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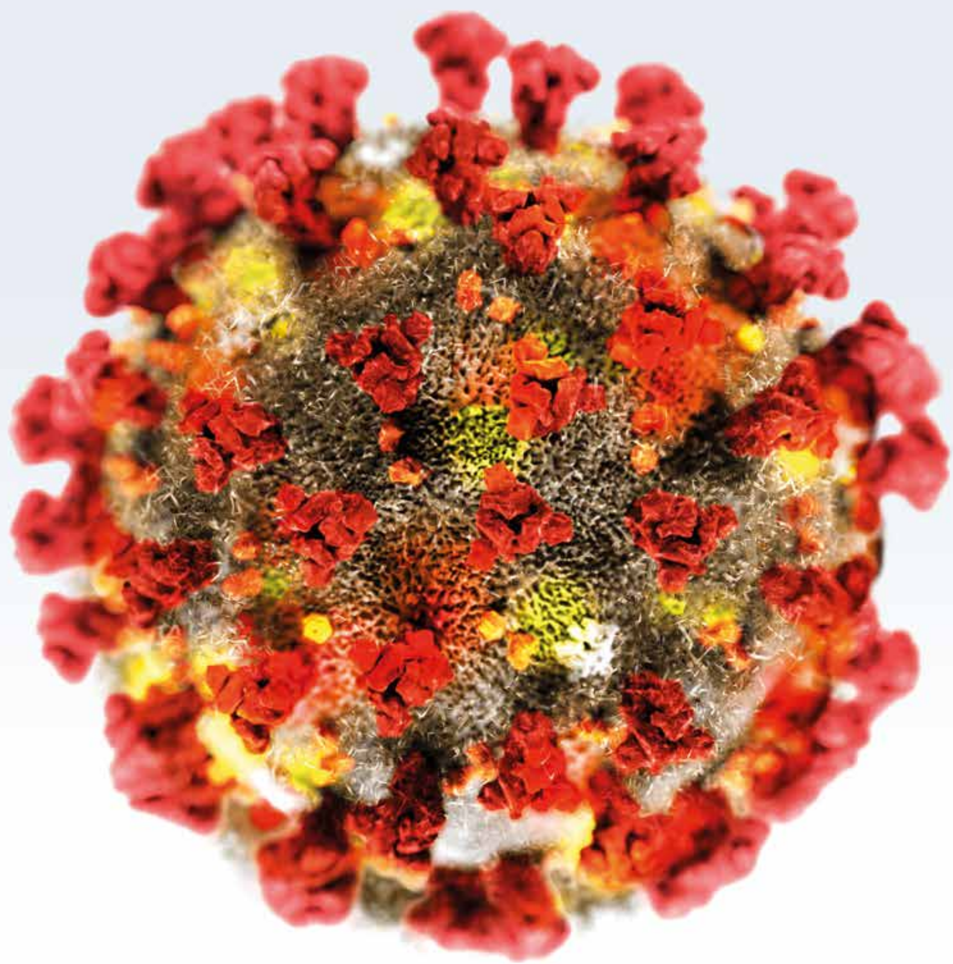

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Photonics and the Fight Against Covid-19

Techniques such as PCR and medical imaging are vital in the fight against the coronavirus, which rely on the continued supply of components by manufacturers such as Hamamatsu Photonics

The novel coronavirus (Sars-Cov-2) continues to spread across the world, impacting everything from daily life to the global economy. In these challenging times, the healthcare sector plays a particularly important role. In addition to protective clothing, respiratory masks and respirators, the ability to test rapidly and accurately is vital. However, rapid testing demands the availability of various laboratory analysers. Meeting the demand for analytical instruments requires that manufacturers continue production, to ensure the continuous supply of critical components across the world. Hamamatsu Photonics is part of the supply chain for products and devices used in the fight against the virus. Our products are integrated into many laboratory analysers and we also work closely with point of care diagnostic manufacturers to develop new instrumentation for rapid testing.

But never forget: The safety and well-being of our employees is our top priority. We are monitoring the guidance of the World Health Organisation and other public health bodies closely, and are taking appropriate measures to provide our employees with a safe and healthy working environment.

How to fight the virus?

Researchers around the globe are striving to develop an effective vaccine against Sars-Cov-2, but this still requires time. To combat the further spread of the coronavirus efficiently, immediate detection of the virus is of crucial importance. The aim is to reduce the chain of infection and thus the infection rate. But to identify who is and who is not infected requires that as many tests as possible are performed. Tedros Adhanom Ghebreyesus, head of the World Health Organisation (WHO), famously said during a press conference in March: ‘Test, test, test’.

Rapid tests and test analysers

To test thousands of people, thousands of rapid tests are required, which in turn calls for great numbers of analytical devices for their evaluation. One common analysis method of these devices is the polymerase chain reaction (PCR). This method is widely used in molecular biology to amplify the patient’s DNA.

How does the PCR test work?

First, a smear is taken from the patient’s mouth, nose or throat. This sample is then sent to a laboratory. Each virus can be identified by a specific characteristic sequence of its genetic material. However, the quantity of the genetic material from the smear must be multiplied in order for there to be sufficient material to determine whether the pathogen is present or not. For this purpose, so-called thermocyclers are used, which initiate the polymerase chain reaction. In 30 to 50 cycles, the DNA is amplified exponentially. If the pathogen is present in the sample, its genetic material will amplify and will be detected. If there is no genome of the pathogen, it will not go through the multiplication process and therefore not be detected. Using a fluorescence dye, the amplification of the pathogen genome can be monitored in real time. This is called real-time PCR. It usually takes several days before the patient receives the test result. To send the sample to the laboratory takes the longest time, the test itself takes up to five hours.

Hamamatsu Photonics has decades of expertise in the development and manufacture of optical technologies. Several manufacturers of laboratory devices choose Hamamatsu Photonics for products such as photomultiplier tubes (PMTs), photodiodes and cameras that allow the optical detection of the target DNA sequence. We are proud to supply our products to manufacturers of laboratory analysers all over the world that are contributing to fighting the virus.

Medical imaging as a further diagnostic tool

Severe cases of Covid-19 are associated with pneumonia, which can lead to changes in lung tissue. As a further diagnostic tool of coronavirus, medical imaging techniques such as computed tomography (CT) and conventional radiography of the thorax are used. Changes of lung tissue are visible in the images obtained through these methods. In some cases, the pneumonia associated changes of lung tissue are already visible despite the test results of PCR being negative. With computed tomography or thorax x-rays, the severity of the disease can be assessed and the clinical indication in severe cases monitored.

Compared to PCR, an advantage of medical imaging is that the results are available immediately. On the other hand, ionising radiation is used in CT and X-Ray, so the health benefit for the patient must outweigh the radiation risk. Hamamatsu Photonics’ contribution in the field of x-ray detection is apparent by a portfolio of suitable x-ray detectors, which it supplies to numerous medical equipment manufacturers around the globe.

Ambient Light Sensor Calibration with Tunable Light Sources

High resolution, high brightness light sources drive profitability in manufacturing of spectral sensors

As worldwide production of smartphones now exceeds 1.5 billion units per year, premium brands focus on advancing core functionality to win market share. Ambient light sensors play a key role in display quality, camera performance, and battery life.

Ambient light sensor calibration

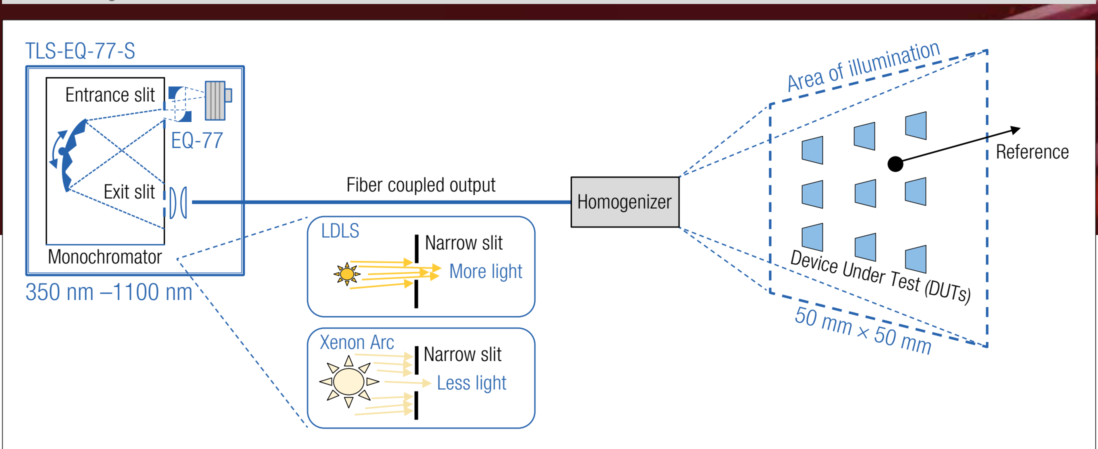


Figure 1: A tunable broadband source is used to calibrate ambient light sensors.

Contribution of ambient sensors to smartphone performance

Did you know that the backlight of an LCD display accounts for approximately 40 % of the overall power consumption of a mobile device? There are typically at least two ambient light sensors at work to extend the battery life of a device by adjusting the display brightness.

Ambient light sensors, also referred to as color or spectral sensors, are simple, low-cost components that have a disproportionately large impact on the performance of high-end smartphones.

These sensors are responsible for turning off the display when a user raises their device to their ear for a call and are used to control the brightness of the smartphone display to optimize the user's experience based on the level of ambient light present.

Another important function of ambient light sensors in smartphones is white color balance for the display and onboard camera. The smartphone relies on a sensor to correct the white balance, ensuring great images regardless of lighting conditions.

Ambient light sensor calibration procedure

The calibration process of high-quality sensors requires illumination with narrow bands of monochromatic light that match the spectral range of the sensors.

The sensors are comprised of a small number of photodiodes (3-12) with optical coatings that each transmit a different wavelength band of light. The response of each sensor is compared to a reference measurement from a spectrometer to evaluate unit-to-unit variation. An example calibration setup, featuring the TLS-EQ-77-S Laser-Driven Tunable Light Source (LDTLS™), is shown in figure 1.

High resolution source increases process throughput
The high spectral radiance of Energetiq's Laser-Driven Light Source, around which the LDTLS product was designed, enables lots of light to be coupled through a narrow monochromator slit. This provides a unique combination of narrow-bandwidth and high in-band light flux. For accurate calibration, the bandwidth of light illuminating the sensors must be narrow enough to provide the required spectral resolution.

While the bandwidth of the monochromatic light source is a critical parameter for the accuracy of the calibration, it is the in-band light flux that drives process efficiency, throughput, and profitability.

Read more by visiting
www.energetiq.com/sensorcalibration

Read more
For a more in-depth explanation, please read our app note titled "Ambient Light Sensor Calibration with Tunable Light Sources".

Additional benefits of LDTLS
The high light throughput of the LDTLS is not the only benefit for ambient light sensor calibration. The table below highlights several additional benefits.

Laser-Driven Light Source/LDTLS features	Benefits
High radiance	High in-band light flux enables high process throughput
High spatial stability of plasma	Consistent output for accurate measurements
Long-term light flux stability	Consistent output for accurate measurements
Convenient fiber-coupled output	Ease of integration
Infrequent maintenance	9000 hours between bulb replacements (4× longer than xenon bulbs)

"Triode MCP Assembly" Overturns the Accepted View of What a Microchannel Plate (MCP) Can Do!

Making mass spectrometry a handy and easy-to-use tool by approaching issues from a different angle!

Ion detector with high gain and stable operation even in low vacuum environments!

A completely new and innovative device for ion detection has been developed for use in mass spectrometers that are commonly used to identify substances. It is an MCP assembly designed with a unique triode structure and it overturns the generally accepted view "an MCP cannot be used at low vacuum levels." Using a detector that operates at low vacuum levels, it will eliminate the need for preparing large vacuum pumps for mass spectrometers allowing downsizing and cost reduction of the equipment. As just one of the promising applications, this new MCP assembly is already getting attention as a portable explosive trace detector for airport security.

We talked to two people involved in developing and marketing this new MCP assembly. Let's hear what they have to say.

(Left) Masahiro Hayashi
Manuf. #5, Electron Tube Division

(Right) Joji Sakakiyama
Business Planning Management
Business Headquarters

"An MCP cannot be used at low vacuum levels." This is a generally accepted view that has proven to be a barrier until now.

Firstly, let me ask both of you "What exactly is mass spectrometry?"

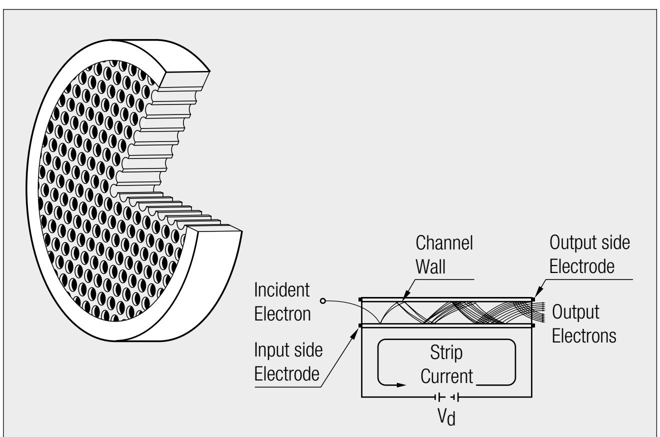
Sakakiyama: Mass spectrometry is an analytical technique used to identify and quantify a substance by ionizing the atoms and molecules of the substance, measuring the mass-to-charge ratio and the number of ions.

Hayashi: What makes mass spectrometry special is its capability to detect even trace amounts of a substance. For example, let us suppose the Tokyo Dome (baseball stadium) is filled with water and a tiny amount of salt on the tip of a toothpick is dissolved in that water. Mass spectrometry has the extremely high sensitivity needed to detect the salt within all that water.

What are the features of the triode MCP assembly you have newly developed for mass spectrometry?

Sakakiyama: A typical MCP consists of a multitude of micro glass capillaries fused together and sliced into a thin plate less than 1 mm thick (see figure 1). When electrons pass through each capillary, or channel, they are multiplied by secondary emission.

Figure 1: Structure of a typical MCP



Hayashi: Our Company developed MCPs about 40 years ago. At that time the MCP had been mainly used for night-vision goggles, that enabled viewing of clear images even in darkness. In night-vision goggles, faint light is converted into electrons at the photocathode and the electrons multiplied in individual MCP channels, which are then reconverted into light.

The MCP then started to be used in mass spectrometry, right?

Hayashi: Yes, the MCP is known to be sensitive not only to light, but also to ions. Moreover, since the sensitive area of the MCP can be enlarged, it has started to be used as an ion detector for time-of-flight (TOF) mass spectrometry.

Sakakiyama: However, the current theory is that the MCP is unusable at vacuum levels lower than 10^{-4} Pascals. Since atmospheric pressure is 10^{5} Pascals, this means the MCP could only be used at high vacuum levels, where the number of molecules and atoms contained in the atmospheric air are reduced to less than one billionth.

Is this generally believed to be true?

Sakakiyama: Yes, it is. When our customers use a conventional MCP, we still ask them to use it at vacuum levels higher than 10^{-4} Pascals. Meanwhile, for many years, we have had customers saying: "I really wish I could use an MCP at lower vacuum levels."

Why do the customers want to use the MCP at lower vacuum levels?

Hayashi: To increase the vacuum levels, the air in the equipment must be sufficiently evacuated. This usually takes a long time and requires a large vacuum pump. When using a typical MCP, a high voltage of 1 kV is usually applied across a glass plate less than 1 mm thick. If the vacuum level is not high enough, the residual gases will cause electrical discharge leading to malfunctions.

Sakakiyama: So, for these customers who wanted an MCP detector that operates at lower vacuum levels, our new MCP will make their lives easier.

What do you mean by "making it easier"?

Sakakiyama: For example, it will shorten the vacuum evacuation time required for the equipment to be operational.

Hayashi: The MCP assembly we have developed is intended for use in compact desktop mass spectrometers, which usually use a small vacuum pump. This means the vacuum level that can be obtained is relatively low.

Sakakiyama: Ion detectors have been the bottleneck in developing a desktop mass spectrometer with satisfactory performance, as they were unusable at low vacuum levels. There were market needs for such a compact, portable and low cost mass spectrometer and our new triode MCP assembly makes this now a reality.

> Our triode MCP assembly is a breakthrough that delivers high gain (multiplication factor) even at low vacuum levels.

Are your competitors taking the same approach?

Sakakiyama: On our competitor's websites, we see ion detectors with low vacuum levels, but they use a different method from ours.

How does your triode MCP assembly differ from competitors' products in terms of performance?

Hayashi: Our triode MCP assembly can be used at vacuum levels one to two orders of magnitude lower than our competitors. Our customers, who have tested our new product in their own equipment, have verified this.

Sakakiyama: As the operating vacuum level of the detector decreases, the required capacity of the vacuum pump also decreases. This is very important because the size and cost of mass spectrometers is dependent upon the vacuum pump capacity. Another feature of our triode MCP assembly is that it still maintains high gain (multiplication factor) even when used at low vacuum levels.

Hayashi: Yes, it exhibits a high gain of 10^6 to 10^7, even in operation at low vacuum levels. In contrast, rival products can only achieve lower gain and still at higher vacuum levels. (Figure 2).

What are the benefits of using a detector with high gain?

Hayashi: The gain of the detector is an important factor that affects the analytical sensitivity of mass spectrometers. As we mentioned at the beginning of this interview, a great feature of mass spectrometry is that it can identify trace substances. The higher the gain of the detector, the more accurate and quicker the measurement will be, even when the amount of ions is small. This also increases the throughput or processing speed.

Sakakiyama: Since our newly developed triode MCP assembly can be used at low vacuum levels, it will help reduce the size and cost of mass spectrometers, making them more portable. What's more, the high gain operation will sharply boost the processing speed.

> We changed our approach to "controlling" the generated ions rather than "suppressing" ion generation.

Therefore, your triode MCP assembly has solved a big problem posed by conventional mass spectrometry. How did you succeed in using it at low vacuum levels without lowering the gain?

Hayashi: As shown in figure 3, an ordinary MCP assembly has a biplanar structure consisting of a two-stage MCP and a signal readout electrode called the anode. When ions enter the MCP they are converted to electrons, which are multiplied and finally collected by the anode as an output signal. When the vacuum level is low, residual gas molecules and atoms remaining in the vacuum system react with the electrons from the MCP that causes the generation of positive residual gas ions.

So, those generated ions are not needed?

Hayashi: That's right. When residual gas ions are generated, they move back toward the MCP via an electric field, which is the opposite direction of electrons moving to the anode. This is called

Figure 2: Vacuum level and gain

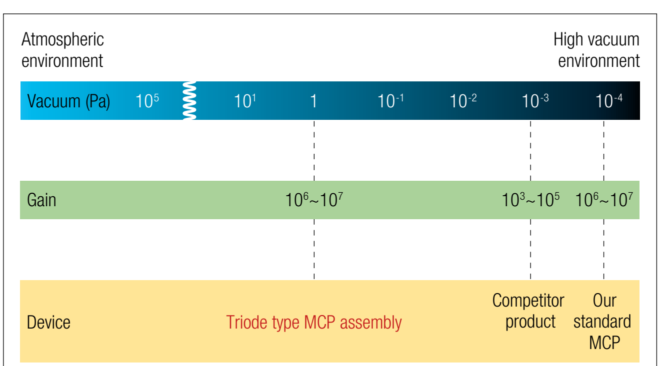
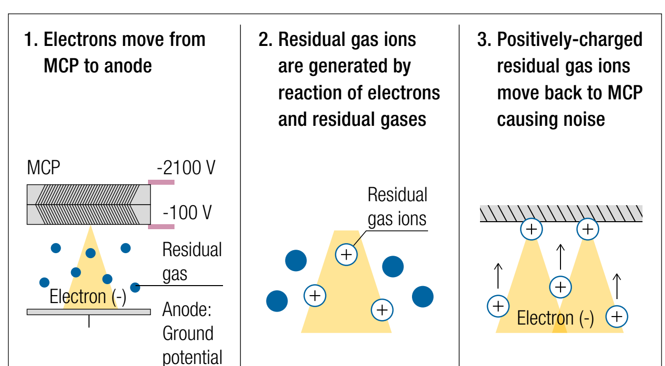


Figure 3: Biplanar structure and ion feedback mechanism

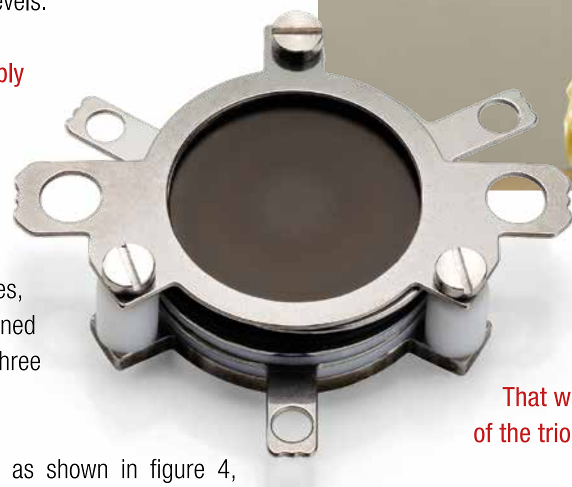


"ion feedback" (in figure 3). When ion feedback occurs, the residual gas ions collide with the channel walls of the MCP and cause the emission of electrons. These electrons are then multiplied in the MCP channel walls generating noise signals. If these noise signals increase, they will disturb and degrade the high sensitivity and accuracy of the measurements required for mass spectrometry.

Sakakiyama: For this reason, most users have until now believed "MCPs cannot be used at low vacuum levels."

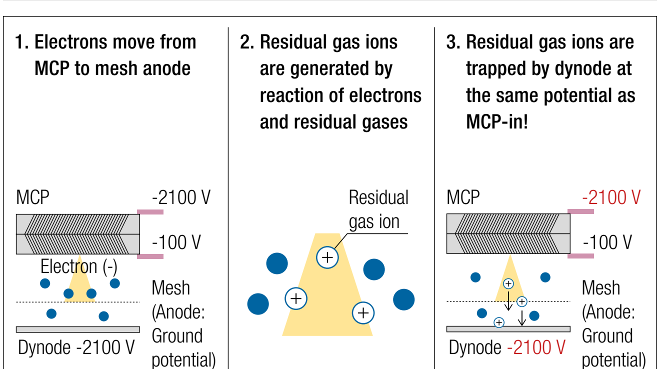
Therefore, your new triode MCP assembly has "broken the mold"?

Sakakiyama: Yes, in contrast to the biplanar structure which comprises of two electrodes, MCP and anode; the triode MCP assembly has three electrodes, MCP, mesh anode and dynode. We coined the name "triode" from 'tri' meaning three and 'electrode'.



Hayashi: In the triode MCP assembly as shown in figure 4, the MCP input side is at the same potential as the dynode. This means that if residual gas ions are generated, they are trapped by the dynode while passing through the mesh anode. Meanwhile the output signal is detected by a mesh anode placed between the MCP and the dynode. During the initial stages, we tried hard to suppress the generation of ions caused by the residual gases reacting with electrons, but the lower the vacuum level, the greater the number of ions generated. We eventually gave up and had to admit that it was impossible to suppress the generation of ions. We thought it would be better to try to control the generated ions rather than to suppress the generation of ions. We finally found a solution utilizing the potential gradient in the triode MCP assembly.

Figure 4: Triode structure



Triode structure is also a space-saver.

That was a terrific idea, but where did the idea of the triode structure come from?

Hayashi: A triode structure had already been employed in vacuum tube transistors. Inserting a mesh or grid as the third electrode is a well-known technique. About 10 years ago, our senior engineers had already applied the triode structure to an MCP to enhance the signal output speed.

Let us take a look at the actual triode MCP assembly. It is smaller than I thought!

Sakakiyama: This product has an effective diameter of 14.5 mm. Previously made samples include those with a smaller effective diameter of 7 mm.

Hayashi: Our MCP is a very small device. Most competitors' products are relatively large compared to the MCP and their detectors are even larger after assembly. In contrast, the MCP itself is a thin plate of around 0.5 mm thick and even when two MCPs are stacked, the total thickness is only 1 mm. In addition, the distance from the MCP to the mesh anode is at the millimeter scale. Therefore, the overall size of the triode assembly, complete with the electrodes, is a thickness of around 7 mm. After taking the space-saving benefits into account, I believe the triode structure is the ideal approach. Our new triode MCP assembly delivers a space-saving package, high gain and stable operation at low vacuum levels. I do not think there are any other techniques that can simultaneously deliver all these features.

Try its performance, it goes beyond and breaks boundaries!

How are sales going at present?

Sakakiyama: We first introduced this new triode MCP assembly at the ASMS (American Society for Mass Spectrometry) annual conference, the world's largest conference on Mass Spectrometry. Using connections established at that conference our sales promotion activities are currently for customers in the United States and European countries.

Hayashi: The greatest feature of the triode MCP assembly is that it can be used at low vacuum levels and is ideal for use in compact desktop mass spectrometers. So the main market is industries that manufacture small, compact mass spectrometers, so called 'miniature MS'. Our triode MCP assembly is also suitable for large-scale mass spectrometers however MCP assemblies with higher specifications are normally used, typically with higher gain and speed. This is due to the high vacuum conditions needed by the detector in such large-scale mass spectrometers.

Tell me about the future prospects for this triode MCP.

Sakakiyama: Some customers have already decided to use our new triode MCP assembly for Mass Spectrometry based explosive trace detectors. We expect it to deliver a much greater performance compared to current technology employed by the homeland security market.

Hayashi: Other potential applications include inspecting for residual pesticides in agricultural products, animal and plant quarantine stations and in healthcare, checking for health conditions from the exhalation of human breath. The equipment becomes affordable, it has the potential for use in point-of-care-testing for the early detection of disease. Family health checks could be made at home and the data sent to the hospital. There are various technical issues to be addressed, for example, how to operate it at even lower vacuum levels and to further reduce the size so that the equipment is more portable and easy to carry.

Sakakiyama: As the long-accepted view is "an MCP cannot be used at low vacuum levels" even when we emphasized this to our customers, they did not immediately believe it. However, when our customers tested our new triode MCP assembly they discovered its incredible performance. Therefore, we are eager for our customers to evaluate our product and see the high performance and advantages for themselves.

Application example of a triode MCP assembly

Ion mobility mass spectrometry has been the mainstream for explosive trace detectors used at airport security. However, it suffers from false detection errors and only detects a limited number of compound types. Equipment using our triode MCP is the first mass spectrometer Trace Detector which offers the benefits of both reducing false detection errors and boosting processing speed.

For further information see page 24

SiPM Technology Increases the Safety of Charged Particle Therapy through Improved Beam Range Verification

Abstract

In charged particle therapy, it is of great importance to monitor the range of the ion beam within patients to guarantee the safety and effectiveness of the treatment. An innovative bi-modal system based on Hamamatsu MPPC Silicon Photo Multipliers (SiPM) technology was developed to monitor range variations and check compliance with the planned treatment. The system is based on the detection of the secondary radiation emitted by nuclear interactions of the beam with the patient's body. The system, named INSIDE, is the result of a collaboration between the Universities of Pisa, Sapienza Roma, Torino, Bari Polytechnic, the National Institute for Nuclear Physics (INFN), Historical Museum of Physics and the Enrico Fermi Study and Research Center (CREF), the Center of Oncological Hadrontherapy (CNAO). The INSIDE system is now undergoing clinical trials at CNAO.

Introduction

Charged particle therapy (CPT), or hadrontherapy, is an advanced radiotherapy technique that uses accelerated proton or carbon ion beams to treat solid tumors with extreme precision. Charged particles release most of their energy at the end of their path (in the region called the Bragg peak) which is dependent on the energy of the particles. This property allows healthcare staff to target cancer cells very specifically, significantly reducing the dose to the surrounding healthy tissue. To verify that the treatment has been delivered according to plan, instruments indirectly measure the position of the Bragg peak in a process called "beam range verification".

The most widely used approach for proton CPT is Positron Emission Tomography (PET). This technique measures the activity of the positron emitting radionuclides produced by the nuclear interactions between the beam and the traversed tissue. In carbon ion therapy, Interaction Vertex Imaging (IVI) is a promising technique but it is so far clinically unexplored. IVI exploits the production of secondary charged particles upon the nuclear fragmentation of carbon ions in tissue. The charged fragments, emitted at almost the same velocity of the primary ion, exit the patient and pass through a tracking system that reconstructs their emission point and provides information of the primary ion beam's range.

INSIDE (INnovative SolutIons for Dosimetry in hadronthErapy) [1] is an innovative beam range verification system based on the complementary information provided by two different detection systems, a PET scanner and an IVI system called a dose profiler (DP). The INSIDE detector technology is based on inorganic scintillating crystals (for the PET detector) and scintillating fibers (for the DP detector), with read-outs based on Hamamatsu MPPC SiPMs.

SiPMs have many properties that make them ideally suited for such a demanding application. Because of their small size and flexibility when designing the sensor, it is straightforward to build a detector configuration optimized for the constraints on the patient set-up and on that beam. The pixel dimension can be adjusted during manufacture to set the desired spatial resolution of ~2 mm. SiPMs have a fast response time which, when coupled with the appropriate electronics read-out scheme, means that data can be processed at the rates on the order of hundreds of kHz. Finally, SiPM technology is fully compatible with the safety requirements of a treatment room, as no high voltages are needed.

The first phase of the INSIDE project, which focused on the development of the two detectors, was carried out between 2013 and 2016. Patient experimentation and clinical studies represent the second phase of the INSIDE project. These took place in one of the three CNAO treatment rooms where the two detectors have been installed on a movable cart that can be positioned next to the patient bed without interfering with the treatment beam (figure 1). The third phase of the project is full clinical trials.

Figure 1: The INSIDE system in the CNAO treatment room.

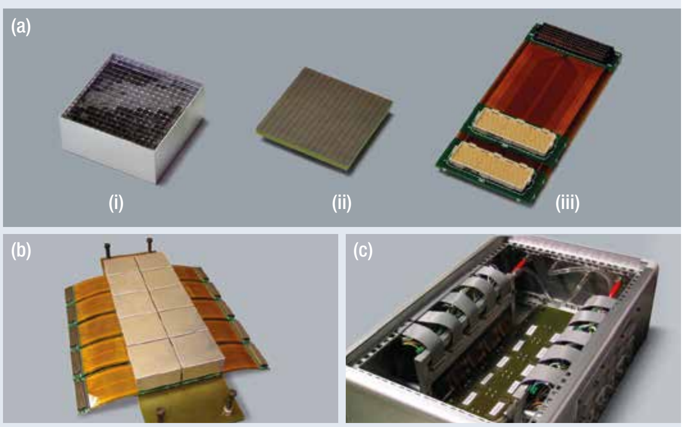


Figure 2:
(a) (i) LSF crystal array, (ii) SiPM array and (iii) hybrid rigid-flex circuit for connection to front-end electronics.
(b) 10 detection modules assembled in a 2 × 5 array (PET head).
(c) Aluminum box hosting the PET head with details of the modules placement (on the backside), front-end boards on the sides and cooling pipes.

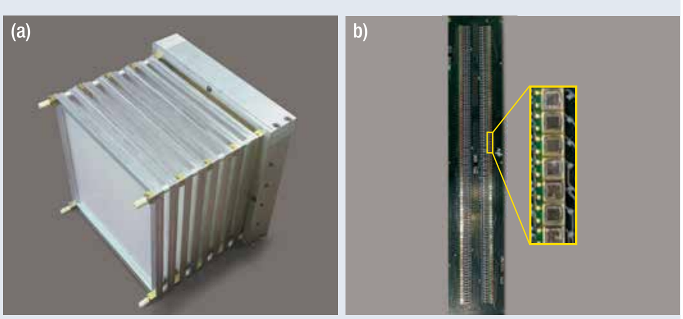


Figure 3:
(a) Picture of the DP layers showing the fibers fixed to the aluminum frame.
(b) Picture of a SiPMs board.

Detector

The INSIDE PET detector is made of two planar heads placed 60 cm apart, above and below the patient bed with the treatment room isocenter in the center of them (figure 1). Each head (figure 2) is composed of a 2 × 5 array of detection modules developed by Hamamatsu (model S12642-1616-3577(X)). The heads are enclosed in a 0.5 mm thick aluminum case and have a total area of 112 mm (transaxial) × 264 mm (axial, along the beam direction). Each of the detector modules in the heads have an array of 16 × 16, 3 × 3 × 20 mm lutetium fine silicate (LFS) crystals. The LFS array is optically coupled to a matching array of MPPC SiPMs with a microcell size of 50 μm. A rigid-flex electronics board for connecting to the front-end electronics makes up the final element of the detector modules. Each module has an area of 51.2 × 51.2 mm.

The INSIDE DP detector (figure 3) is made of 8 scintillating fiber stereo-layers, fixed in place with an aluminum frame, that allow reconstruction of the track to extrapolate the emission points of protons exiting the patient. The DP planes are made of 500 × 500 μm multi-cladding scintillating fibers, which are measured with Hamamatsu MPPC SiPMs (model S12571-050P) with a 1 mm^2 active area. Each SiPM is coupled to two fibers. 384 fibers make a plane whose active area is 19.2 × 19.2 cm. The DP is placed 50 cm from the treatment room isocenter and is tilted at 60 degrees with respect to the beam direction (figure 1). The inter-plane distance is 2 cm.

All detector channels for both systems are processed by custom integrated front-end electronics and highly parallelized data acquisition systems based on field programmable gate arrays (FPGAs). Two independent cooling systems stabilize the detectors temperature by means of circulating refrigerated water.

Performance

The INSIDE system has been installed and tested at CNAO with their clinical beams. Its performance was assessed in several measurement campaigns.

Following the pulsed time structure of the CNAO beam, the PET system was operated both during the actual delivery of the beam spill (single event count rate of 20 MHz) and during the interval between two consecutive spills. The coincidence time resolution (CTR) is 450 ps and the coincidences are calculated on the fly after applying a time window of 2 ns. The PET image reconstruction was done with a fast MLEM iterative algorithm whose output is provided with a small delay of a few seconds with respect to the actual beam spill. This is a short enough time to allow treatment interruption in case of a detected error in the beam range. The INSIDE PET detector has been successfully used to monitor a patient with a lacrimal gland tumor in two consecutive treatment sessions [2].

The DP has a detection efficiency of ~ 90 % and is therefore capable of performing fragment tracking at up to 100 kHz [3]. The fragment tracking is performed using a tracking algorithm based on the Hough transform. The 3D coordinates of the fragment production point were calculated using the point of closest approach (PCA) of the track to the incoming beam direction. The backtracking resolution is of 7 mm at 50 cm from the isocenter.

A clinical trial totaling 20 patients (10 with proton beams and 10 with carbon ion beams) with selected head and neck or brain pathologies has been carried out to test the effectiveness and potential clinical benefits of an on-line treatment verification device [4]. First results are shown in figure 4.

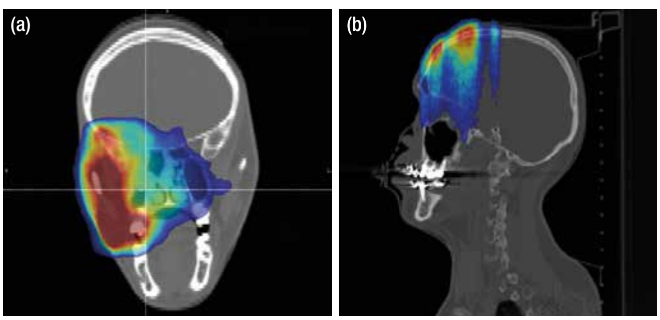


Figure 4:
(a) **PET image superimposed to the CT of a patient treated with proton beams (coronal view).**
(b) **PCA map superimposed to the CT of a patient treated with carbon ions (sagittal view).**

Conclusions

Presented here is the first bi-modal system for treatment range monitoring in charged particle therapy. INSIDE is able to simultaneously acquire and process annihilation photons and charged nuclear fragments thus providing a robust tool for bream range verification.

The first clinical results suggest INSIDE's suitability for acquiring data within a treatment fractions with both modalities. The stability and reproducibility of the system also allows us to compare data from different fractions, thus providing longitudinal beam monitoring of the entire treatment cycle.

Hamamatsu MPPC SiPM technology proved to be instrumental to the successful integration of the INSIDE system in a clinical setting and makes it the ideal solution for multi-modal on-line beam range verification in charged particle therapy.

Acknowledgements

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Authors

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ORCA-Fusion C14440-20UP, Digital CMOS Camera for Scientific Measurement

Significantly Increased S/N in the Weak Light Region from a Unique Viewpoint

New-generation CMOS camera for scientific measurement

CMOS cameras for scientific measurement (sCMOS cameras) are used at the forefront of Life science research, from molecules to cells, tissues, and individuals. In the past in order to improve the performance of sCMOS cameras, it has been thought that improving the “Quantum Efficiency” (QE), which converts light into electrons, is the most appropriate method. Hamamatsu Photonics, however, has shown a new path to the evolution of sCMOS cameras with a unique approach that focuses on “reducing readout noise.” We will introduce our new-generation sCMOS cameras, ORCA-Fusion.

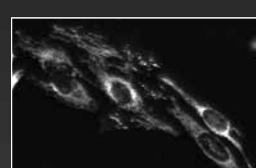
Contributing to the development of sciences in various areas through detection technology for ultra-weak light areas

Live cell imaging, which observes the activity of live cells in real time, is an essential tool for life science, such as developing new pharmaceuticals and conducting genetic researches. To support this development, we have been researching fluorescence observation methods and cameras for scientific measurement that accurately capture a small amount of light. The origin of Hamamatsu Photonics scientific measurement cameras was in the 1960s, when we released our first Measurement TV camera system.

Above all, sCMOS cameras, which are suitable for imaging in weak light areas, are ideal for observing living cells due to minimizing light damage to living organisms and have become indispensable for research in the life science field. In 2010, we launched the first generation sCMOS camera, ORCA-Flash 2.8, ahead of the world. In the weak light area that has been cultivated over many years since then, we have developed ORCA-Flash 4.0, the sCMOS camera that combines sensor and circuitry technologies, and moved to the second generation. This technology has also contributed greatly to the development of the Nobel Chemical Prize “Super-Resolution Microscopy Technology,” which was awarded by Dr. Betzig, Dr. Hell, and Dr. Moerner et al. in 2014.

Achieved 2 × S/N compared to conventional models by pursuing low-noise

While live cell imaging technology has been developed, further improvement in the signal-to-noise ratio (S/N) of images has become a major challenge. In biological observations, the light sensitivity of the camera is closely related to the progress of research. If we can observe with less light with less excitation light, we can reduce phototoxicity and fluorescence fading, which makes it possible to observe over a longer period of time. There are two main approaches to making sCMOS cameras more sensitive: improving QE and reducing readout noise. Up to now, it has generally been considered that improving QE is the most effective way to achieve high sensitivity. However, the weaker the light, the greater the effect of noise on the signal-to-noise ratio. Hamamatsu Photonics has therefore developed a new dedicated sensor specifically designed for low readout noise and has succeeded in significantly reducing readout noise while keeping QE intact by combining its proprietary circuit technology. As a result, the S/N ratio is increased to the highest 2 ×, the image quality is greatly improved by suppressing the variation between pixels, and the frame rate is improved by shortening the exposure time. By further improving the basic performance of the camera, it can be expected to be applicable for a wider range of applications.



Mitochondria of HeLa Cells stained with fluorescent dyes (Imaging by ORCA-Fusion)

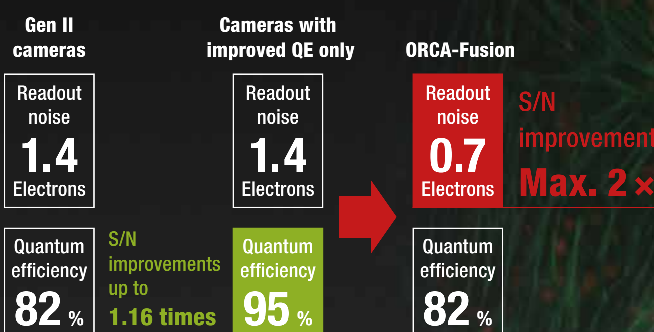
HISTORY

Hamamatsu Photonics cameras for scientific measurement	2010 FIRST-GENERATION ORCA-Flash 2.8	2011 SECOND-GENERATION ORCA-Flash 4.0	2018 THIRD-GENERATION ORCA-Fusion
Number of pixels	2.8 M pixels 1920 (H) × 1440 (V)	4.2 M pixels 2048 (H) × 2048 (V)	5.3 M pixels 2304 (H) × 2304 (V)
Frame rate	45.4 frames per second	100 frames per second	89.1 frames per second
Readout noise	3 electrons rms	1.4 electrons rms	0.7 electrons rms

Main features

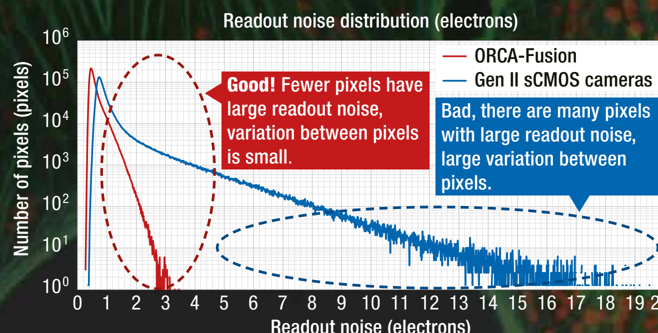
Low readout noise 0. 7 electrons rms

The new approach of “reducing read noise” realizes a readout noise of 0. 7 electrons rms, which is ½ of the conventional one. As a result, we have achieved a signal-to-noise ratio of up to 2 ×.



Acquires highly uniform images

Drastic decrease of pixel-to-pixel variation eliminates the need for image correction, which was previously essential, making it suitable for quantitative measurement.

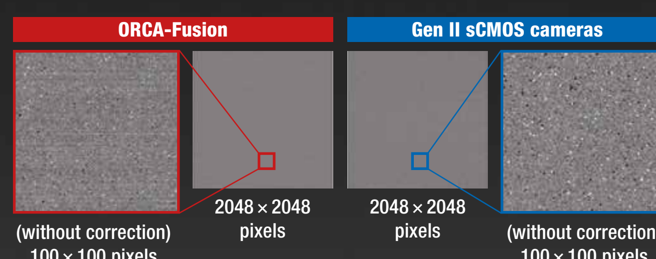


Imaging simulation example: ultra-low light fluorescence live cell imaging

Examples of images captured by each camera are shown according to the number of incident photons.

* The Gen III shows the new sCMOS camera and the Gen II shows the old sCMOS camera.

Comparison of dark images between ORCA-Fusion and Gen II sCMOS cameras



2 × faster frame rate in Light Sheet Mode

Equipped with Light Sheet Mode (patented), similar to the previous ORCA-Flash 4.0. It achieves high-speed processing at 100 frames per second, which is 2 × compared to the same vertical pixel count.

Target is Multi-Photon Counting

With the new approach of reducing readout noise, the potential of sCMOS cameras is once again expanding. The ultimate goal is to realize a camera that can detect multiple photons simultaneously with the accuracy of detecting each photon. Hamamatsu Photonics is pursuing further reduction of readout noise together with improving QE, which is a conventional method, to realize the products that meet the needs of a wider range of customers than ever before.

Type II Superlattice Infrared Detector P15409-901

Compound Opto-semiconductor that Can Detect up to 14.5 μm World's First Mass Production without Using Substances Restricted by the RoHS Directive

Hamamatsu Photonics is actively engaged in environmental conservation activities and in the pursuit of environmentally friendly manufacturing. We have contributed to the preservation of the global environment, the reduction of environmental burden and have been developing products with the impact on the environment always in mind. As a compound opto-semiconductor device capable of detecting up to 14.5 μm, the world's first "Type II superlattice infrared detector," was successfully mass produced without using substances restricted by the RoHS Directive*1, is one such product that reflects our efforts.

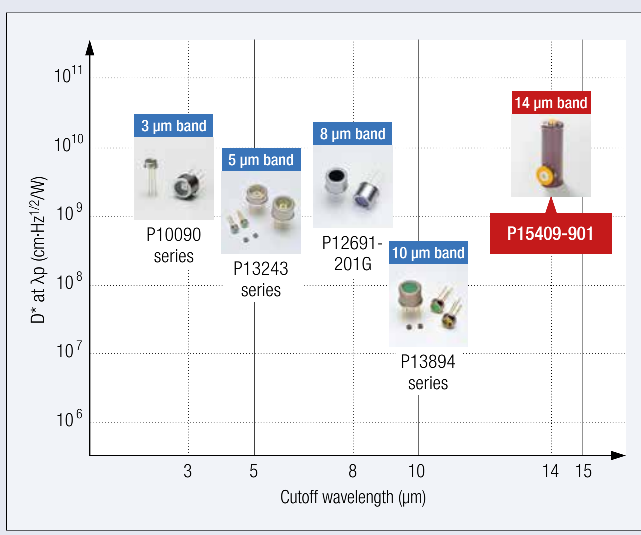
Mid infrared spectrophotometers that are required to comply with RoHS Directives

Spectrophotometry is an analysis method in which substances contained in liquids and gases are identified by using the property that the ratio of light emission and absorption varies depending on the bonding state of molecules and atoms.

The Fourier transform infrared spectrophotometer (FTIR) is used in a wide variety of fields such as food, agriculture, and medical care because it covers a wide range of absorption bands of organic substances existing near 14 μm.

However, many mid infrared detectors used in FTIR have elements containing mercury and cadmium, which are regulated by an EU RoHS Directive, so there was a need to develop an alternative product. Therefore, we have been developing infrared detectors that can detect up to the 14 μm band, which was not possible with conventional InAsSb*2 photovoltaic detectors.

Hamamatsu infrared detector lineup



Mass production of Type II superlattice infrared detectors

Until now, Hamamatsu has developed and sold InAsSb photovoltaic detectors that can detect up to 11 µm.

In the past, Type II superlattice infrared detectors have been considered as a way of detecting mid infrared light with a wavelength longer than 11 µm, but there was a problem in mass production because it required high manufacturing technology. So, we solved the manufacturing problems by using the crystal growth technology of compound opto-semiconductor devices cultivated over many years and achieved the world's first mass production of Type II superlattice infrared detectors.

Spectral response

More analytical instruments without restricted substances

Infrared wavelengths are not only used in FTIR but also in a wide range of other applications, such as gas component analysis and object temperature measurement. Such analytical instruments and measuring instruments may also use detectors containing substances restricted by the RoHS Directive. Replacing those detectors with this product will eliminate the use of restricted substances and achieve higher accuracy.

*1 The RoHS Directive is an EU ban on the use of certain hazardous substances in electrical and electronic equipment. It prohibits the sale of electrical and electronic equipment that contains more than a specified concentration of the restricted substances in the EU market.

*2 InAsSb: In (indium), As (arsenic), Sb (antimony)

*3 GaSb: Ga (gallium), Sb (antimony)

*4 MCT (HgCdTe): Hg (mercury), Cd (cadmium), Te (tellurium)

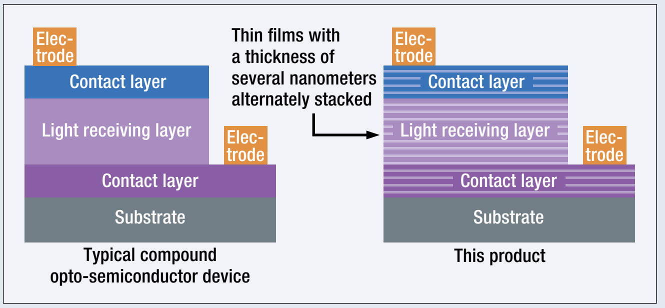
Main features

Hamamatsu's unique manufacturing technology made mass production possible

Unlike typical opto-semiconductors, the main feature of this product is the "superlattice" structure in which thin films of InAs and GaSb*3 compounds, each with a thickness of several nanometers, are alternately stacked to more than 2000 layers.

Mass production was achieved by precisely controlling the amount and timing of stacking InAs and GaSb to the substrate using Hamamatsu's unique compound semiconductor technology and optimizing temperature, pressure, and other conditions to establish a manufacturing method.

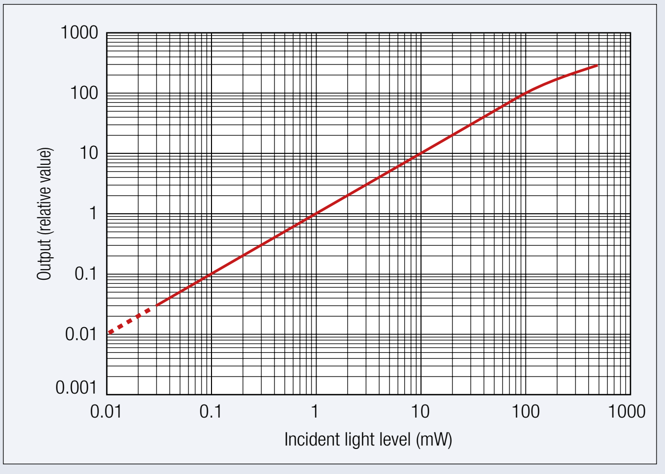
Structure differences



Excellent output linearity

Another main feature of this product is the output linearity up to a higher incident light level compared to the MCT*4 and other conventional detectors. The wide dynamic range can be expected to increase the precision of analyzers.

Linearity



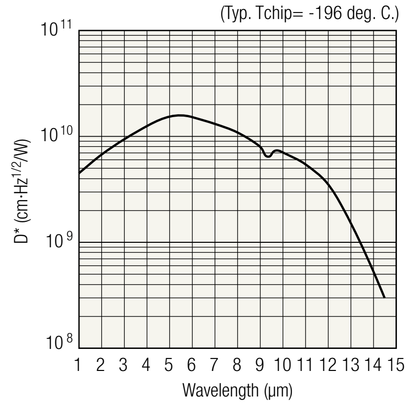
Type II Superlattice Infrared Detector P15409-901

Specifications

Parameter	Specification	Unit
Cooling	Liquid nitrogen	–
Photosensitive area	ϕ0.1	mm
Cutoff wavelength*1	14.5	µm
Peak sensitivity wavelength	5.4	µm
Photosensitivity*2	2.6	A/W
Shunt resistance*3	2.5	kΩ
Terminal capacitance*4	50	pF
Detectivity*5	1.6×10^{10}	$cm \cdot Hz^{1/2}/W$
Noise equivalent power*2	5.5×10^{-12}	$W/Hz^{1/2}$

*1 Wavelength at which signal/noise = 1
*2 $\lambda = \lambda p$
*3 $V_R = 10$ mV
*4 $V_R = 0$ V, f = 1 MHz
*5 $\lambda = \lambda p$, fc = 1200 Hz, Δf = 1 Hz

Spectral response



High-sensitivity, High-speed Response Infrared Detector with Sensitivity up to 14 µm Band

The P15409-901 is a Type II superlattice infrared detector whose sensitivity has been expanded to the 14 µm band using Hamamatsu unique crystal growth techno-logy and process technology. This product is an environmentally friendly infrared detector and does not use mercury or cadmium, which are substances restricted by the RoHS Directive. This is a replacement for conventional products that contain these substances.

Differences from the previous product

The cutoff wavelength has been extended to approximately 14 µm (longer than the previous MCT photovoltaic detector).

Further, linearity has been improved significantly.

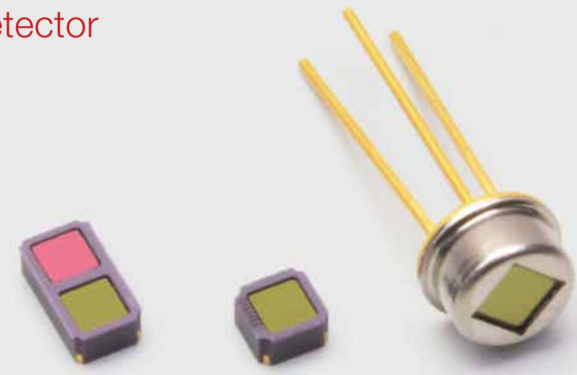
Features

- Metal dewar package (liquid nitrogen cooling)
- High sensitivity
- High-speed response
- Excellent linearity

Applications

- FTIR
- Gas analysis
- Radiation thermometers

InAsSb Photovoltaic Detector P13243 Series (with Band-pass Filter)



Two-element type
P13243-015CF
P13243-016CF

Ceramic type
P13243-033CF
P13243-039CF
P13243-043CF

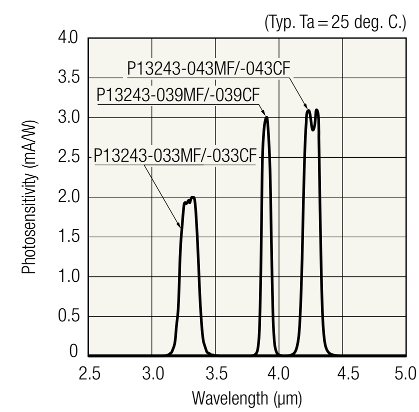
Metal type
P13243-033MF
P13243-039MF
P13243-043MF

Specifications

Type no.	Center wavelength (nm)	Spectral response half width (nm)	Photosensitivity*1 (mA/W)	Detectivity*2 (cm·Hz$^{1/2}$/W)
P13243-033CF/-033MF	3300	160	2.3	5.1×10^8
P13243-039CF/-039MF	3900	90	3	6.5×10^8
P13243-043CF/-043MF	4260	140	3.1	6.9×10^8
P13243-015CF	3300	160	2.3	5.1×10^8
	3900	90	3	6.5×10^8
P13243-016CF	3900	90	3	6.5×10^8
	4260	140	3.1	6.9×10^8

*1 λ = CWL (center wavelength), uniform irradiation on the entire photosensitive area
*2 λ = CWL, fc = 1200 Hz, Δf = 1 Hz

Spectral response



Infrared Detectors with a Band-pass Filter (3.3/3.9/4.26 μm)

These are InAsSb photovoltaic detectors that employ a band-pass filter for the window. Three types are available with different band-pass filter center wavelengths for various applications: 3.3 μm (CH_4), 3.9 μm (reference light), 4.26 μm (CO_2). These are environmentally friendly infrared detectors and do not use lead, mercury, or cadmium, which are substances restricted by the RoHS Directive. These are replacements for conventional products that contain these substances. In addition, a two-element type (P13243-015CF/-016CF), which can detect two wavelengths, is available.

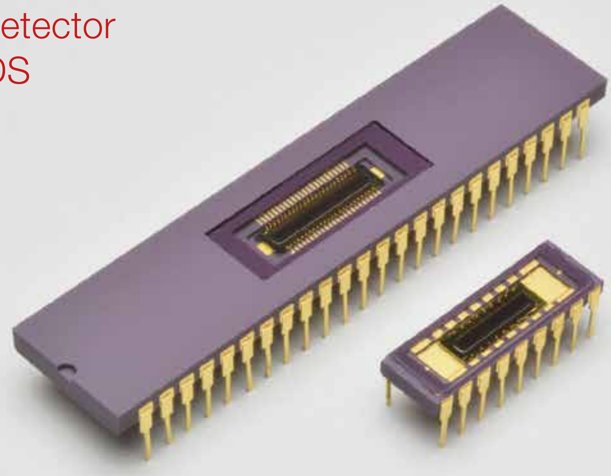
Features

- High sensitivity
- High-speed response: 15 ns
- High shunt resistance: 300 kΩ
- Compatible with to lead-free solder reflow

Applications

- Gas detection (CH_4, CO_2)
- Flame detection

InAsSb Photovoltaic Detector P15742-016DS/-046DS



Specifications

Parameter	P15742-016DS	P15742-046DS	Unit
Cooling	Non-cooled		–
Element size	0.45 × 0.7 (× 16 ch)	0.2 × 0.7 (× 46 ch)	mm
Element pitch	0.5	0.25	mm
Cutoff wavelength	5.3		μm
Peak sensitivity wavelength	3.5		μm
Photosensitivity*1	7.0	14.6	mA/W
Shunt resistance*2	100	60	kΩ
Detectivity*3	1.0×10^{9}		$cm \cdot Hz^{1/2}/W$

*1 $\lambda = \lambda p$ *2 $V_R = 10$ mV *3 $\lambda = \lambda p$, fc = 1200 Hz, Δf = 1 Hz

Photodiode Array with Sensitivity up to the 5 μm Band for Simple Spectrophotometry

These are 16 ch/46 ch InAsSb photodiode arrays that can detect up to the 5 μm band. Low crosstalk has been achieved by adopting a back-illuminated structure.

Differences from previous products

Like the InAsSb photovoltaic detector P13243 series, these are an array type with a 5 μm band cutoff wavelength. The wavelength is longer than that of the conventional InGaAs photodiode array G12430-016D/-046D.

Features

- High sensitivity
- 16 ch/46 ch array
- Back-illuminated structure: Low crosstalk

Applications

- Radiation thermometers
- Infrared spectrometer

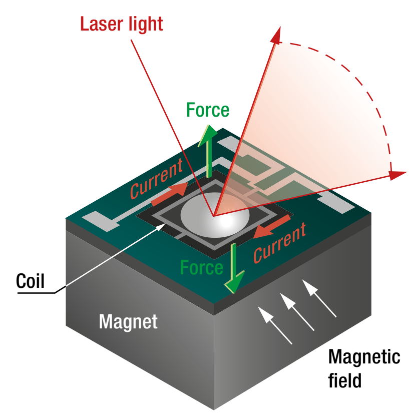
MEMS Mirror
S13989-01H

Lineup

Parameter	S12237-03P	NEW S13989-01H
Appearance		
Type	For 1D scanning	For 2D scanning
Scan mode	1-axis linear scan	2-axis raster scan
Mirror size (material)	ϕ2.6 mm (aluminum)	ϕ1.23 mm (aluminum)
Optical deflection angle	±15°	Fast axis: ±20° Slow axis: ±12°
Drive frequency	100 Hz max.	Fast axis: 29.3 kHz typ. Slow axis: 100 Hz max.
Recommended operating temperature	-20 to +70 deg. C.	-20 to +60 deg. C.

Structure and principle

It employs a drive method that uses an electromagnetic actuator. When a current is run through the coil in the magnetic field of the magnet, Lorentz force is generated according to the Fleming's rule, tilting the mirror. In addition, the mirror can be driven two-dimensionally with the combination of two springs formed by MEMS processing.



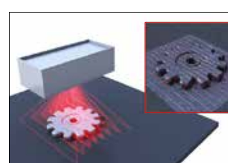
Miniature, High Performance Electromagnetically Driven MEMS Mirror for 2D Laser Scanning

This is an electromagnetically driven mirror that incorporates our unique MEMS (micro-electro-mechanical systems) technology. With two-axis operation (X axis and Y axis), 2D scanning (raster scanning) becomes possible using reflections of laser light or the like. Typically, electro-magnetically driven mirrors have magnets arranged around the mirror chip, but Hamamatsu MEMS mirrors have a strong compact magnet arranged underneath the mirror chip. It achieves a wide optical deflection angle (fast axis: ±20°, slow axis: ±12°). In addition, it features high reliability owing to the hermetic seal package, low voltage operation, and linear operation that allows the optical deflection angle to be set as you like.

Features

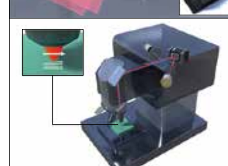
- Compact
- Wide optical deflection angle
- Low voltage operation:
  - Suitable for installation with equipment
- High reliability:
  - Hermetic seal package
- Linear operation possible (S12237-03P, slow axis of S13989-01H)
  - Optical deflection angle can be set as you like

Application examples



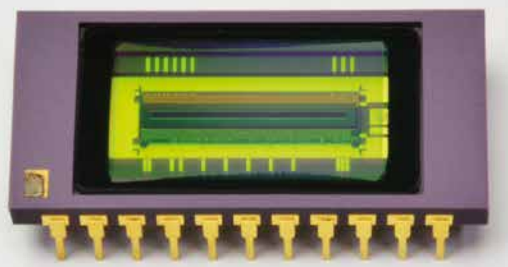
Machine vision

Laser ranging



Laser microscope

InGaAs Linear Image Sensor G14714-1024DK

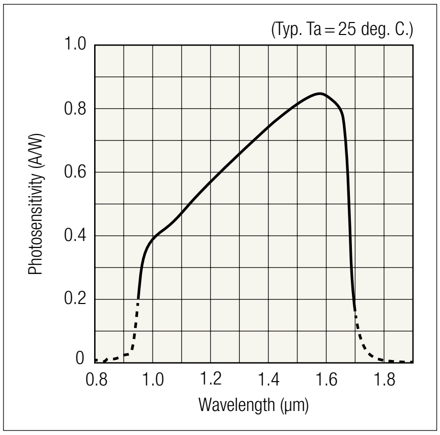


Specifications

Parameter		Specification	Unit
Pixel size (H × V)		12.5 × 12.5	μm
Pixel pitch		12.5	μm
Number of effective pixels		1024	pixels
Spectral response range		0.95 to 1.7	μm
Conversion efficiency	Cf = 1.25 pF	0.128	μV/e-
	Cf = 0.13 pF	1.23	
	Cf = 0.04 pF	4.0	
	Cf = 0.02 pF	8.0	
Dark current*1		0.5	pA
Readout noise*2		1.2	mV rms
Clock frequency		15 max.	MHz

*1 CE = 8.0 μV/e-
*2 CE = 1.23 μV/e-

Spectral response



1024 Pixels, High-speed Line Rate Near Infrared Sensor (0.95 to 1.7 μm)

The G14714-1024DK is an InGaAs linear image sensor designed for foreign object detection. The CMOS chip consists of charge amplifiers, shift registers, and a timing generator. Charge amplifiers are configured with CMOS transistor array and are bump-bonded to each pixel of the InGaAs photodiode array. Since the signal from each pixel is read out in charge integration mode, high sensitivity and stable operation are attained in a wide spectral response range.

The signal processing circuit on the CMOS chip enables the selection of an optimum conversion efficiency (CE) for your application from the available four types using external voltage.

Features

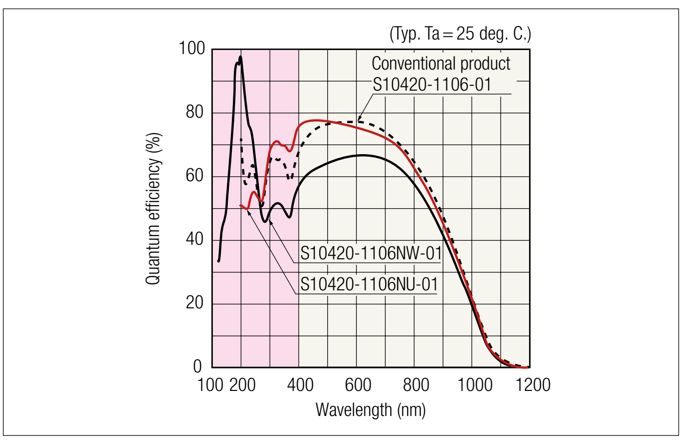
- High-speed line rate: 40000 lines/s max.
- High-speed data rate: 15 MHz max.
- Selectable from four conversion efficiency types
- Built-in timing generator
- Built-in temperature sensor
- Room temperature operation

Applications

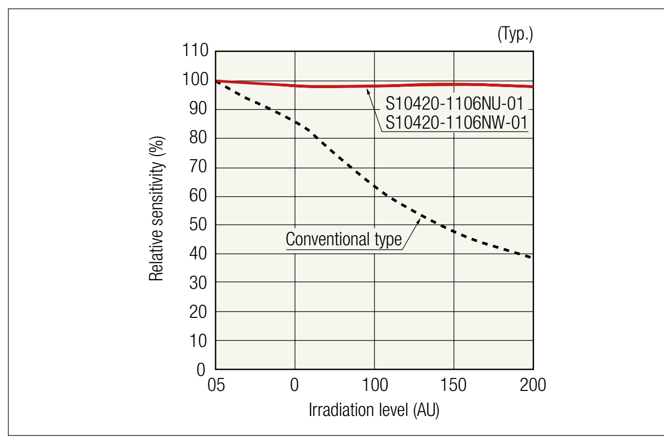
- Foreign object detection
- Agricultural product inspection

CCD Area Image Sensor
S10420-1106NU-01/-1106NW-01

Spectral response (typical example, without window)



Variation in the spectral sensitivity due to UV light irradiation



Features High Resistance in the UV Region

These are CCD area image sensors derived by improving the previous product (S10420-1106N-01), which achieved high-sensitivity in the UV to visible region by employing a back-thinned structure, and adopting a new structure for the photo-sensitive area to improve the UV resistance.

Differences from the previous product

As compared to the previous product (S10420-1106N-01), the sensitivity deterioration after UV light irradiation is suppressed significantly. Two new types have been added to the lineup: the S10420-1106NU-01, which features improved UV resistance while maintaining the basic characteristics of the previous product, and the S10420-1106NW-01, which features high sensitivity in the vacuum UV region.

Features

- High sensitivity in the UV region (S10420-1106NW-01)
- High full well capacity
- Wide dynamic range
- With anti-blooming function
- Non-cooled type
- Driver circuit C11287 (sold separately) available

Applications

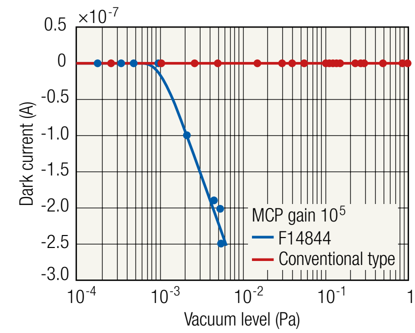
- Spectrophotometry
- Gas chromatography
- Excimer laser monitor
- Vacuum UV to UV light monitor

MCP Assembly F14844

Specifications

Parameter	Specification	Unit
Max. operating pressure	1	Pa
Gain (Min.)	1×10^6	–
Effective area	ϕ14.5	mm
Resistance	300 to 600	MΩ
Dark count (Max.)	3	$s^{-1} \cdot cm^{-2}$

Output waveform (typ.)



Next-generation Ion Detector Ideal for Miniature Portable Mass Spectrometers

The F14844 is an MCP assembly with a unique triode structure*1 designed to vary the potential gradient and to suppress ion feedback*2 noise. When operating a conventional MCP, it must be used at vacuum levels higher than 1.3×10^{-4} Pa.
The F14844 operates with high stability even at a low vacuum level of 1 Pa while maintaining a high gain of 1×10^6.
This makes the F14844 a useful tool for portable desktop mass spectrometers in which it is difficult to install a large vacuum pumping system. The F14844 is a breakthrough ion detector that allows downsizing and cost reduction of the equipment.

Features

- High pressure operation: up to 1 Pa
- High gain: 1×10^6 or more
- Effective area: 14.5 mm dia.
- Long life: 3 C/cm² or more

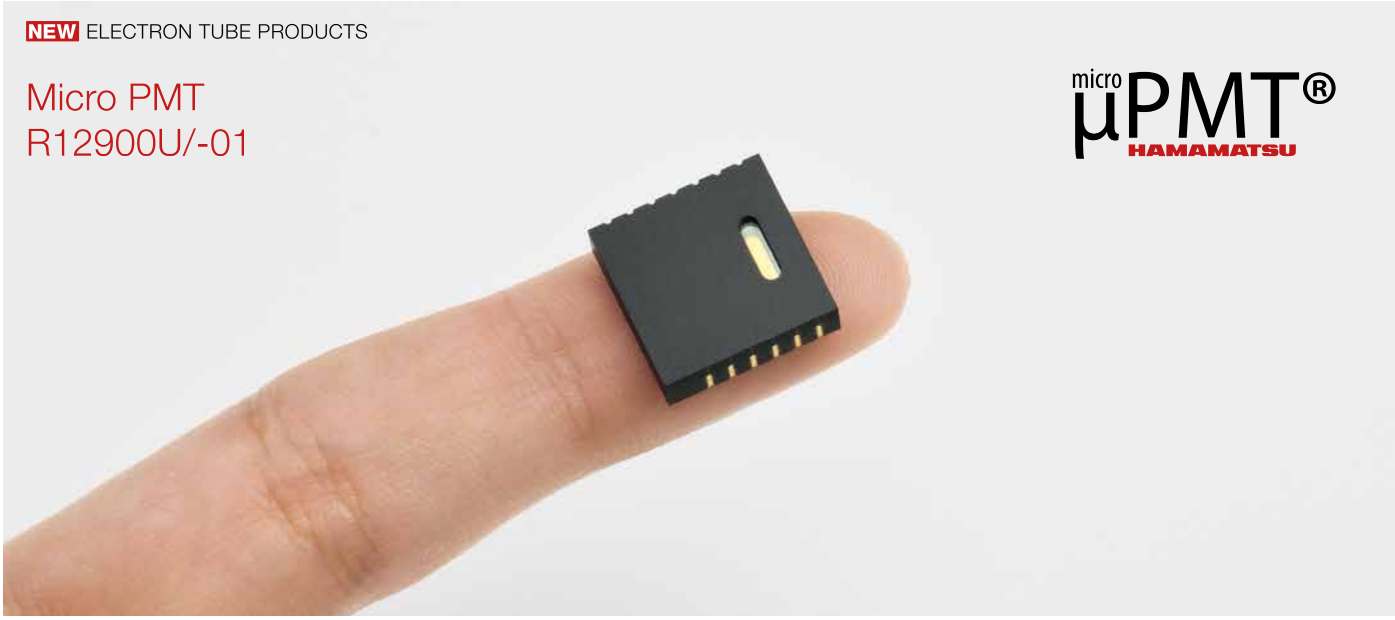
Applications

- Compact mass spectrometer (miniature MS)
- Security-related devices (explosive material and drug testing)
- Agriculture-related devices (pesticide testing)
- Medical devices (infection detection by breath analysis)

*1 Structure consisting of three electrodes which are the MCP-out, mesh anode, and dynode.
*2 Ion feedback is the cause of unstable operation that occurs under low vacuum conditions.

NEW ELECTRON TUBE PRODUCTS

Micro PMT R12900U/-01

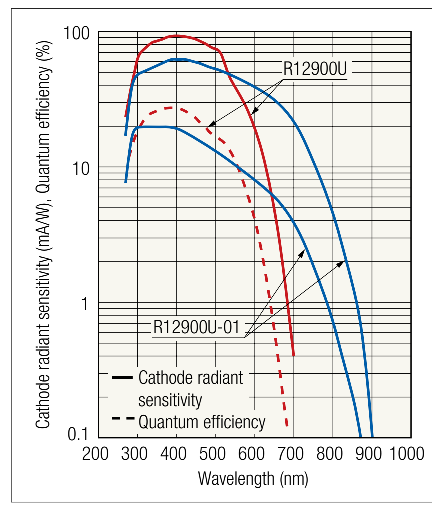


Specifications

Parameter	R12900U	R12900U/-01	Unit
Spectral response range	300 to 650	300 to 850	nm
Effective photocathode area	1 × 4		mm
Gain*1	2.0×10^6	3.5×10^5	–
Anode dark current*1, 2	0.3		nA
Rise time*1	1.2		ns
Size (W × H × D)	14 × 3.5 × 14		mm
Weight	1.1		g

*1 Input voltage 900 V, at 25 deg. C.
*2 After 30 min storage in darkness

Spectral Response



World's Smallest, Thinnest, Lightest PMT*

The R12900U and R12900U-01 are micro PMTs designed to be small and lightweight and assembled into a finger-tip size package without including a high-voltage power supply circuit. This thin small package can be easily installed in various instruments, for example for multipoint measurements or multi-wavelength measurements using an array of micro PMTs. These will open up new applications that require lightweight portable measuring devices with very high sensitivity offered by photomultiplier tubes.

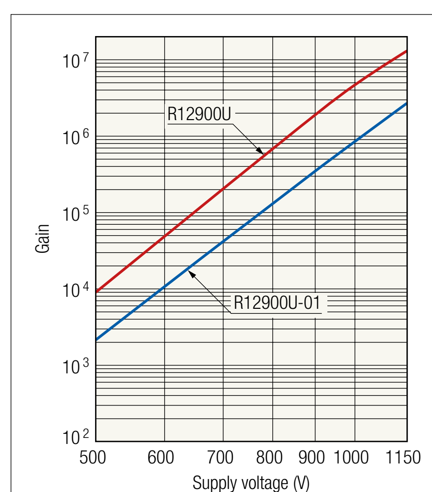
Features

- Compact, thin, light weight
- High sensitivity and low noise
- Highly resistant to vibration and shock

Applications

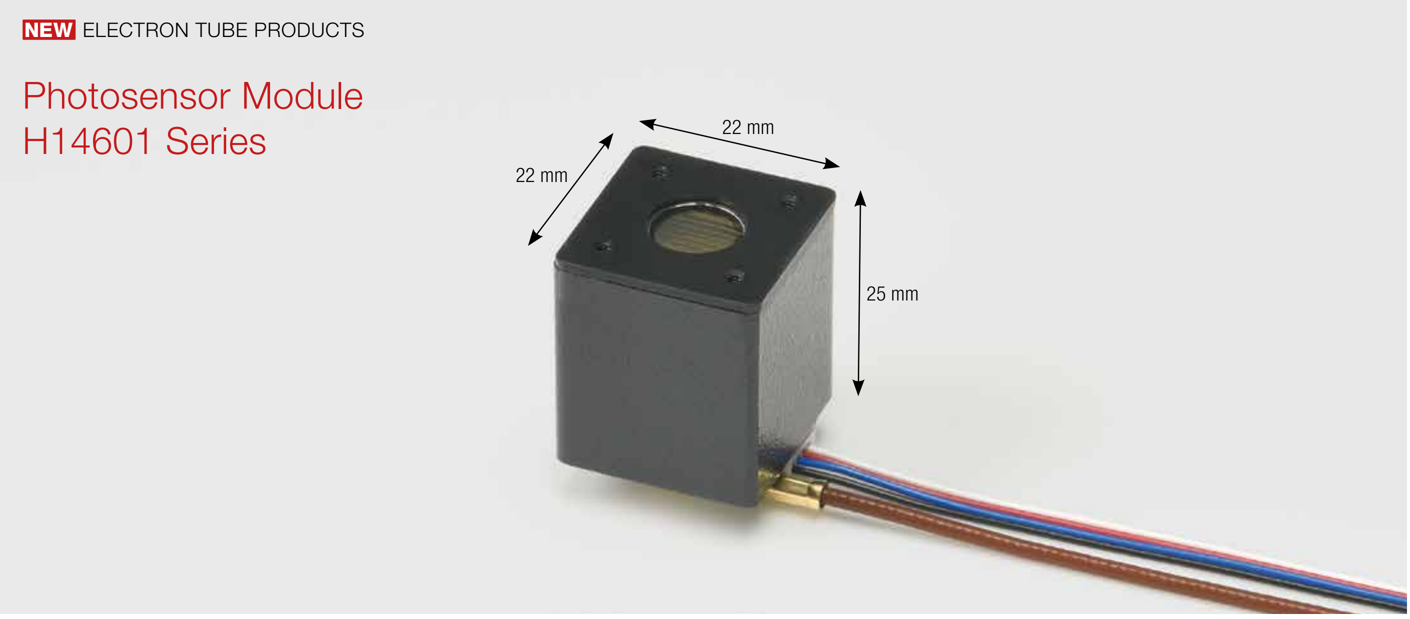
- Portable devices
  - Environmental measurement
  - POCT (point-of-care testing)

Gain



* As of May 2020, based on our research

Photosensor Module H14601 Series

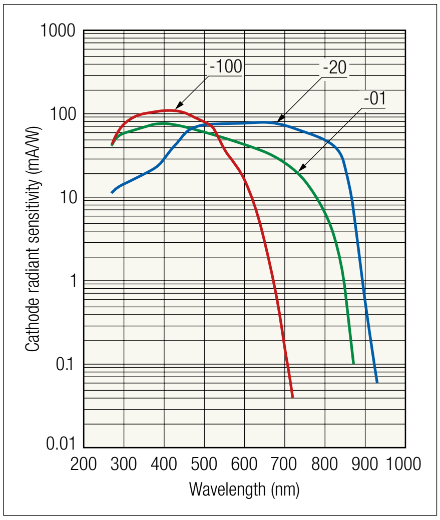


Specifications

Parameter	H14601-100	H14601-01	H14601-20	Unit
Spectral response range	300 to 650	300 to 870	300 to 920	nm
Effective photocathode area	ϕ8			mm
Input voltage	+4.5 to +5.5			V
Maximum input current	3.5			mA
Maximum output signal current*	100			µA
Maximum ripple noise* (p-p)	0.2			mV

*Control voltage +0.9 V

Spectral response



Compact Photosensor Module Incorporating a TO-8 Package Photomultiplier Tube

The H14601 series is a photosensor module that incorporates a TO-8 package photomultiplier tube along with a high-voltage power supply and a voltage divider and provides a current output cable.
Its volume is one half of the volume of the prior product (H10721 series) and so helps reduce the size of equipment. Pin output type H14600 series is also available.

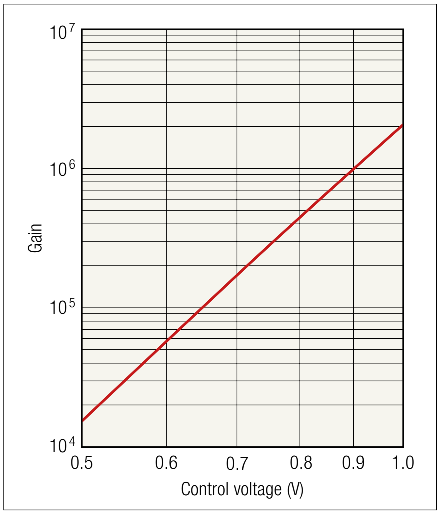
Features

- Compact cable type module
- Low voltage (+5 V) operation
- Low power consumption

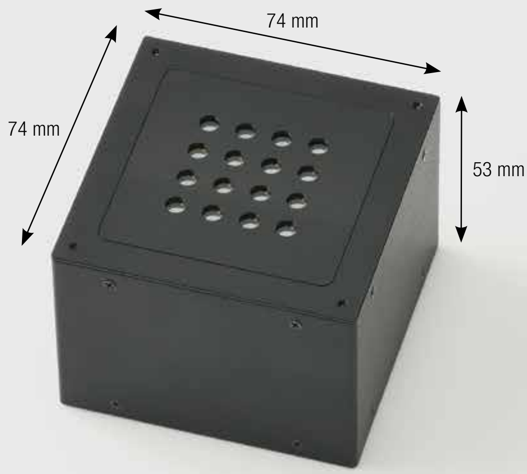
Applications

- Portable high-sensitivity devices
- Environmental measurement
- POCT (point-of-care testing)

Gain



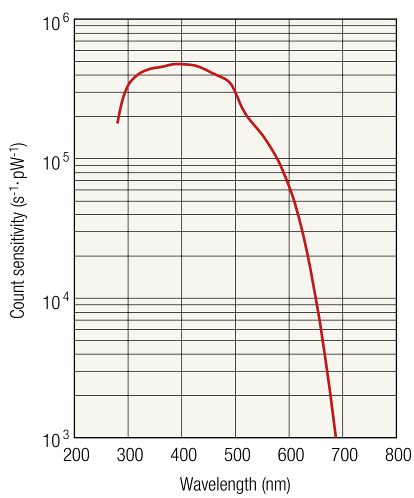
Photon Counting Head H14870



Specifications

Parameter	Specification	Unit
Spectral response range	300 to 650	nm
Dark count (1 ch)	50	s^{-1}
Count linearity	3×10^6	s^{-1}
Pulse pair resolution	33	ns
Count uniformity between each channel	1:2	–
Cross-talk	0.05	%

Count sensitivity



4 × 4 Multichannel Photon Counting Head for 96 Well Microplate Reader

The H14870 is a 16-channel photon counting head with light input openings arranged at an interval equal to the well-to-well spacing for 96-well microplates. The H14870 allows simultaneous measurements of 16 wells and so shortens the measurement time (improves the throughput).

Features

- 16 channels (4 × 4 multichannel)
- Effective area: ϕ5 mm/channel
- Low voltage (+5 V) operation
- High-speed data transfer: LVDS output

Application

- Microplate reader

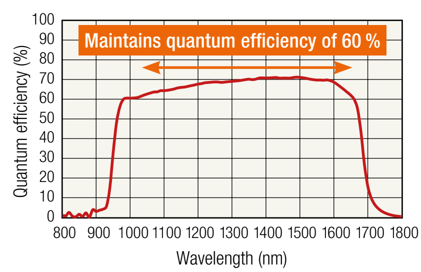
NEW SYSTEMS PRODUCTS

InGaAs Line Scan Camera C15333-10E

Specifications

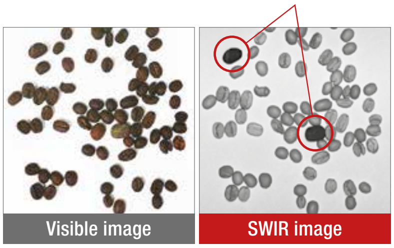
Parameter	Specification
Imaging device	InGaAs line sensor
Effective number of pixels	1024 (H) × 1 (V)
Pixel size	12.5 μm (H) × 12.5 μm (V)
Effective area	12.8 mm (H) × 0.0125 mm (V)
Maximum line rate	Internal mode: 40 kHz (21 μs exposure time)
	Sync readout: 40 kHz

Spectral Response



Imaging example: Contaminant detection

Stones that are difficult to detect in visible images because of their similar size and hue can be easily detected in SWIR images.



Sample: Coffee beans
Contaminant: Stones
Wavelength: 1200 nm
Illumination: Reflection

Suitable for In-line Non-destructive Inspection

SWIR (short wavelength infrared) imaging is a great solution for non-destructive inspection. It sees under the surface, differentiates materials based on their SWIR spectral signatures, and offers a safe and convenient way to ensure product quality. Example applications include checking liquid volumes in packages, inspecting contents of sealed containers, and detecting damages and contaminants in agricultural products. In addition, applications in the semiconductor industry include Si wafer pattern inspection and solar cell defect detection. Integrating SWIR imaging into production lines requires cameras such as the C15333-10E InGaAs line scan camera, whose high SWIR sensitivity and fast line rate are ideal for real time, in-line non-destructive inspection.

Features

- High sensitivity in SWIR
- 1024 pixel linear array
- Maximum line rate: 40 kHz
- Interface: Employs Gigabit Ethernet
- Equipped with high quality images (Back ground subtraction, Real time shading correction)

Applications

- Food and agricultural products (damage inspection, quality screening, material discrimination etc.)
- Semiconductors (Si wafer pattern inspection, solar cell inspection by EL/PL etc.)
- Industry (moisture content, leak detection, container inspection etc.)

NEW LASER PRODUCTS

LD Irradiation Light Source SPOLD L13920-711

Specifications

Parameter		Specification
Light output (with maximum current setting)	Output end of laser transmitting optical fiber	360 W
	Output end of irradiation unit	320 W
Laser type		Laser diode (LD)
Oscillation type		CW
Peak oscillation wavelength (25 deg. C.)		940 nm ± 20 nm
Cooling method		Water cooling (distilled water)
Dimensions (W × H × D)		Approx. 480 mm × 250 mm × 500 mm (excluding projecting parts)
Light condensing diameter		≥ ϕ0.8 mm

High Power LD Irradiation Light Source that Enables High-speed, Wide Range Processing

Water cooled, fiber output LD irradiation light sources for high speed and large area processing, suitable for a variety of thermal processing applications.

Features

- Light source suitable for large-area, high-speed processing
- Realize higher light output than the conventional lineup (1.8 × compared to the conventional lineup)
- Optimized beam profile for various processing operations
- Compatible with lightweight and compact cooling devices
- Can be mounted in a 19-inch rack

Applications

- Thermal processing of sheet metal
- Soldering
- Plastic welding
- Sintering of metal nanoink

Related products

Irradiation unit A13933 series and A15558 series

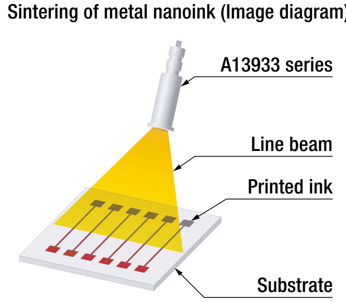
A13933 series

A15558 series

We have a lineup of irradiation unit with a cooling-mechanism suitable for L13920-711 that achieves high power.

Application example

Sintering of metal nanoink (Image diagram)



Empowering Breakthroughs with Light at Photonics West 2020

At this year's Photonics West, exhibition attendees saw how Hamamatsu's products empower breakthroughs with light. In the center of our booth, a special display area hosted demonstrations showing how our photonic technologies can be used in real-life applications, such as LiDAR, Industrial and Analytical.

For LiDAR, there were two demonstrations focused on distance measurement using photon counting, featuring our newest MPPC PCI (photon counting image sensor) products.

The first demonstration for distance measurement was based on the direct TOF (time-of-flight) method using a 16-channel 1D MPPC PCI and a pulsed laser diode. This demonstration showed that measurement is possible with a distance resolution of 7.5 mm (time resolution: 50 ps).

The second demonstration measured distance by using a 32 × 32 ch 2D MPPC PCI. The distance was calculated by the time gap between the laser output and the reflected light, and the displayed color changed according to the distance information. In addition to this, a dedicated counter for LiDAR products hosted another demonstration which compared detectors; APD, MPPC, and SPPC, by projecting the difference of output waveforms by ND filter, bandpass filter and aperture.

For industrial, three demonstrations showcased how our photonic products can be used in the areas of laser scanning, SWIR imaging, and gas analysis.

The 2D raster scan demonstration showed the ability to scan various laser patterns using the integrated 2D raster MEMS mirror. The laser scanned horizontally at high speed, from the upper-left corner to the lower-right corner of a screen.

Another demonstration featured SWIR imaging, which is widely used in non-destructive inspection for semiconductor, agriculture, food packaging, and all kinds of security purposes. The demonstration showed how our SWIR InGaAs cameras and image sensors can be used to distinguish defects and foreign contaminants by revealing wavebands that are typically invisible to our eyes.

Our gas analysis demonstration showed how our infrared devices have the capability to provide real-time measurements of CO_2 concentration. The measurement of gas concentration can be vital to process control and preventative maintenance.

For analytical, two demonstrations showcased how our photonic products can be used for the applications of mortar degradation analysis and plastic sorting.

The demonstration for real-time on-site measurement using a portable device featured one of our newest products, the FTIR Engine (1100 to 2500 nm spectral range), designed for portable applications. Non-destructive degradation analyses of bridge and tunnel concrete are some of its many applications. The demonstration showed the results from using the FTIR engine to measure mortar (no air entrainment) degradation.

Also there was a demonstration that showed how our MEMS-FPI module can identify the type of plastic or textile based upon its reflectance waveform.

These demonstrations are only a sampling of what our products can do. We look forward to Photonics West 2021, where we plan to continue to showcase our newest photonic components and systems and how they can be used in various applications to ensure accurate measurements, improve productivity, and empower more breakthroughs.

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