tr>
<tr>
<td>Radiation tolerance (60 kV)</td>
<td>1,000,000</td>
<td>Gy</td>
</tr>
<tr>
<td>X-ray tube voltage</td>
<td>20 to 90</td>
<td>kV</td>
</tr>
</tbody>
</table>

### Imaging example

- Dry battery
- Earphone

X-ray Non-destructive Inspection Sensor Connecting to PC via USB
CMOS linear image sensors developed for close contact optical systems. These long photosensitive area image sensors with CMOS chips arranged in a row, enable high sensitivity and high-speed readout in a wide range.

**Features**
- Effective photosensitive area length: 194.97 mm (1536 pixels): S11720-20 390.04 mm (3072 pixels): S11720-40
- Pixel size: $127 \times 127 \, \mu m$ (200 dpi)
- High-sensitivity: 40800 V/lx-s (gain = 8)
- High-speed readout: 45.4 klines/s
- SPI communication function
- Built-in 16-bit A/D converter

**Applications**
- Film inspection
- Printed circuit board appearance inspection
- Print inspection
- Industrial line scan camera

**Long Photosensitive Area Image Sensors with CMOS Chips Arranged in a Single Row**
This CMOS linear Image sensor has achieved a readout speed of 40 MHz max. and a line rate of 34 kHz max. The Image sensor has a timing generator, bias generator, 12-bit A/D converter, and is easy to handle because of its digital I/O.

### Features
- **Pixel size:** 7 (H) µm × 200 (V) µm
- **1024 pixels**
- **Effective photosensitive area length:** 7.168 mm
- **High-speed readout:** 40 MHz max.
- **Simultaneous integration of all pixels**
- **Variable integration time function** (electronic shutter function)

### Applications
- Encoders
- Position detection
- Machine vision

### 40 MHz Operation, Digital Output

The CMOS linear Image sensor has a timing generator, bias generator, 12-bit A/D converter, and is easy to handle because of its digital I/O.
This 16-element APD array achieves high sensitivity and low-bias operation in the short-wavelength region. The gap between the elements is small (60 µm), enabling a compact package. It is also possible to arrange and use multiple products.

**Features**
- Gap between elements is small: 60 µm
- Small variation between elements
- Low-bias operation: 160 V typ.

**Applications**
- Flow cytometer
- Particle measurement

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**Si APD Array S15249**

**High Short-wavelength Sensitivity**

**Surface Mount Type 1 × 16 ch APD Array**

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**Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Package</td>
<td>COB (chip on board)</td>
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<tr>
<td>Dimensions (W × D × H)</td>
<td>13.2 × 4.5 × 1.65</td>
<td>mm</td>
</tr>
<tr>
<td>Photosensitive area (per element)</td>
<td>0.7 × 2.0</td>
<td>mm</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>350 to 1000</td>
<td>nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength**</td>
<td>620</td>
<td>nm</td>
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<tr>
<td>Breakdown voltage**</td>
<td>160</td>
<td>V</td>
</tr>
<tr>
<td>Cutoff frequency**</td>
<td>100</td>
<td>MHz</td>
</tr>
</tbody>
</table>

*1 M = 50  
*2 I₀ = 100 µA  
*3 M = 50, λ₀ = 450 nm, R_L = 50 Ω

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**Spectral response**

(Typ. Ta = 25 deg. C., M = 1)
This is a backside-illuminated type Si photodiode that has achieved high reliability against ultraviolet light. It exhibits low sensitivity deterioration under UV light irradiation and is suitable for applications such as monitoring intense UV light sources. It is designed with minimal dead space around the product making it possible to arrange multiple products side by side.

**Features**
- High sensitivity in UV region: 
  \[ \text{QE} = 75\% \ (\lambda = 200 \text{ nm}) \]
- High UV tolerance
- Compatible with lead-free solder reflow

**Application**
- Monitoring UV light source
- Atmosphere analyzer etc.

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**Back-illuminated Si Photodiode with CSP* Structure and High UV Tolerance**

* Chip Size Package
Optically Detects Tiny Pinhole Defects as Small as 1 μm in Diameter in Plate/Sheet Workpieces

The C15477 is designed to detect pinhole defects as small as 1 μm in diameter in large plate/sheet workpieces and does all this quickly with just a single unit. A light source unit irradiates light on a workpiece. A light collector unit efficiently collects the light passing through the pinhole defects in the workpiece. This is then detected as an electrical signal by the photomultiplier tube, which is a highly sensitive photodetector, making it easier and more accurate to find even tiny pinhole defects in the workpiece. Compared to other methods for detecting pinholes, such as the use of fluids or gases, this optical method applies no actual physical pressure to the workpiece during inspection. The C15477 will improve inspection accuracy and speed for tasks such as inspecting pinhole defects in fuel cell separators for fuel cell vehicles, aluminum laminate films for pouch rechargeable batteries, and pressed thin plates.

**Features**
- High-accuracy and high-speed detection
- Non-contact inspection
- Custom design available to match workpiece size

**Applications**
- Fuel cell separators
- Aluminum laminate films for pouch rechargeable batteries
- Pressed thin plates

**Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum detectable pinhole size</td>
<td>1 μm</td>
<td></td>
</tr>
<tr>
<td>Detection area</td>
<td>480 x 180 mm</td>
<td></td>
</tr>
<tr>
<td>Input voltage (DC)</td>
<td>24 V</td>
<td></td>
</tr>
<tr>
<td>Current consumption</td>
<td>0.5 A</td>
<td></td>
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</tbody>
</table>

**Optical pinhole inspection setup**

**Principle of optical pinhole inspection**

- **No pinhole**
  - Light source unit
  - No light passes through pinhole

- **Pinhole defect**
  - Light source unit
  - Light passes through pinhole

*Sold separately*
Photosensor Module
H15460-40

Delivers a Wide Field-of-view and High Resolution in Two-photon Excitation Microscopy

The H15460-40 is a photosensor module which employs a GaAsP photocathode with high sensitivity in the visible region. It has a wide photosensitive area of 14 mm × 14 mm and a built-in amplifier which delivers low noise and high speed operation.

Features
- Large effective area: 14 mm × 14 mm
- High sensitivity: GaAsP photocathode
- Low noise, high frequency bandwidth amplifier used

Application
- Two-photon excitation microscopy

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Effective area</td>
<td>14</td>
<td>mm</td>
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<tr>
<td>Spectral response range</td>
<td>300–740</td>
<td>nm</td>
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<td>Frequency bandwidth (-3 dB)</td>
<td>DC–30 MHz</td>
<td>–</td>
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<tr>
<td>Current-to-voltage conversion factor</td>
<td>0.02</td>
<td>W/uA</td>
</tr>
<tr>
<td>Ripple noise (peak to peak) (max.)</td>
<td>1</td>
<td>mV</td>
</tr>
</tbody>
</table>

Size comparison

- H15460-40: Effective area 14 mm × 14 mm
- Conventional type: Effective area φ5 mm

Spectral response (typ.)

Ripple noise (typ.)
Head-on Type Photomultiplier Tube R3550P-600

NEW ELECTRON TUBE PRODUCTS

The R3550P-600 is a 25 mm diameter head-on photomultiplier tube developed for use in photon counting applications. Compared to a bialkali photocathode photomultiplier tube (R1924P) with the same shape, the R3550P-600 is low noise and designed to minimize the noise increase, even when the ambient temperature rises, allowing stable operation up to 70 deg. C. In addition, when compared to our previous product (R3550P) with a low-noise bialkali photocathode, the quantum efficiency of the R3550P-600 is enhanced by 80% (increased from 18% to 33% at 375 nm). The R3550P-600 will improve accuracy in low-light-level measurement applications, while maintaining low-noise performance.

Features
- High sensitivity
- Low noise
- Less noise increase even at higher temperatures
- Stable operation up to 70 deg. C.
- High vibration and shock resistance

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>R3550P-600</th>
<th>R1924P</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photocathode type</td>
<td>Low noise super-bialkali</td>
<td>Bialkali</td>
<td>–</td>
</tr>
<tr>
<td>Anode dark count at 25 deg. C.  (typ.)</td>
<td>30</td>
<td>100</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>Anode dark count at 37 deg. C.  (typ.)</td>
<td>50</td>
<td>350</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>Maximum operating temperature</td>
<td>70</td>
<td>50</td>
<td>deg. C.</td>
</tr>
<tr>
<td>Vibration resistance</td>
<td>200</td>
<td></td>
<td>m/s²</td>
</tr>
<tr>
<td>Shock resistance</td>
<td>1000</td>
<td></td>
<td>m/s²</td>
</tr>
</tbody>
</table>

Spectral response

Applications
- Chemiluminescence measurement
- Biomedical fluorescence measurement
- Hygiene monitor
- Level gauge
High Speed Gated Image Intensifier Unit C14245

The C14245 series consists of an image intensifier (I.I.), a high-voltage power supply circuit and a gate drive circuit, all in a compact cubic housing. The unit easily connects to the body of most large-sized high-performance cameras, which has been difficult for our previous product (C9546 series) with an L shape configuration. The lens mount, C or F, can be selected to meet the application needs.

Features
- Compact and lightweight: 100 mm (W) × 100 mm (H) × 45 mm (D)
- Cubic shape easily connects to camera
- Available with three spectral response ranges from UV to near IR
- Excessive light protection included
- C-mount and F-mount easily exchangeable

Application
- Discharge observation
- Observation of invisible phenomena in UV and near IR regions
- Observation of high-speed phenomena
- Observation of low light emissions under microscope
- Cell observation by fluorescence
- Night surveillance

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photocathode type</td>
<td>Multialkali</td>
<td></td>
</tr>
<tr>
<td>GaAsP</td>
<td>GaAs</td>
<td></td>
</tr>
<tr>
<td>Spectral response range</td>
<td>185 to 900</td>
<td>nm</td>
</tr>
<tr>
<td>280 to 720</td>
<td>370 to 920</td>
<td></td>
</tr>
<tr>
<td>Input/output faceplate size*</td>
<td>18</td>
<td>mm</td>
</tr>
<tr>
<td>Image intensification (typ.)</td>
<td>1MCP 1.1 × 10⁴</td>
<td></td>
</tr>
<tr>
<td>2MCP 2.2 × 10⁴</td>
<td>4.0 × 10⁴</td>
<td>(lm/m²)/lx</td>
</tr>
<tr>
<td>Limiting resolution (typ.)</td>
<td>1MCP 64</td>
<td>Lp/mm</td>
</tr>
<tr>
<td>2MCP 57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Type with 25 mm diameter is also available.

Imaging example

UV visualization: Discharge due to insulation failure
Photocathode: Multialkali

C14245 imaging

Visible image

Insulation failure point
Discharge
A Perfect Fusion of Low Noise and High Quantum Efficiency

The ORCA®-Fusion BT is a digital CMOS camera that adopts the latest Backside-illuminated sensor. By increasing the quantum efficiency while maintaining the low readout noise characteristic of the ORCA®-Fusion, the S/N (signal-to-noise), has been dramatically improved. The ORCA®-Fusion BT demonstrates high performance not only in low light areas but also in bright areas.

Features
- Low readout noise: 0.7 electrons (rms)
- High QE: 95% @ 550 nm
- Large field of view:
  2304 pixels × 2304 pixels (5.3M pixels),
  sensor with diagonal dimension of 21.176 mm
- High resolution:
  Pixel size 6.5 μm × 6.5 μm

Applications
- Wide-field fluorescence microscopy
- Time-lapse live cell imaging
- Lightsheet microscopy
- Super resolution microscopy
- Synchrotron radiation imaging

S/N comparison of scientific CMOS cameras

The S/N of ORCA®-Fusion BT has dramatically improved by increasing the quantum efficiency while maintaining the low readout noise characteristic of ORCA®-Fusion.

S/N × 1.16
Gen II BSI camera

S/N × 2.32
Gen III sensor

ORCA®-Fusion BT

Low noise × High QE

Time-lapse live cell imaging by low light excitation

By suppressing the excitation light that causes phototoxicity and photobleaching, long-term observation in living cells has been made possible.

Sample: H9c2, Objective lens: Apo TIRF 60XC (NA1.49), ND: 8, Interval: 15 sec

Nucleus:
HCS NuclearMask
Stains / Exposure 20 ms

Mitochondria:
Mito Tracker / Exposure 500 ms

Membrane:
CellMask Plasma Membrane stains / Exposure 500 ms
**NEW LASER PRODUCTS**

**Pulsed Fiber Laser**  
L15187

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**Features**
- Independent control of pulse width and repetition rate  
- High beam quality  
- Linear polarization  
- Fiber-out type

**Applications**
- Surface modification  
- Marking  
- Thin film removal  
- Cutting  
- Laser CVD

---

**Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1064</td>
<td>nm</td>
</tr>
<tr>
<td>Average output power</td>
<td>30</td>
<td>W</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>80–200</td>
<td>kHz</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
<td>–</td>
</tr>
<tr>
<td>Polarization direction</td>
<td>Vertical</td>
<td>–</td>
</tr>
<tr>
<td>Pulse width</td>
<td>200–700</td>
<td>ns</td>
</tr>
</tbody>
</table>

**Processing example 1**

Material: Polyimide film  
Pulse width: 50 ns*

* Pulse width: 50 ns is custom-made.

**Processing example 2**

Material: SUS  
Pulse width: 50 ns

---

Nanosecond pulsed fiber laser which is linearly polarized achieving high reliability. Since independent control of pulse width and repetition rate is possible, processing conditions can be set for various kinds of applications.

In addition, pulse time waveforms can be set to the default.
Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1064</td>
<td>nm</td>
</tr>
<tr>
<td>Pulse energy</td>
<td>8</td>
<td>mJ</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>Singleshot to 10*</td>
<td>Hz</td>
</tr>
<tr>
<td>Pulse width</td>
<td>&lt;2</td>
<td>ns</td>
</tr>
<tr>
<td>Cooling method</td>
<td>Air cooling</td>
<td>–</td>
</tr>
<tr>
<td>Remarks</td>
<td>Built in laser driver (DC+24 V / Max. 2 A)</td>
<td>–</td>
</tr>
</tbody>
</table>

* By inputting a trigger signal externally via TTL, the laser is output from the single shot to 10 Hz range.

Example of coal-ash fuel content detection test (Applications for LIBS)

The measurement of elemental compositions of Fe, Si, Ca, Al and C which are main components of coal, coal ash, steel slag and etc.

Data courtesy of Prof. Yoshihiro Deguchi (Faculty of science and engineering, industry, graduate school of society, Tokushima University)

Pulsed Solid State Laser Built-in Laser Driver
Ideal for LIBS Light Sources

This is a simple, low-cost and high-output pulsed solid state laser light source that incorporates a laser control unit such as an optical pulse generator and a thermal control circuit.

It can be used as the light source for various kinds of analytical instruments (LIBS, etc).

Features
- Low power consumption
- Simple handling
- Rugged design

Applications
- Light source for analytical instruments
- Range Finder
- Ablation
The Most Suitable Sub-Nanosecond Pulsed Laser for Micro Processing

A passively Q-switched laser with short pulse and high beam quality, suitable for a wide variety of micro material processing applications.

Applications
- Micro processing (dicing, drilling)
- Surface modification (repair)

Features
- Sub-nanosecond pulse
- High repetition, variable repetition rate
- Built-in feedback function
- Compact
- High robustness

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>L15776-01</th>
<th>L15776-02</th>
<th>L15776-03</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>266</td>
<td>532</td>
<td>1064</td>
<td>nm</td>
</tr>
<tr>
<td>Repetition rate**1, 2</td>
<td>50</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>Pulse width**1, 2</td>
<td>0.35</td>
<td>0.5</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Pulse energy**1, 2</td>
<td>23</td>
<td>66</td>
<td>110</td>
<td>µJ</td>
</tr>
<tr>
<td>Dimensions (W × H × D)</td>
<td>410 × 215 × 403</td>
<td>365 × 215 × 360</td>
<td></td>
<td>mm</td>
</tr>
</tbody>
</table>

*1 Average value over 1 minute during operation at a repetition rate of 50 kHz.
Repetition rate can be varied in steps from a single shot to (50,000/n) Hz (n = 1, 2, ..., 50000).
*2 In L15776-01, if the actual value deviated from this specification due to long-term use, the characteristics can be recovered by manual shifter or temperature adjustment.