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NEWS 2017 01

COVER STORY PAGE 2

UV Curing – Higher Power, Higher Efficiency

AUTOMOTIVE

TELECOMMUNICATIONS

ELECTRONICS

GRAPHIC ARTS

UV Curing – Higher Power, Higher Efficiency

Hamamatsu Photonics are specialists in the design and manufacture of high quality optoelectronic products. We have a long history of expertise in the industry, developing our technologies since the inception of the company in 1953.

Our standing as a world leader in the photonics industry allows us to push the boundaries of what is possible with our products. Our recently expanded range of air-cooled UV-LED light sources reflect our ability to respond to customer needs and stay on top of trends in markets using UV curing, such as printing and labelling.

Why UV-LED?

UV-LED sources are the efficient, environmentally friendly upgrade to the metal halide lamps still used for curing in some parts of today's industries. The long lifetime of the LEDs, coupled with their efficiency at specific wavelengths are just some of the reasons why the market is moving towards this technology.

Key Benefits of UV-LED Sources

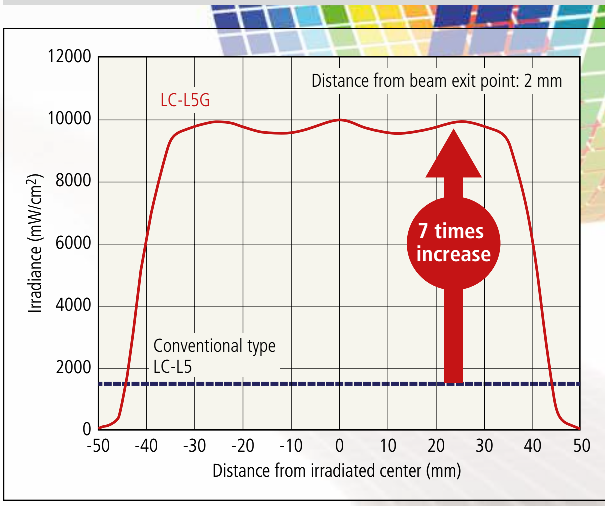
- A lifetime of 20,000+ hours before any replacement is needed
- Lack of heat released means that various substrates can be used
- Consistent cure rates from the ability to adjust the lamp intensity
- Lower power consumption leads to savings in electricity costs
- Air cooling removes the need for chillers/external coolers
- Different wavelengths and/or irradiation areas available

LIGHTNINGCURE® LC-L5G, Linear Type UV-LED Light Sources

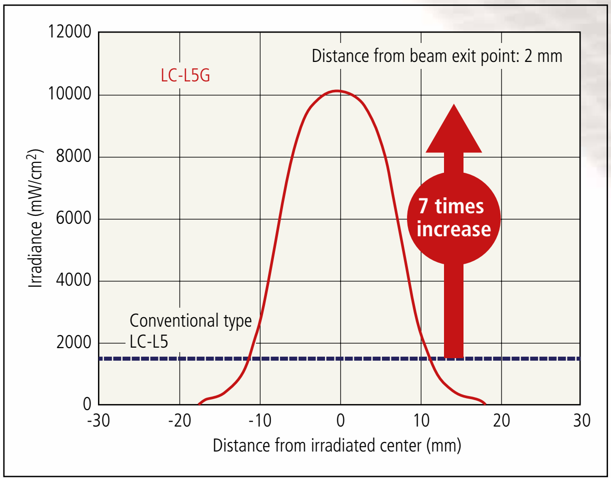
UV-LED light sources are designed as an efficient replacement for today's metal halide lamps.

The LC-L5G maintains the compact size, lightweight and air cooling of the previous model, but delivers a light intensity of around 7 times higher. This enables the UV source to be used in applications where high output is required to replace conventional lamps.

X direction



Y direction



Content

High-speed digital scanner simultaneously views brightfield and fluorescence images making it specifically ideal for research tasks

A new model in the NanoZoomer series widely used in pathology and research fields throughout the world is now on the scene. This new model is called the NanoZoomer S60 and has a special design even more optimized for research fields. Its greatest feature is that it incorporates our scientific CMOS camera which can now be called an industry standard for fluorescence imaging. This means the user can now capture high-speed fluorescence images as well as brightfield images. Another advantage is that it handles a 52 mm by 76 mm glass slide which is double the size of standard glass slides, giving a powerful assist for getting digital data from samples indispensable for cancer and brain research. We talked to 5 people involved in developing the NanoZoomer S60. Let's hear what they have to say.

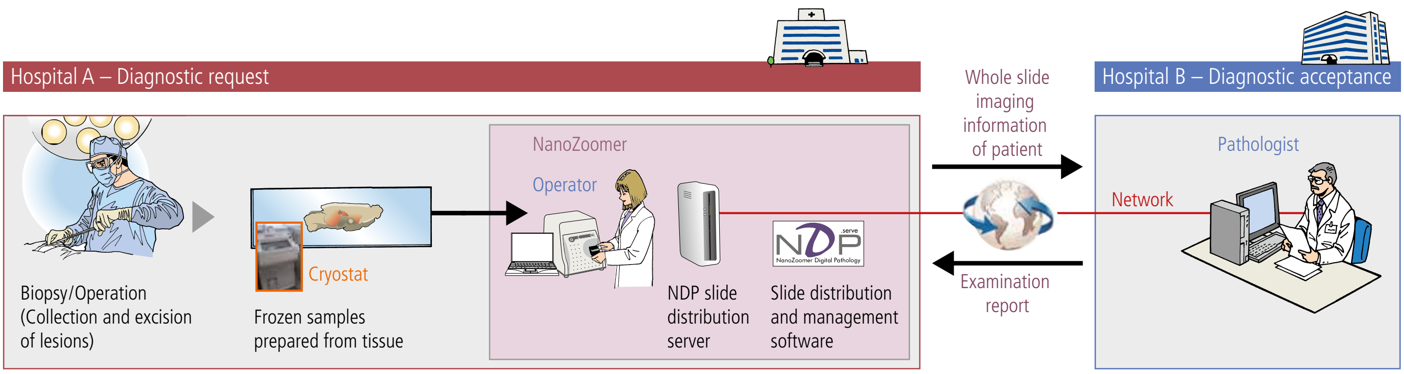
NanoZoomer S60

It all started from trying to solve the problem of pathologist shortage

First of all, what features does the "NanoZoomer series" offer?

Ogura: To put it simply, it's a system for converting tissues or cells mounted on a prepared slide into digital images. Its development started about 10 years ago and we currently sell four different types according to the required application.

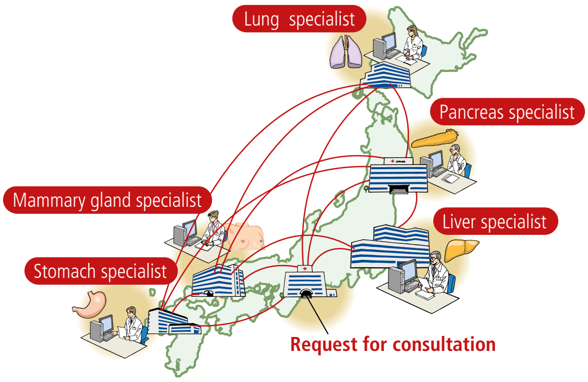
Hashimoto: Its development originally stemmed from a shortage of pathologists. In large hospitals, pathologists swiftly diagnose suspicious tissues and cells found during surgery to check for cancer, and so on. They provide pathological diagnoses of tissues and cells right on the spot so that surgery can be swiftly completed. However,



Operation example of whole slide imaging #1: Teleconsultation of intraoperative rapid diagnosis with distant hospital

there simply are not enough pathologists available across the country, so that regional hospitals and small hospitals with few beds available have to take measures such as asking outside pathologists to standby for part-time duties on the day of surgery or rapidly sending the cell or tissue sample to a facility where pathologists are working. The surgery can then continue after the pathologist contacts the hospital with a diagnosis.

Tsuchiya: In view of these circumstances, the first NanoZoomer model was developed to convert the sample into digital information so that medical specialists for each organ can make observations and diagnoses from remote locations. Solving these problems of pathologist shortage and regional difference was assumed to require developing a digital slide scanner capable of both high-speed and accurate observation that would also have to operate over a network.



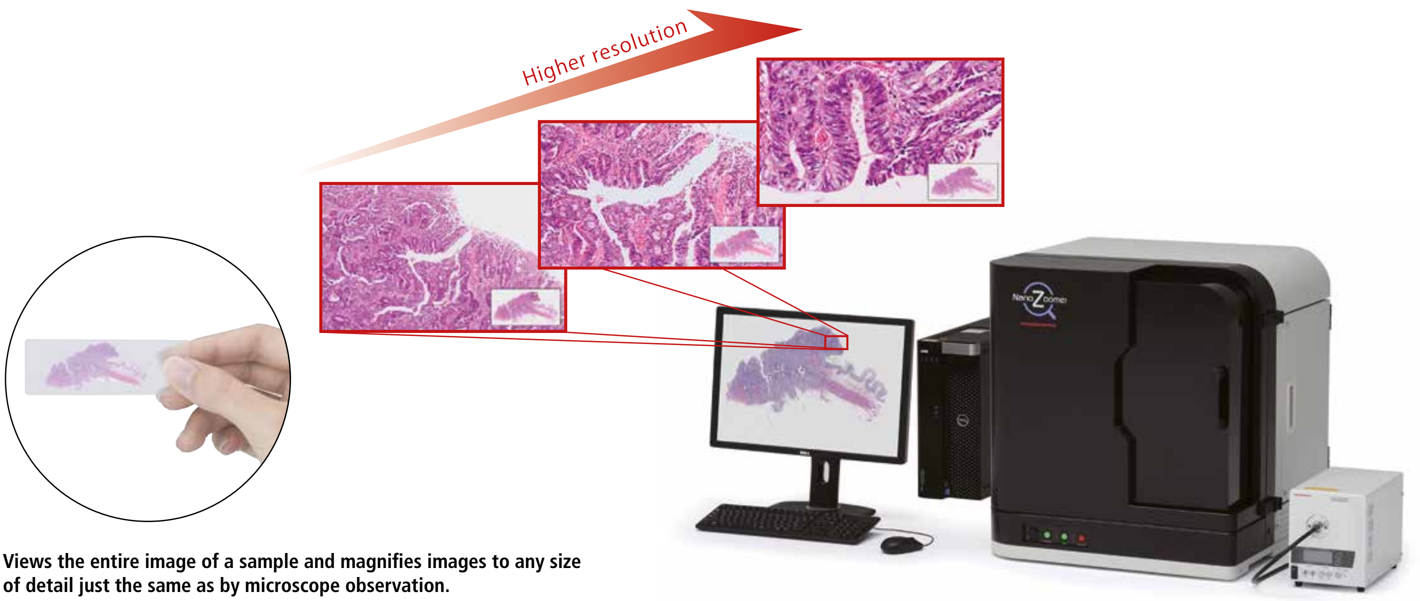
Operation example of whole slide imaging #2: Organ consultation
In the future, a network between pathologic diagnostic specialists on a case or organ basis and a network within a specific area will be constructed. And it is thought that it becomes a system which can receive specialized pathology diagnosis from familiar hospitals.

So you made the microscope into what could be called a digital device?

Toyoda: A whole slide scanner such as the NanoZoomer can be considered a convenient tool to make microscope observations. Conventional microscopes or first-generation microscopes are used for on-site placement and observation of the sample. Second-generation microscopes were next introduced to the market, allowing remote operation over a network where for instance a doctor at a remote location received a message saying, "The sample is now mounted in the microscope" and the doctor could then make observations via a network. This method, however, required a human assistant to change the slide and contact the doctor.

Hashimoto: Third-generation microscopes like the NanoZoomer that next appeared on the market were capable of automatically changing slides without human assistance, and acquiring images the doctor could see, although there was a time-lag. So convenience was drastically improved.

Ogura: But, the NanoZoomer was not built to compete with the microscope. If the sample must be observed on-site and in real-time, then the microscope is a much better choice. However, the whole slide scanner proves itself a powerful tool when used in combination with a system for converting a sample to a digital format, copying it, searching for it on a database, and observing it over a network.



Views the entire image of a sample and magnifies images to any size of detail just the same as by microscope observation.

Pursuing "speed" from every possible aspect

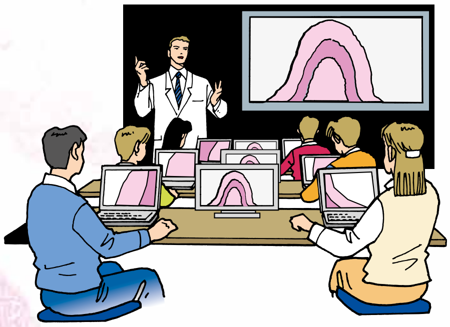
I have heard the NanoZoomer is superior, in what points?

Hashimoto: Ten years ago, when digital processing was not really available in the field of pathology, most attention was focused on speedily capturing a sharp image. Currently, however, the speedy capture of a sharp image is taken for granted and the priority is instead given to how to best utilize the data that was obtained.

Susuki: If I had to put the unique features of the NanoZoomer series into one word, it would be "SPEED." This means the pursuit of "SPEED" from different aspects in addition to image capture speed, such as the speed when zooming in on an image and the speed at which the device can be set up and start operating after delivery. We have a proven track record of supplying the NanoZoomers that meet diverse customer needs in different applications. We feel this record gives the customer a feeling of security.

What market does the NanoZoomer series specifically target?

Toyoda: The largest market including overseas is the research field. Next is the field of pathology followed finally by the medical education field. Up until now, in a pathology class of medical school faculty, if you had 100 medical students, then you had to prepare 100 sets of glass slides and microscopes for those students. Moreover, since each student peers through a different microscope, it is impossible to have all students look at the same spot on the glass slide. Using a digital medium, however, allows everyone to see the same spot on their computer and so is extremely convenient and practical for instructions in actual situations. For these reasons, the NanoZoomer is being enthusiastically accepted in the field of medical education.



Operation example of whole slide imaging #3: Student education

Ogura: The NanoZoomer S60 was released in the spring of 2016 targeting the research field for sales. We hope that its use will spread widely in the field of cancer research and pharmaceutical drug development.

Interviewees (from the left)
Yuusuke Tsuchiya: Team Leader of Life Science Team, System Sales Promotion Dept., Systems Division
Jinichi Susuki: System Design Dept. #48, Systems Division (in charge of software development)
Yuuich Toyoda: System Design Dept. #48, Systems Division (in charge of S60 development)
Takashi Ogura: Product Specialist of Life Science Team, System Sales Promotion Dept., Systems Division
Yoshinori Hashimoto: System Design Dept. #48, Systems Division (in charge of application development)

Our newest model the S60 is specifically designed for research

Let's shift our topic to the newest model, the S60.
What is its point of ultimate appeal?

Susuki: The S60's true strongpoint is that it takes sharp and clear fluorescence images. The initial NanoZoomer model was able to capture fluorescence images, but capturing fluorescence images on a level the customer really wanted required a long exposure time. However, the need for capturing fluorescence images such as for cancer research created a greater demand. To meet this demand, we have released a new NanoZoomer that incorporates an "ORCA-Flash4.0" which is viewed as an industry standard camera for fluorescence imaging.

Ogura: The previous model used a single camera to capture both transfer images and fluorescence images. But when used in research applications, the camera didn't have enough sensitivity to the fluorescence emitted from the sample, so a long exposure time was needed to get a good image. What this meant was that the scanning speed for fluorescence images was slow compared to transfer images. The S60, however, uses two different cameras, a transfer image camera and an "ORCA-Flash4.0" camera which has high sensitivity enough to capture fluorescence images. So the S60 gives both a high-quality image along with a speed higher than the previous model.

What proved to be a really thorny issue when developing the S60?

Toyoda: The previous camera model captured both fluorescence and transfer images with the same camera, so aligning the image positions was easy. The S60, however, captures images for the same target object using two cameras, one for transfer images and one for fluorescence images, so these images have to be overlapped on one another. This positioning alignment was an extremely tough problem to conquer. We were aiming for an accuracy of one micrometer.

Susuki: If we ignored the cost, we could obtain the required accuracy by taking the hardware approach alone. However, results from reviewing the overall cost balance convinced us to use software to make the final accuracy alignment. The issue causing us the most problems was how to cleanly couple images together. Joining the images required a target object to identify the image shape. However, there are sections on the slide containing nothing at all, so we wondered what we should do …We finally overcame the problem by applying an image recognition algorithm.

Advantage in brain, cancer, and new drug discovery research

How is the S60 applied in research fields?

Tsuchiya: The field of brain research that makes use of mice and marmosets is becoming intensely active in recent years. In one actual example of research use, a brain slice is mounted on the glass slide and digital images are captured to create a database. Ordinary models capture images from just a segment extracted from the brain, but the S60 can capture data from a 52 mm by 76 mm glass slide which is double the ordinary size to allow acquiring data from the entire brain.

Toyoda: Besides the brain research application, other research focuses on finding the causes of cancer. Cancer research involves observation using fluorescence imaging to find out how genes and proteins that cause cancer are distributed within the tissues. Applications also include research for discovering new drugs. The S60 can also be used to assess the safety of newly developed drugs.

Are there products from other companies that can rival the S60?

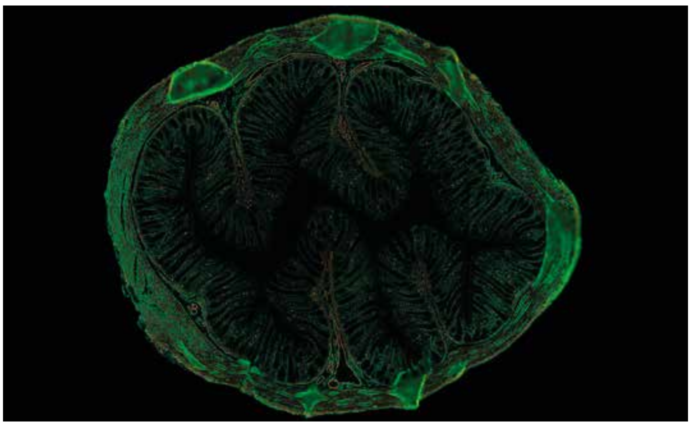
Toyoda: There is a system that combines a fluorescence imaging unit with a brightfield imaging unit, and delivers the same performance as the S60 by using those two units. But the S60 is the only "All-In-One" device capable of viewing fluorescence images, offering double-size slide handling capability, and providing superb high-speed performance.

Susuki: When making a tissue database for brain research, you may have to scan 1,000 slides to make one piece of data. So if you try this without using the S60, then creating data for just one slide will take dozens of minutes. If you repeat that process for 1,000 slides, then you have to expend an enormous amount of time and manpower. Research requires making rapid progress, so I think the researchers want to leave simple tasks like scanning to someone else and concentrate on making a database and analyzing data.

Research requires speedy work ...

Tsuchiya: The other day, we visited a customer doing brain research. He was surprised to find out that the S60 could also be used for acquiring research data. He knew that slide databases for brain research were in wide use, but didn't know how to go about creating such a database. He was apprehensive about that task, thinking that slide scanning likely involved a tremendous amount of time and manpower. Since then, I deeply felt that there is a market need for an automated device capable of making research slides.

Ogura: There are in fact many cases where researchers and instructors in areas other than pathology do not know that the NanoZoomer is capable of making whole slide imaging. That is all the more reason for widening knowledge about whole slide imaging technology in the research field.



Fluorescence imaging example: Rat Gut Section

Tsuchiya: For example, in the Brain Science Institute at RIKEN conducting cutting-edge research, several units of the NanoZoomer are being used. I think the staff there are well aware that the NanoZoomer is an indispensable tool for brain research work.

Aiming for a pathology and research standard

Now let's hear some comments about the future.
Where will the NanoZoomer series including the S60 likely be headed from hereon?

Hashimoto: One goal is coming up with a device that serves as a standard for the pathology market. I am not talking about a hardware device alone, but rather a device and application including software that will become an accepted and well-known presence on the market. In the case of the S60, it was originally launched on the market as a specialized tool for research. So, I would like us to aim for making it into a true standard in research applications.

Tsuchiya: It has been about half a year since the NanoZoomer S60 was released, yet it has good sales mainly in the European marketplace. The NanoZoomer series was originally marketed with the European research market as the main sales target, so we got requests from people there wanting speedier capture of fluorescence images.

Ogura: We succeeded in speedily capturing fluorescence image data, so in terms of sales, I would like to see a wider spectrum of proposals for ways to use this data in research from now on. I think those type of efforts would boost the superiority of the S60 even further.

Hashimoto: I think there are a lot of things we should do from now on in terms of hardware development work. I would like to see improvements like capturing good images without requiring much effort, such as by capturing a perfect image just by pressing a button and capturing images even faster.

Ogura: The NanoZoomer series is useful for a "scan, observe, and send" type workflow cycle. From here onwards, I would like to work on the hardware and software improvements needed to make this cycle proceed even more smoothly.
Solving one problem will also create a new challenge. In this way, our customers come up with demands that constantly require overcoming higher hurdles. This means we have to contrive a system to keep dealing with all these issues and problems.

Digital Slide Scanner – NanoZoomer series

High-end model
NanoZoomer-XR

FLUORESCENCE IMAGING

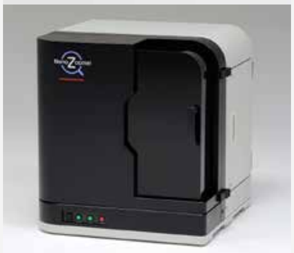
Comes with rapid automatic processing of up to 320 slides, dynamic focus, and image quality judgment functions

- Scanning speeds 20x mode (15 mm x 15 mm): Approx. 35 s
- Scanning speeds 40x mode (15 mm x 15 mm): Approx. 45 s
- Slide capacity: Max. 320 slides

Standard model
NanoZoomer S210

Automatic processing of up to 210 slides and a solid history of stable performance

- Scanning speeds 20x mode (15 mm x 15 mm): Approx. 60 s
- Scanning speeds 40x mode (15 mm x 15 mm): Approx. 150 s
- Slide capacity: Max. 210 slides



Double size slide model
NanoZoomer S60

FLUORESCENCE IMAGING

Supports up to 30 double size slides or up to 60 standard size slides automatically

- Scanning speeds 20x mode (15 mm x 15 mm): Approx. 60 s
- Scanning speeds 40x mode (15 mm x 15 mm): Approx. 150 s
- Slide capacity: Max. 60 slides

Compact model
NanoZoomer-SQ

Compact and affordable model

- Scanning speeds 20x mode (15 mm x 15 mm): Approx. 150 s
- Scanning speeds 20x mode (15 mm x 15 mm): Approx. 275 s
- Slide capacity: 1 slide

Scanning speeds are in the case of brightfield image.

Specifications

Product name Type number		**NanoZoomer-XR C12000-03**	**NanoZoomer S210 C13239-01**	**NanoZoomer S60 C13210-01**	**NanoZoomer-SQ C13140-L03, -D02**
Scanning speed	20x mode, 15 mm x 15 mm	Approx. 35 s	Approx. 60 s	Approx. 60 s	Approx. 150 s
	40x mode, 15 mm x 15 mm	Approx. 45 s	Approx. 150 s	Approx. 150 s	Approx. 275 s
Objective lens		20x N.A. 0.75 User can select 20x or 40x mode at start of scanning.			
Compatible glass slides		26 mm x 76 mm (Thickness from 0.9 mm to 1.2 mm)	26 mm x 76 mm (Thickness from 0.9 mm to 1.2 mm)	26 mm x 76 mm 52 mm x 76 mm (option) (Thickness from 0.9 mm to 1.2 mm)	26 mm x 76 mm (Thickness from 0.9 mm to 1.2 mm)
Slide loader	Standard size	320 (40 slides x 8 cassettes)	210 (30 slides x 7 cassettes)	60 (20 slides x 3 cassettes)	1
	Double size	-	-	30 (10 slides x 3 cassettes: option)	-
Scanning resolution	20x mode	0.46 μm/pixel			
	40x mode	0.23 μm/pixel			
Focusing method		Pre-focus map Dynamic Pre-focus	Pre-focus map	Pre-focus map	Pre-focus map
Z-stack feature		Yes			
Fluorescence imaging module		Option	-	Option	-
Barcode reader		1D barcode (standard feature), 2D barcode (option)			
Image compression		JPEG compression, uncompressed image (8 bit)			
Slide format		JPEG compression image + slide information			
Power supply voltage		AC100 V~AC240 V			
Power consumption		Approx. 300 VA	Approx. 160 VA	Approx. 225 VA	Approx. 72 VA

Hamamatsu shines at Photonics West 2017

SPIE Photonics West was held in San Francisco, California, from January 31 through February 2. With over 23,000 attendees and 1,300 exhibitors, it is the biggest trade show in the photonics industry and has become the ideal platform to announce the release of new products.

This year, the technologies that generated the most interest were NIR-sensitive silicon photomultipliers (SiPM), MEMS mirrors, LCOS spatial light modulators, IR light sources and detectors, compact xenon flash lamps, and the W-VIEW GEMINI-2C image splitting optics for microscopy. We also showcased several products that can be used for food safety and quality, automotive LIDAR for autonomous and ADAS, and UV printing.

Booth visitors enjoyed engaging demos such as a car racing game that highlighted HUD technology by using Hamamatsu's MEMS mirror to project a virtual image of their car's data as they "drove." Another popular demo used a micro-spectrometer's precise color measurement capabilities to identify several different types of beer.

Hamamatsu also presented at various industry events and conference sessions. These talks covered topics related to photodetector selection, SiPM, single-photon avalanche diodes (SPAD), MEMS mirrors, and scientific CMOS cameras.

For more details about Hamamatsu at Photonics West 2017, visit: www.hama.photo

An MPPC application example – Pushing spray measurement to the limits

Dr. Sebastian Albrecht,
Production Manager and Head of
Electronic Development Division
02.11.2016

Figure 1: The SpraySpy® measurement system.

Abstract:

To control the performance of a spray, reliable knowledge of the spray parameters is essential. The company AOM-Systems from Darmstadt (Germany) uses the Time-Shift-Technique to measure these parameters. Built into this system is the new generation of the Hamamatsu multi-pixel photon counter (MPPC).

In the following article, an introduction and motivation to the goals of spray measuring is given. The challenges of measuring a spray are shortly outlined. The electronical set-up for detection and amplification of the signals is explained on the example of droplet detection.

Introduction:

The importance of particle characterization cannot be underestimated [Tropea2011]. Industrial solutions for fuel sprays, exhaust gas treatment, pharmaceutical sprays or the food industry are examples where reliable knowledge of the spray parameters can be crucial for both the economy and the performance of a process. But also for the spray coating of goods, which practically all goods undergo in the production process, the size and velocity of droplets are essential. Small droplets dry out on their way to the surface to be coated or become overspray while big droplets carry a momentum eventually destroying the glossy surface by leaving craters and darkening the color of the paint.

In such processes, the parameters controlling the spray are usually chosen by experience or "trial and error" which leads both to a high scrap rate and long iterative feedback loops in process evaluation.

Though there was the possibility to measure size distributions of a spray in a laboratory environment, those systems are either unstable in appraiser influence, unsuitable for the rigid environment of a production line or supply insufficient information. A good overview of these techniques is given in [Tropea2011].

To master the challenge of industrial spray measuring, the company "AOM-Systems GmbH" [AOMS2016] has developed a system working in a backscatter mode. The compact dimensions make an in situ measurement of both size and velocity of droplets in a spray possible while there is no need to adjust any optical setup [Schäfer2014]. With the information of size and velocity available, the spray parameters can be set directly and maintenance cycles can be predicted. Sneaking into the properties of the spray this technology is named the "SpraySpy®" technology.

The optoelectrical challenge:

The "SpraySpy®" uses the so-called "timeshift technique" measuring the curvature of a droplet and a "time of flight" measurement to determine the velocity of a droplet [ABDT2002]. A laser is focused into the spray giving backscattered light under certain angles each time a droplet passes the measurement volume. The time of this pulse arriving at the detector depends on the velocity and size of the drop. This signal is then transformed to an electronical pulse which then gets captured by an ADC and processed by a computer. In the early versions of "SpraySpy®", the detection was realized through photomultiplier tubes (PMT),

Application Report

Pushing spray measurements to the limits

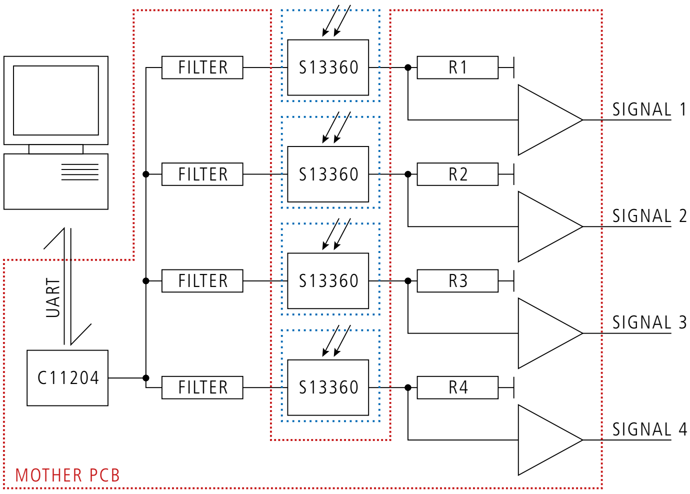


Figure 2: Electrical configuration. The C11204 power supply module is controlled by a UART interface to the computer. The voltage is filtered and drives four S13360 MPPCs in parallel. The current flowing from the MPPC is transformed to a voltage through the resistors R1 ...R4 and amplified.

giving good signal levels and a wide detection bandwidth with an optical power as much as 10 nW. But measurements taken with tubes suffer from change of environmental conditions such as ambient temperature, humidity and magnetic fields by a change in gain and dark current [HAM-PMT]. The omnipresent need for small, cheaper and better devices demands that electronics fulfill these requirements too.

The Hamamatsu Photonics OPTO-SEMICONDUCTOR HANDBOOK [HAM-Semi] stated that "...The MPPC is also immune to magnetic fields, highly resistant to mechanical shock, and will not suffer from 'burn in' by incident light saturation, ...The MPPC is a high performance, easy-to-operate detector that is proving itself useful in a wide range of applications and fields including medical diagnosis, academic research, and measurements". The decision was made to try the new technology in cooperation with the engineers from Hamamatsu. An evaluation kit was borrowed and after a few days an initial prototype was set up testing samples of both the MPPCs and the driver module C11204. The only concern was the temperature dependence of the signal gain, which is easily correctable with the temperature correction functionality of the C11204.

Additionally, it should be mentioned, that the signal recovered from a PMT usually has a negative sign, while the signals acquired from an MPPC deliver a positive voltage. After internal panels had reviewed the design the final layout looks as shown in figure 2.

Software was written to control the C11204 via the UART bridge. The biggest challenge was to set up the communication with the power supply for the MPPC and especially the checksum of the control string. Here, additional examples could have helped, though this issue is partially corrected with the newest review of the command reference for the C11204. Once this was overcome, the MPPCs were working very smoothly.

Circuit description:

For a better integration, the circuit is divided into two classes of PCBs: The mother board is hosting the C11204 with its UART-Bridge and the amplification or impedance matching. The MPPCs themselves are sitting on separate 1˝ tall PCBs together with a temperature sensor.

Starting from the controlling PC, a voltage is selected, specifying a certain gain. The driving voltage of 50 to 60 Volts is provided by the C11204. On the motherboard, this voltage is filtered and is transferred via SMA cable to a separate daughter-PCB hosting the S13360 MPPC. The current flow generated by the low light level is small enough, that a single controller can drive four MPPCs without any problems. The captured signal is returned to the mother-PCB where the signal is amplified through a noninverting operational amplifier configuration. Care has to be taken choosing the value of the resistor to ground (R1 ...R4, figure 2). These resistors form a lowpass with the terminal capacitance of the MPPC significantly modifying the dynamic of the captured signals. In our case 1 kilo Ohm gave good results for signals between 0.1 and 1 MHz. The current driving the MPPCs can easily be measured through the UART interface of the C11204 and is less than 1 mA for four MPPCs at the given photon rate at our setup. An excellent signal strength is reached and we find no need to further amplify the signal. With a little less than one eurocard board of space (100 mm x 160 mm), the optical acquisition system is simplified and more compact than in the previous setup.

Figure 3: The SpraySpy® measurement system measuring the spray cone of a typical food industry nozzle.

Conclusion:

Having both the photomultiplier tubes and the multi-pixel photon counters tested, one can say: With a PMT, a very well tested signal acquisition is possible. Linearity is given over a wide range and the technology is well established. Still a high voltage has to be applied and a control has to be installed in some way.

Using MPPCs, one gets a signal which is of high quality while the electronical layout may be smaller and the overall costs are reduced. The sensors are more robust in terms of electric fields and mechanical shock.

This makes MPPCs the right choice for optical signal detection in our field of application.

Sources:

[AOMS2016] http://www.aom-systems.com

[Tropea2011] C. Tropea, Optical particle characterization in flows. Annual Review of Fluid Mechanics, 43(1):399-426, Jan 2011

[Schäfer2014] Walter Schäfer and Cameron Tropea, "Time-shift technique for simultaneous measurement of size, velocity, and refractive index of transparent droplets or particles in a flow", Applied Optics 53, 4, Feb. 2014

[ABDT2002] H.-E. Albrecht, M. Borys, N. Damaschke, and C. Tropea, "Laser Doppler and Phase Doppler Measurement Techniques". Springer Berlin Heidelberg, 2002

[HAM-PMT] PHOTOMULTIPLIER TUBES Basics and Applications (CHAPTER 13: ENVIRONMENTAL RESISTANCE AND RELIABILITY), http://www.hamamatsu.com/resources/pdf/etd/PMT_handbook_v3aE-Chapter13.pdf

[HAM-Semi] Hamamatsu Photonics, OPTO-SEMICONDUCTOR HANDBOOK, Chapter 3 Si APD, MPPC, https://www.hamamatsu.com/resources/pdf/ssd/e03_handbook_si_apd_mppc.pdf

Application Report

MPPC/SiPM – the ultimate Photosensor?

MPPC (Multi-Pixel Photon Counter)/SiPM – the ultimate Photosensor?

Prof. Dr. Peter Seitz,
Hamamatsu Photonics

In 1946, the world's first general-purpose computer ENIAC was revealed to the astounded public. The ENIAC employed 17,478 vacuum tubes and it consumed 150 kW of electricity. Barely 20 years later, the first all-transistor desk-top calculators appeared on the market, and since then, nobody in their right mind is using vacuum tubes any more for building a computer.

In photosensing, the situation is completely different: The photomultiplier tube was invented in 1934, and already six years later, the first all-silicon photodiode was demonstrated in 1940. Despite the amazing progress of silicon technology since this time, millions of photomultiplier tubes (PMT) are still being sold every year. What is the reason behind this baffling fact, why have semiconductors not completely replaced PMTs until today, and are the recent developments of novel semiconductor devices such as silicon photomultipliers (Si-PM) heralding the demise of the vintage PMTs?

In order to understand all this, we need to go back to basics:
How can a semiconductor detect light? What limits this process, and what is the influence of the photocharge-detection electronics?
In the following discussion, we will consider only three main factors, as illustrated in the simple model of figure 1:

1. The conversion of incoming photons into mobile electron-hole pairs in a semiconductor
2. The transport of photocharges to the electronic detection circuit, including the possibility of charge multiplication on the way
3. The influence of the noise of the detector electronics on the precision of the photocharge measurement

Photosensing with semiconductors and the dark noise problem

Whenever electrons are sufficiently confined in space, they are not free any more to assume any energy state; rather their possible energy states are quantized and arranged in "allowed energy bands". In a semiconductor the situation is such that the electrons just fill up the highest occupied energy band, as illustrated in figure 2a. At zero temperature, the electrons are all bound to their atomic cores, and there are no mobile electrons for the conduction of current. This would take an amount of energy corresponding to at least the bandgap energy E_g to lift an electron from its bound energy state to a mobile energy state; thus a mobile electron-hole pair is created. There are two ways in which this energy can be supplied to the electrons: Either by thermal excitation or by incident photons. As a consequence, a semiconductor at temperature T always has a certain concentration of mobile electron-hole pairs, which is – in a simplified case – proportional to exp $(-E_g/(2kT))$, where k indicates Boltzmann's constant, $k = 1.381 \times 10^{-23}\ m^2\ kg\ s^{-2}\ K^{-1}$. This situation is illustrated in figure 2b, and it is the root cause of the famous "dark current": It is physically not possible to distinguish between a mobile electron that has been excited thermally and one that has been excited by an incident photon of sufficient energy, as illustrated in figure 2c.

Some readers might wonder why this discussion of semiconductors is pertinent for vacuum devices, since it is well known that PMTs are employing photocathodes. As it turns out, the best photocathodes are semiconductors, and PMTs experience therefore the same effects as any other kind of semiconductor photosensor, in particular also concerning dark current.

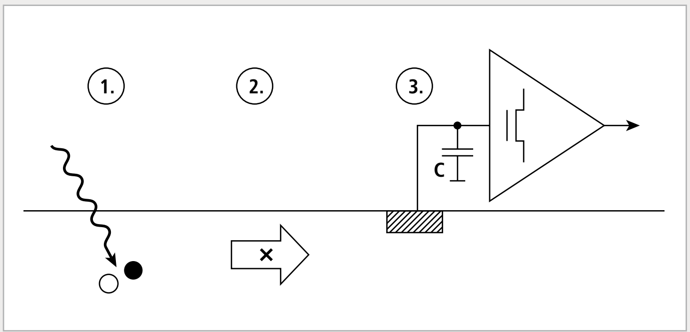


Figure 1: Simplified model of the main effects in a semiconductor photosensor
1. An incident photon with sufficient energy is converted into a mobile electron-hole pair.
2. The photogenerated mobile charges ("photocharges") are transported to the electronic charge detection circuit. On this way, the avalanche effect may multiply the transported charges.
3. At the detection node the charges to be measured are placed on the gate of the circuit's first transistor with the effective capacitance C of the detection node.

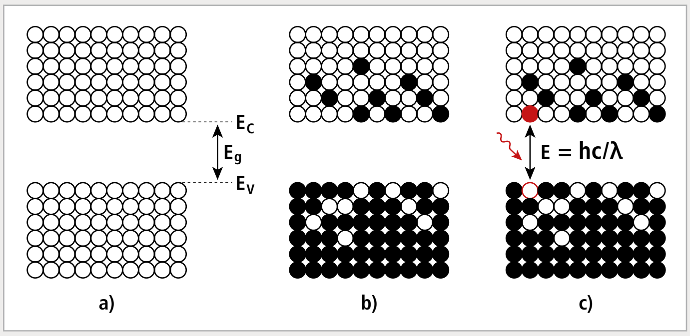


Figure 2: Energy band model of a semiconductor
a) At zero temperature the electrons fill the available energy state just to the highest value E_V (valence band). All electrons are bound to their core and no electric conductivity is possible.
b) At non-zero temperature the thermal energy is sufficient to excite some bound electrons into a mobile state in the conduction band above E_C, where they can contribute to the conduction of current. This process leaves a vacancy in the valence band behind, corresponding to a mobile hole.
c) If an incident photon with wavelength λ has an energy E = hc/λ that is larger than the bandgap $E_g = E_C - E_V$, the photon is absorbed and an additional electron is excited to a mobile energy state. However, there is no way this photo-excited electron can be distinguished from a thermally excited electron.

Looking at the exponential equation given above, it is immediately clear that there are three possible approaches to reduce the dark current in a photosensor:

1. Appropriate selection of the semiconductor material, so that the bandgap energy is as high as possible (for minimum dark current), but low enough that the incoming photos can still generate mobile electron-hole pairs (for sufficient quantum efficiency). As an example of how enormous the influence of the bandgap energy (and therefore the cutoff wavelength) is, consider the following three materials:

   The best silicon photosensors (for example the recent generation of Hamamatsu's MPPCs) show a dark current density of the order of 0.05 pA/cm^2 at room temperature. Silicon has a bandgap of 1.12 eV, corresponding to a cutoff wavelength of 1,107 nm.

   The photocathode type S-24 is a semiconductor with a bandgap of 1.80 eV, corresponding to a cutoff wavelength of 690 nm. An S-24 based PMT has a dark current density of as low as 3 x 10^{-7} pA/cm^2 at room temperature.

   In case infrared radiation must be sensed, a narrow-bandgap semiconductor such as InGaAs should be used. The bandgap of InGaAs is 0.73 eV, corresponding to a cutoff wavelength of 1,700 nm. A good InGaAs PIN photodiode such as Hamamatsu's G11193 series has a dark current density of about 105 pA/cm^2 at room temperature.

2. The dark current can be substantially reduced through cooling: In the case of silicon, the dark current is halved for every reduction of the temperature by about 80 deg. C. As a consequence, the dark current of a silicon-based photodetector can be reduced by an order of magnitude when the temperature is lowered by about 240 deg. C.

3. Since thermal excitation of the dark current occurs uniformly in the sensitive volume of the photosensor, one can significantly reduce the dark current by limiting the depth up to which the photosensor is still sensitive to incoming photons. This is particularly effective in PMTs, where the semiconductor photocathode is usually only a few 100 nm thick. However, this implies that the photosensor loses sensitivity and quantum efficiency. Obviously, there is a tradeoff to be made between quantum efficiency and dark current.

From the above it is very clear how the specifications of a photodetection problem influence the choice of optimum photosensor: The room-temperature dark current density of an excellent silicon-based photosensor can be around 0.05 pA/cm^2, which corresponds to about 312,000 electrons/cm^2/s. If the required photosensitive area in a low-light sensing problem is large (100 x 100 µm^2 or more), and the typical exposure time is long (seconds), then it is simply not possible to solve the problem with a silicon-based photosensor of any type. In such cases, PMTs with larger-bandgap semiconductor photocathodes are indispensable: Assuming that the photosensitive area is 1 cm^2, a PMT with S-24 photocathode would have a room-temperature dark count rate of less than 2 electrons per second.

Application Report

MPPC/SiPM – the ultimate Photosensor?

Electronic charge detection noise and the CMOS image sensor revolution

The purpose of the electronic charge detection circuit is to measure the amount of photogenerated charge Q and to produce an output signal – often a voltage – that is proportional to the charge Q. Whatever the details of the circuit are, the first stage always consists of a field effect transistor on whose gate the charge Q to be measured is placed. Due to the effective capacitance C at the gate of the transistor, the charge Q will change the gate voltage by the amount $\Delta V = Q/C$. This voltage change influences the current through the transistor, and this current is then processed further. Unfortunately, the current through a transistor's channel is not constant; rather it fluctuates statistically caused by the thermal motion of the charges in the channel, the so-called Johnson noise. If one calculates back to which charge noise σ_Q this current noise in the channel would correspond (so-called "input-referred charge noise"), one obtains the following equation:

$$\sigma_Q \approx C \sqrt{\frac{4kT\,B}{g_m}}$$

with the bandwidth B and the transistor's transconductance g_m.

It is obvious what can be done to reduce this input-referred charge noise: The most effective measure is to reduce the effective input capacitance C. However, the smaller C is, the lower the maximum (full-well) charge Q_{max}. In today's CMOS image sensors, a typical value of C = 1.6 fF corresponds to $Q_{max} = C\,\Delta V$ = 10,000 electrons, assuming a voltage swing of ΔV = 1 V. Therefore, reducing C to sub-fF levels would significantly impair image quality due to visible Poisson noise in the pixels.

Another possibility would be to reduce the temperature T. However, lowering the temperature from 300 K to 150 K only reduces the noise by a factor of 1.414, which is disappointingly small.

At first sight, it appears that also reducing the bandwidth B is not really an option because reducing B would imply also lowering the readout rate. This was true when CCD image sensors with one or only a very few output stages were employed, with a typical bandwidth B of several 10 MHz. The significant progress brought by CMOS image sensing (CIS) technology was the implementation of a low-pass filter in each column, so that the effective bandwidth for each column is of the order of only 100 kHz. This is the real revolution brought to the image sensing domain by CIS technology: In this way, careful "bandwidth engineering" in so-called sCMOS (scientific CMOS) image sensors leads to input-referred charge noise values of a fraction of one electron at room temperature (the current world record stands at $\sigma_Q \approx 0.22$ electrons r.m.s.).

It is obvious, sCMOS image sensors are capable of detecting a single photon! And given a large enough effective capacitance for the storage and measurement of the photogenerated charge, a dynamic range of 4-5 orders of magnitude is easily obtained!

But one thing is still exclusive: While it is possible with sCMOS imagers to detect whether a photon has arrived during the exposure time, the small bandwidth of the photocharge detection electronics makes it impossible to determine the exact time at which the photon arrived. This precise timing capability is the exclusive domain of photosensors with gain!

The avalanche effect and its use in APDs and SPADs

The transistor noise equation shown above makes it very clear that there is a tradeoff in electronic circuits between the detection noise and the detection speed: Only if we are ready to accept a long measurement time ("averaging") can single electrons/photons be detected. And if we want to be fast, our signal must consist of a relatively large packet of photoelectrons. As a consequence, the simultaneous detection of a single photon and its precise time of arrival necessitates a physical amplification mechanism which does not add much noise in the process; this multiplication is illustrated by the transport arrow with multiplication sign in figure 1. Fortunately, the avalanche effect is just what is required: A single photoelectron can be converted into a packet of electrons with arbitrary size. This multiplication takes place with subnanosecond speed, and with a timing precision of less than 10 ps. A PMT is the perfect device for this task. The exact arrival time of each individual photon can be detected thanks to the avalanche effect in a PMT.

The solid-state equivalent to the PMT is the APD, the avalanche photodiode. Unfortunately, the choice of semiconductor materials from which good APDs can be fabricated is much more restricted than the semiconductors for good photocathodes. As a consequence, PMTs are still irreplaceable if single photons must be detected with high timing precision over large areas.

However, the avalanche effect in semiconductor devices has a property that cannot be found in PMTs: While in PMTs only electrons are involved in the multiplication process, in semiconductors electron-hole pairs are involved. Because electrons and holes are moving in opposite directions in an electric field, the avalanche can become self-sustaining in an APD when the electric field surpasses a critical value. The voltage that needs to be applied to make this happen in an APD is the breakdown voltage V_{BR}, which is typically a few 10 V. When the voltage on an APD is below V_{BR}, the APD is operating in the so-called linear mode, with

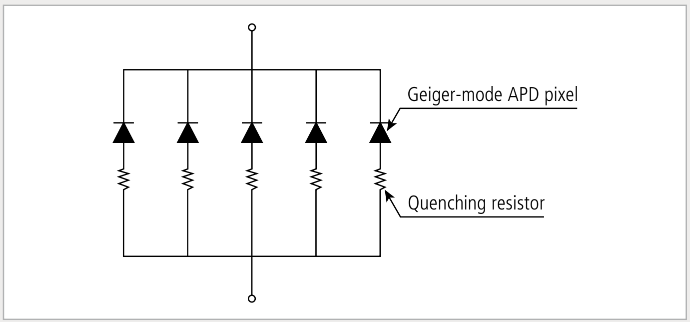


Figure 3: Construction of an MPPC (also called Si-PM), consisting of the parallel operation of several SPADs (APDs operated in Geiger mode), each provided with its own quenching resistor.

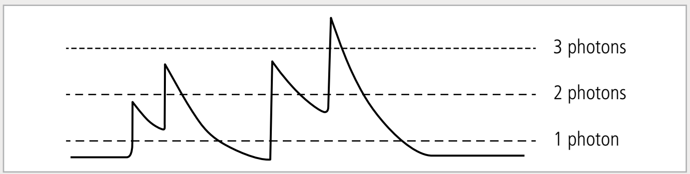


Figure 4: Typical signal of an MPPC, when several photons are impinging concurrently or shortly after each other. By exploiting the amplitude of the signal, it becomes possible to detect also the quasi-simultaneous incidence of several photons without any dead-time effects.

a voltage-dependent multiplication factor. When the voltage is above V_{BR}, the APD is operating in the Geiger mode, and it is then also called a SPAD (Single Photon Avalanche Device). In a SPAD, the incidence of a single photon is sufficient to produce a self-sustaining avalanche. This avalanche, triggered by a single photo-generated (or thermally excited) electron, would never stop, and we therefore need to put an end to it. This is accomplished with a "quenching circuit", which consists in the simplest case of a single resistor. During the time required to suppress the avalanche, the photodetector is not responding to incident photons. For this reason, this time is called "dead time". In the case of a simple quenching resistor, the dead time is typically several 10 ns long, while active quenching circuits can reduce the dead time to 10-20 ns.

From SPAD to MPPC and Si-PM

Although a dead-time of 50 ns (in the case of a quenching resistor) does not seem much, it can still be an important impediment for the use of SPADs in case the incident photon flux shows a large dynamic range: A SPAD cannot distinguish whether one or several photons were incident during the dead-time. In order to overcome this shortcoming of SPADs, so-called Silicon Photomultipliers (Si-PM) or MPPC (Multi-Pixel Photon Counters) were invented. As illustrated in figure 3, such an MPPC consists of several APDs, each with its own quenching resistor, connected in parallel and operated above the breakdown voltage. Whenever two photons are incident quasi-simultaneously, the current pulse at the output of the MPPC is twice as high as in the case of one incident photon. In this way it becomes possible to determine the number of incident photons by carrying out an electronic pulse-height analysis of the MPPC's output with a multi-threshold circuit, as illustrated in figure 4. As a consequence, an MPPC is not only capable of detecting the incidence of a single photon, while determining its exact time of arrival, it is also possible to make photon flux measurements with a very high dynamic range exceeding five orders of magnitude, i.e. D/R > 100 dB.

Of course, several MPPC devices can be arranged in a two-dimensional array, forming an MPPC image sensor. Such an MPPC imager shows ultimate single-photon sensitivity, it also provides exact time-of-arrival information, it has a high dynamic range, and the photon number information is already available in digital format. However, this almost-ideal performance comes at a price: Since each MPPC pixel requires its own multi-threshold pulse-height analysis electronics, time-to-digital converter (TDC), digital counters and memory cells, all this circuitry needs substantial floor space on the silicon beneath or on the side of a pixel's SPAD array. As a consequence, a typical digital MPPC pixel can have a pitch of the order of 100 µm. Since today's most advanced CMOS image sensors exhibit a pixel pitch of about 1 µm, it follows that 10,000 (analog) CMOS pixels fit on the same area as one (digital) MPPC pixel.

Summary: The optimum photosensor for your photonic measurement problem

Finally, we are able to answer the question with which we started: Despite the amazing advances of semiconductor technology over the past 60 years, there is still no universal solid-state photosensor, and there are still applications where PMTs are simply irreplaceable:

Today, all types of photosensors – PMT, sCMOS, APD, SPAD and MPPC – are capable of detecting the arrival of a single photon. In case a large number of very small – micron-sized – pixels is required, only sCMOS technology is an option. Conversely, when it is necessary to know also the exact arrival time of an individual photon, only PMT, APD, SPAD and MPPC solutions are possible. If a very large dynamic range of the time-of-arrival measurement capability is required, only PMT and MPPC technology can provide the necessary performance. In case a large photosensitive area, long exposure times, accurate time-of-arrival information and a high dynamic range are needed – and strong cooling is not permitted – only PMTs with suitable photocathode materials are an option. And MPPCs are the only possibility when image sensing with single-photon resolution, exact time-of-arrival determination, a high dynamic range, low power consumption and digital output in a single-chip solution are required.

SiPM for your application?

Try our MPPC/MPPC modules and find out!

MPPC modules

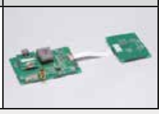
Analog output type

Type no.	Photo	Built-in MPPC	Photosensitive area	Pixel pitch	Photoelectric sensitivity	Noise equivalent power	Temperature control	Supply voltage
C13365-1350SA		S13360-1350CS	□1.3 mm	50 µm	1 x 10^9	0.5 fW/$Hz^{1/2}$	Temperature compensation (non-cooled)	±5 V
C13365-3050SA		S13360-3050CS	□3.0 mm			1.2 fW/$Hz^{1/2}$		
C13366-1350GA		TE-cooled type (MPPC for precision measurement)	□1.3 mm	50 µm		0.1 fW/$Hz^{1/2}$	TE-cooled (-20 deg. C.)	±5 V
C13366-3050GA			□3.0 mm			0.15 fW/$Hz^{1/2}$		

Digital output type

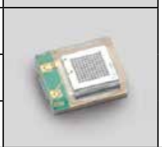
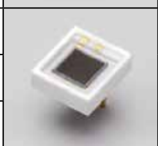
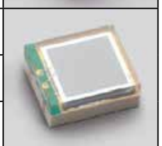
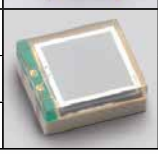
Type no.	Photo	Built-in MPPC	Photosensitive area	Pixel pitch	Photo detection effi ciency (%)	Dark count	Temperature control	Supply voltage
C13366-1350GD		TE-cooled type (MPPC for precision measurement)	□1.3 mm	50 µm	40	2.5 kcps	TE-cooled (-20 deg. C.)	±5 V
C13366-3050GD			□3.0 mm			15 kcps		

Starter kit

Type no.	Photo	Temperature control	Supply voltage	Features
C12332-01		Temperature compensation (non-cooled)	±5 V	■ Evaluates any non-cooled MPPC (sold separately) ■ Includes C11204-01 power supply for MPPC ■ Measurable just by setting MPPC operating voltage from PC

MPPC

Digital output type

Type no.	Photo	Photosensitive area	Pixel pitch	Package
S13360-1325CS		□1.3 mm	25 µm	Ceramic
S13360-1350CS			50 µm	
S13360-1375CS			75 µm	
S13360-1325PE			25 µm	Surface mount type
S13360-1350PE			50 µm	
S13360-1375PE			75 µm	
S13360-3025CS		□3.0 mm	25 µm	Ceramic
S13360-3050CS			50 µm	
S13360-3075CS			75 µm	
S13360-3025PE			25 µm	Surface mount type
S13360-3050PE			50 µm	
S13360-3075PE			75 µm	
S13360-6025CS		□6.0 mm	25 µm	Ceramic
S13360-6050CS			50 µm	
S13360-6075CS			75 µm	
S13360-6025PE			25 µm	Surface mount type
S13360-6050PE			50 µm	
S13360-6075PE			75 µm	

www.hamamatsu.com/us/en/community/mppc/index.html

NEW

InAsSb Photovoltaic Detector P13894 Series

InAsSb (indium arsenide antimonide) photovoltaic detector with high sensitivity achieved in the spectral range up to 11 μm

The P13894 series are infrared detectors that have achieved high sensitivity and high-speed response in the spectral range up to 11 μm using Hamamatsu unique crystal growth technology and process technology. They provide a wider dynamic range than the previous products. They are compact and easy to handle.

Differences from previous products

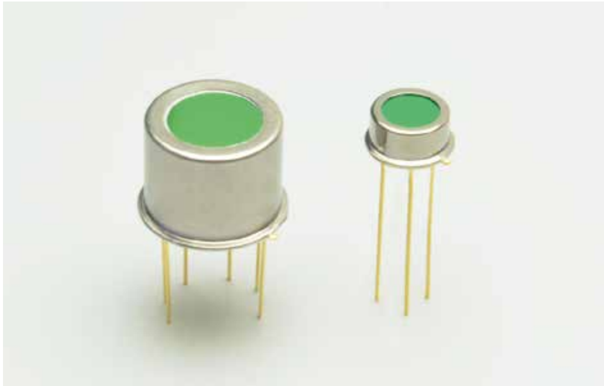
It covers a wider spectral range than the previous InAsSb photovoltaic detectors (spectral response range: 2.5 to 8 μm).

Features

- Spectral response up to 11 μm (P13894-011MA)
- RoHS compliant
- Wide dynamic range
- High-speed response

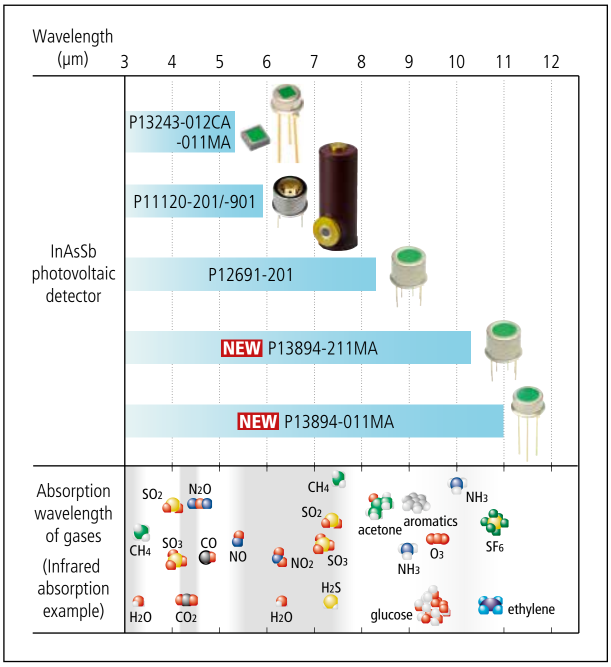
Applications

- Gas detection (NH_3, O_3, etc.)
- FTIR
- CO_2 laser monitor
- Temperature measurement



Left: P13894-211MA, right: P13894-011MA

Lineup



Specifications

Parameter	P13894-211MA	P13894-011MA	Unit
Cooling	2-stage TE-cooled	Non-cooled	-
Photosensitive area	1 x 1		mm
Cutoff wavelength	10.2	11	μm
Peak sensitivity wavelength	5.6		μm
Photosensitivity*1	3.8	1.9	mA/W
Shunt resistance*2	10	2	kΩ
Detectivity*3	3.2×10^8	6.5×10^7	$cm \cdot Hz^{1/2}/W$
Rise time*4	3		ns

*1 $\lambda = 5.6$ μm
*2 $V_R = 10$ mV
*3 $\lambda = 5.6$ μm, f = 1200 Hz, $\Delta f = 1$ Hz
*4 10 to 90 %, no window, $\lambda = 1.55$ μm

Infrared LED
L13771-0330C, L13454-0390C, L13201-0430C

NEW

Mid-infrared LED in ceramic package

These are high-output mid-infrared LEDs with peak emission wavelength from 3 to 5 µm. They have been achieved using Hamamatsu unique crystal growth technology and process technology. They are suitable light sources for CO_2 and CH_4 detectors.

Features

- Peak emission wavelength
  - 3.3 µm (L13771-0330C)
  - 3.9 µm (L13454-0390C)
  - 4.3 µm (L13201-0430C)
- High radiant power output
- High-speed response
- Low power consumption

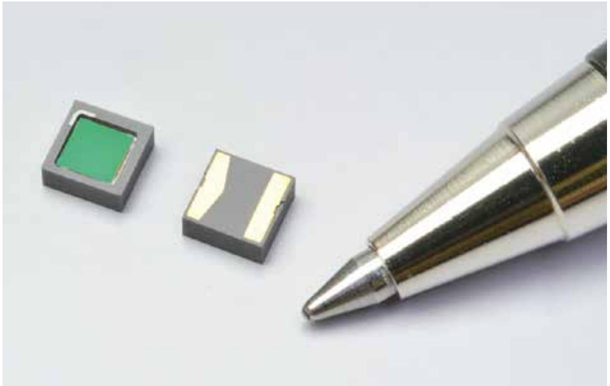
Applications

- CH_4, CO_2 measurement
- CO_2 detectors

Specifications

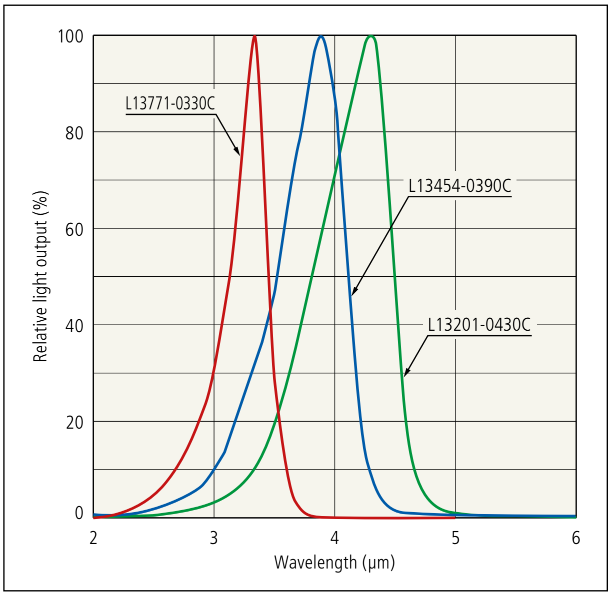
Parameter	L13771-0330C	L13454-0390C	L13201-0430C	Unit
Peak emission wavelength*1	3.3	3.9	4.3	µm
Spectral half width*1	300	500	700	nm
Radiant flux*1	0.25	0.2	0.3	mW
Forward voltage*1	2.1	1.7	1.6	V
Reverse current*2 max.	500	1,000	1,000	µA
Rise time*3		1		µs

*1 I_F = 50 mA (L13771-0330C), QCW mode
I_F = 80 mA (L13454-0390C, L13201-0430C), QCW mode
*2 V_R = 0.1 V
*3 10 to 90 %



L13771-0330C, L13454-0390C, L13201-0430C

Emission spectrum (Typ. Ta = 25 deg. C.)



NEW

Distance Linear Image Sensor S12973-01CT

Measures the distance to an object by TOF (time-of-flight) method

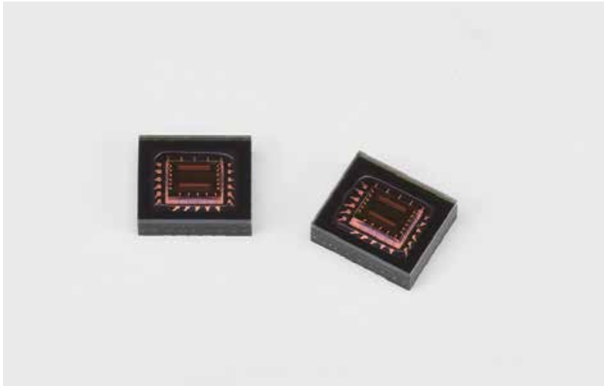
The distance image sensor is designed to measure the distance to an object by TOF method. When used in combination with a pulse modulated light source, this sensor outputs phase difference information on the timing that the light is emitted and received. The sensor signals are arithmetically processed by an external signal processing circuit or a PC to obtain distance data.

Features

- High-speed charge transfer
- Wide dynamic range, low noise by non-destructive readout
- Operates with minimal detection errors even under fluctuating background light (charge drain function)
- Real-time distance measurement

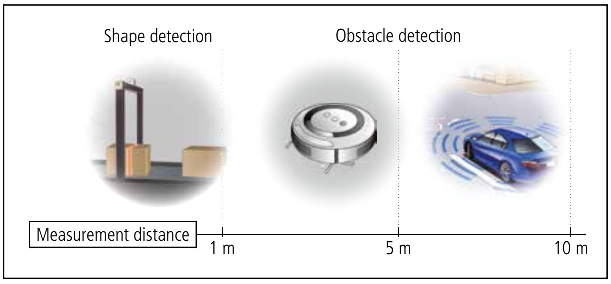
Applications

- Obstacle detection (self-driving, robots, etc.)
- Security (intrusion detection, etc.)
- Shape recognition (logistics, robots, etc.)
- Motion capture



S12973-01CT

Application example



Lineup

Parameter	NEW S12973-01CT	S11961-01CR	S11962-01CR	S11963-01CR	Unit
Type	Linear		Area		-
Number of pixels	64	256	64 x 64	160 x 120	pixels
Pixel pitch	22	20	40	30	μm
Pixel height	50		40	30	μm

CCD Image Sensor S11511 Series

NEW

Enhanced near infrared sensitivity

The S11511 series is a family of FFT (full frame transfer)-CCD image sensors for photometric applications that offer improved sensitivity in the near infrared region at wavelengths longer than 800 nm. In addition to having high infrared sensitivity, the S11511 series can be used as an image sensor with a long photosensitive area in the direction of the sensor height by binning operation, making it suitable for detectors in Raman spectroscopy.

Differences from previous products

Our unique technology in laser processing was used to form a MEMS structure on the back side of the CCD. This allows the S11511 series to have much higher sensitivity than our previous products (S11850 series).

Features

- NIR high sensitivity: QE = 40 % (λ = 1,000 nm)
- One-stage TE-cooled type (chip temperature: approx. 5 deg. C.)
- High CCD node sensitivity: 6.5 μV/e⁻
- High full well capacity, wide dynamic range (with anti-blooming function)

Applications

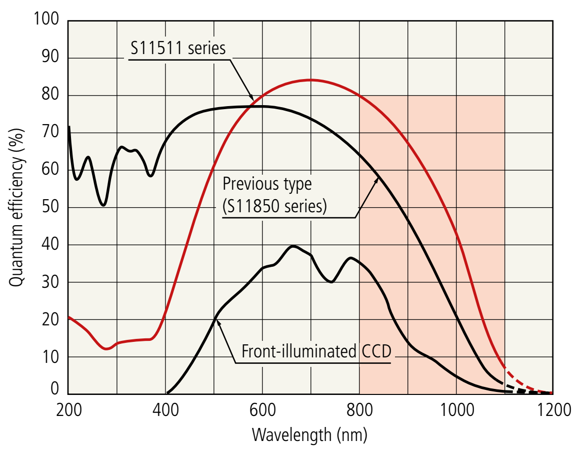
- Raman spectrometers

Specifications

Parameter	S11511-1006	S11511-1106	Unit
Effective number of pixels	1,024 x 64	2,048 x 64	pixels
Image size (H x V)	14.336 x 0.896	28.672 x 0.896	mm
Pixel size (H x V)	14 x 14		μm
Spectral response range	200 to 1,100		nm
Full well capacity (Horizontal)	300		ke⁻
Dark current (MPP mode)	50		e⁻/pixel/s

S11511 series

Spectral response (without window) (Typ. Ta = 25 deg. C.)



Spectral response with quartz glass is decreased according to the spectral transmittance characteristic of window material.

NEW

Photomultiplier Tube R9110-04

High gain and high S/N R9110 version – ideal for microscopy applications

The R9110-04 is a 28 mm (1-1/8 inch) diameter side-on photomultiplier tube. It delivers both high sensitivity and low dark current at the same time to allow upgrading to a higher S/N photodetector without changing current usage conditions.

Differences from previous products

Delivers both higher sensitivity and lower dark current at the same time.

Features

- High gain
- High S/N

Applications

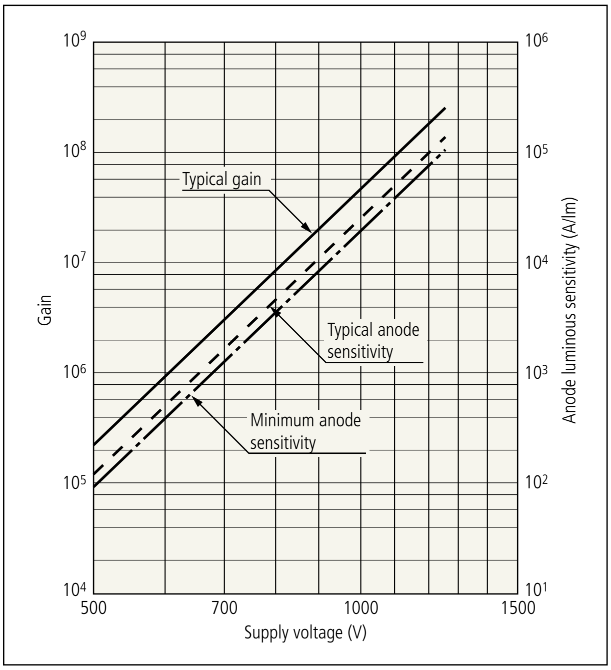
- Scanning fluorescence microscope

R9110-04

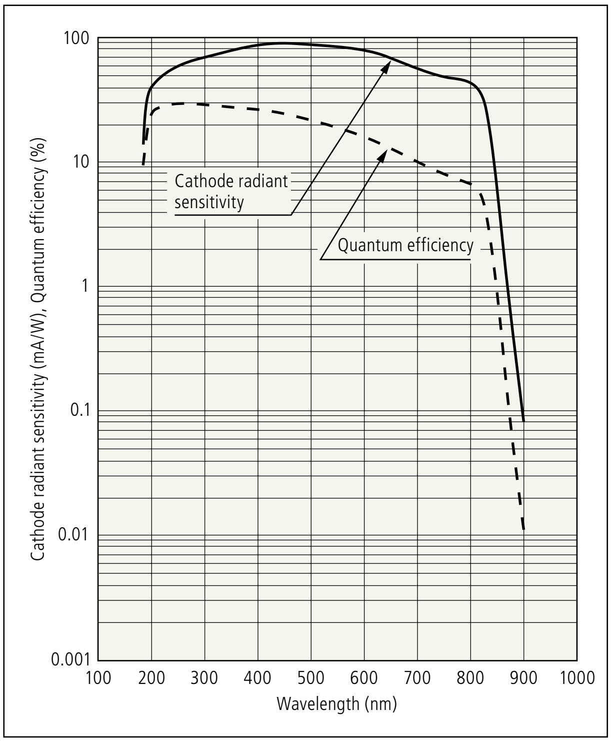
Specifications

Parameter	Specification	Unit
Gain	4.8×10^7	-
Dark current at 1,000 V	5	nA
Spectral response range	185 ~ 900	nm
Radiant sensitivity at 450 nm	90	mA/W
Quantum efficiency at 450 nm	25	%

Anode luminous sensitivity and gain characteristics



Spectral response characteristics



Linear Irradiation Type UV-LED Unit LIGHTNINGCURE® LC-L5G

NEW

High output UV-LED that can be used to replace metal halide lamps – helps reduce the running cost of equipment using UV light sources

GL Series

GL-120 L13341-1205/-2305 **GL-150C** L13750-2306-004/-3306-004
GL-250 L13341-1210/-2310 **GL-430** L13341-1217/-2317

GL series can replace metal halide lamps thanks to enhanced UV light output!

The GL series is a UV light source ideal for drying and curing UV inks, UV coatings, and UV adhesives. The GL series is compact, lightweight, and fan air-cooled, yet offers high UV intensity. The GL series will simplify the design and operation of equipment for applications where high UV power is required or workpieces are transported on high-speed conveyors.

Features

- Fan air-cooling
- Compact and lightweight
- High output: 10 W/cm^2 (at 385 nm) [GL-120/250/430]
- High integrated light intensity [GL-150C]
- Connectable operation of multiple light sources [GL-150C]
- Long shapes [GL-430]

Applications

- UV ink drying
- UV coating drying
- UV adhesive curing
- Light source for fluorescence excitation/flaw inspections

GL-120

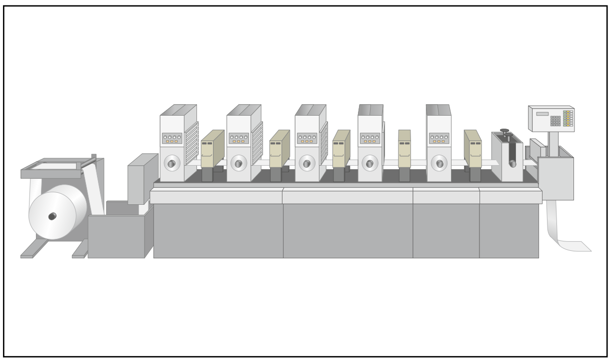
GL-150C

GL-430

Specifications

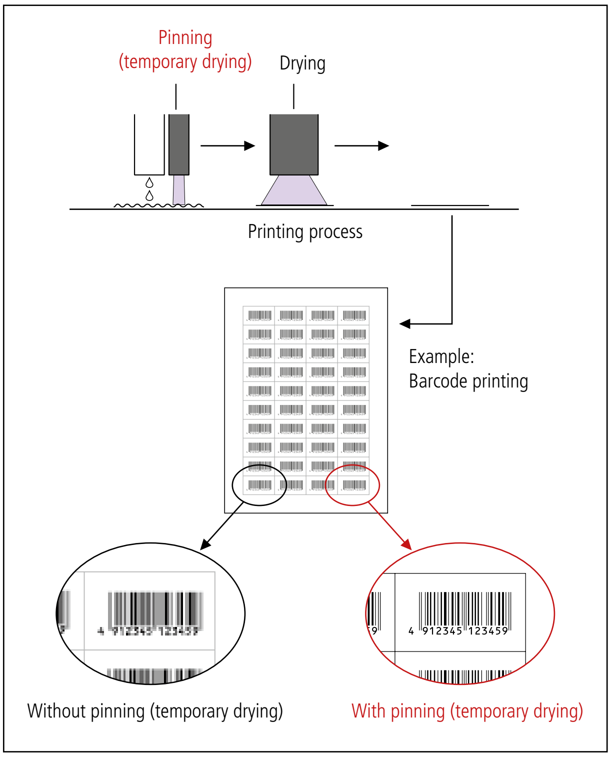
Parameter	GL-120		GL-150C		GL-250		GL-430		Unit
Irradiation area*1	120 x 15		150 x 50		250 x 15		430 x 15		mm
UV irradiance*2	6	10	4	4	6	10	6	10	W/cm^2
Wavelength	365	385	385	395	365	385	365	385	nm
Input voltage (DC)	48		48		48		48		V
Power consumption (Max.)	900		900		1,750		2,900		W
Dimensions (WxHxD)	153 x 200 x 100		152 x 200 x 100		320 x 210 x 100		520 x 210 x 100		mm
Connectable operation	–		○		–		–		–

*1 Area irradiated at a distance 2 mm from the light source.
*2 Maximum UV radiant power within area irradiated at a distance 2 mm from the light source.



GP-75

GC-77



GP Series / GC Series

GP-75 L13342-1203-003/-2203-004/-3203-004/-4203-004
GC-77 L13343-1203-003/-2203-004/-3203-004/-4203-004

Narrow UV irradiation angle reduces ink and adhesive clogging

The GP series and GC series are UV light sources ideal for drying and curing UV inks, UV coatings, and UV adhesives. With its compact and lightweight design, the GP-75 can be easily installed even in narrow spaces; and the GC-77 can operate with two or more units connected to each other. These features allow use in a wide range of equipment, from small to large devices.

Features

- Compact and lightweight
- Fan air-cooling
- Narrow irradiation angle
- Connectable operation of multiple light sources [GC-77]

Applications

- UV ink drying/pinning (temporary drying)
- UV coating drying
- UV tape peeling
- UV adhesive curing/temporary curing
- Light source for fluorescence excitation/flaw inspections

Specifications

Parameter	GP-75		GC-77				Unit
Irradiation area*1	75 x 5		77 x 5				mm
UV irradiance*2	2		2				W/cm²
Wavelength	365	395	365	385	395	405	nm
Input voltage (DC)	48		48				V
Power consumption (Max.)	45	40	45	40			W
Dimensions (WxHxD)	77 x 140 x 24		77 x 140 x 24				mm
Connectable operation	–		○				–

*1 Area irradiated at a distance 2 mm from the light source.
*2 Maximum UV radiant power within area irradiated at a distance 2 mm from the light source.

Flat Panel PMT Array H13974

NEW

Large sensitive area from 2 x 2 array of flat panel PMTs. Custom arrays (M x N) also available on request

The H13974 is a flat panel PMT 2 x 2 array. The four flat panel PMTs operate on a single power supply. The anode sensitivity of each flat panel PMT is uniformly pre-adjusted.

Differences from previous products

Provides a larger sensitive area.

Features

- Minimal dead area (effective area ratio: 84 %)
- Large sensitive area
- 16 x 16 (256 channels) pixels
- All channels are capable of detecting single photon peaks

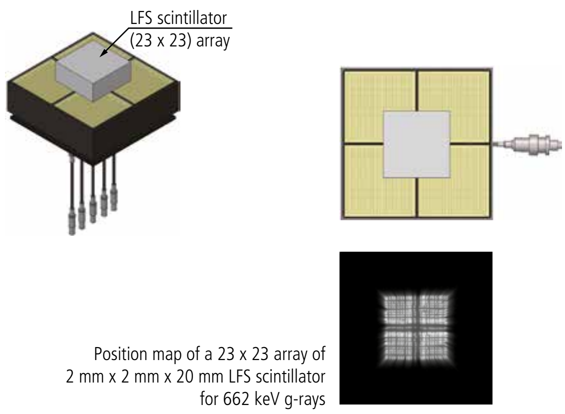
Applications

- Academic research (neutron imaging)
- Medical imaging (CT, gamma camera, etc.)
- Radiation measurement

H13974

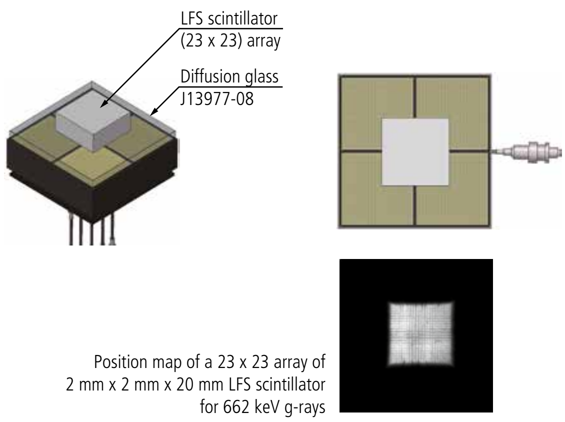
Position map examples

H13974 + LFS* scintillator + signal read-out board E13975



Position map of a 23 x 23 array of 2 mm x 2 mm x 20 mm LFS scintillator for 662 keV g-rays

H13974 + LFS scintillator + diffusion glass J13977-08 + signal read-out board E13975



Position map of a 23 x 23 array of 2 mm x 2 mm x 20 mm LFS scintillator for 662 keV g-rays

*LFS: Lutetium Fine Silicate

Specifications

Parameter	H13974-00-1616	H13974-03-1616	Unit
Spectral response range	300 ~ 650	185 ~ 650	nm
Photocathode type	Bialkali		-
Effective area ratio	84		%
Anode type	16 x 16 matrix (256 channels)		-
Effective photosensitive area (minimum)	48.5 x 48.5 (x 4)		mm
Anode pitch (within PMT)	6		mm
Anode pitch (between PMT)	9		mm

NEW

Photosensor Module H13543

Contains a 25 mm (1 inch) square envelope photomultiplier tube

The H13543 is a current-output photosensor module that contains a 25 mm (1 inch) square envelope photomultiplier tube and high-voltage power supply. The output signal is extracted via cable.

Differences from previous products

A new type with a green sensitivity (550 nm) enhanced photocathode was added to the product lineup.

Features

- Contains a square envelope photomultiplier tube
- Compact size (short overall length)
- High linearity

Applications

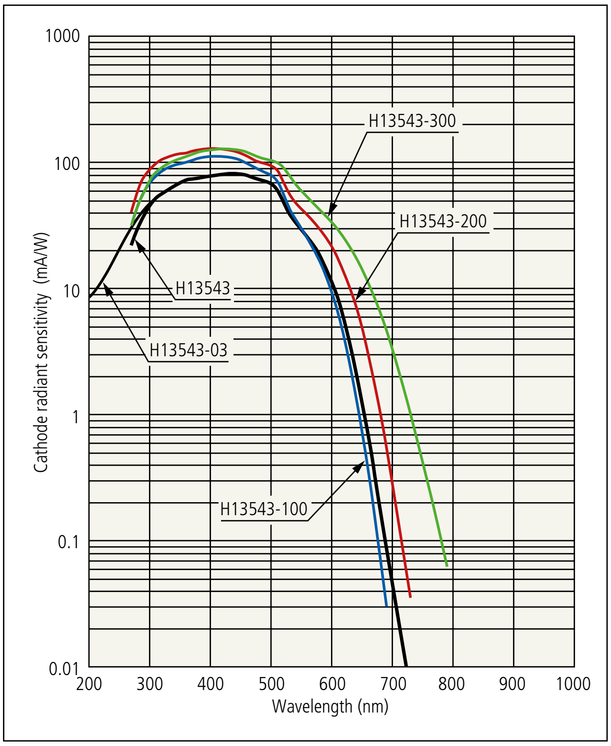
- Radiation measurement

H13543

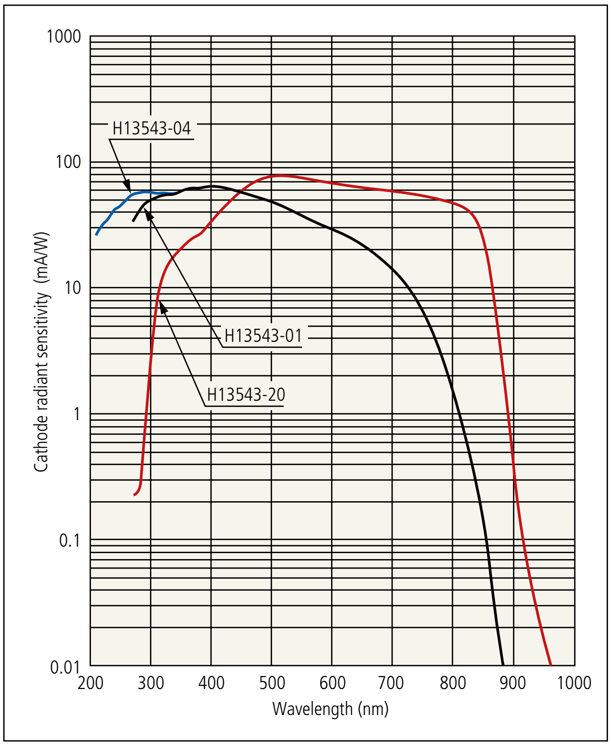
Specifications

Parameter	Specification	Unit
Input voltage	+5	V
Maximum input current	5	mA
Maximum output current	100	µA
Effective area	18 x 18	mm
Ripple noise (p-p) (maximum)	0.5	mV
Settling time	10	s

Spectral response



Spectral response



Counting Unit C13182-01

NEW

Count rate more than 10 times higher than previous products – ideal for use with HPD (hybrid photo-detector)

The C13182-01 is a high-speed counter with a USB interface. Combining this unit with a high-speed amplifier allows configuring a high-speed photon counter that measures random pulses at a count rate of 5 x 10^7 or more (count loss: 10 %).

Differences from previous products

Count rate is more than 10 times higher than previous products.

Features

- Maximum count rate: 5 x 10^7 s^{-1}
- Double counter method allows measurements with no dead time

Applications

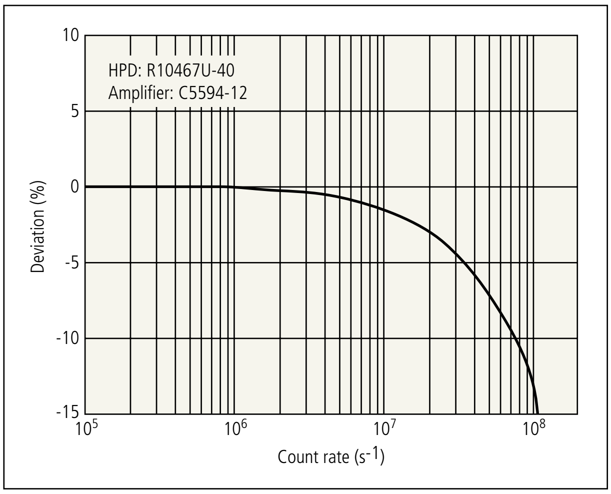
- Photon counting using a high-speed photodetector (HPD, high-speed PMT)

C13182-01

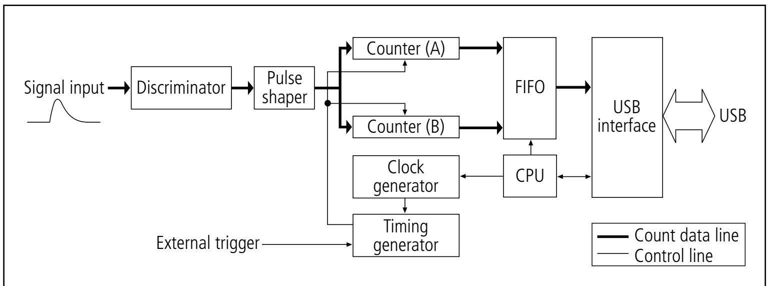
Specifications

Parameter	Specification
Number of input signals	1
Signal input level	+50 mV ~ +1.2 V
Pulse pair resolution	2 ns
Maximum count rate (Randum, at 10 % count loss)	5 x 10^7 s^{-1}
Counter gate time	1 μs ~ 10 s (1, 2, 5 step)
Interface	USB 2.0

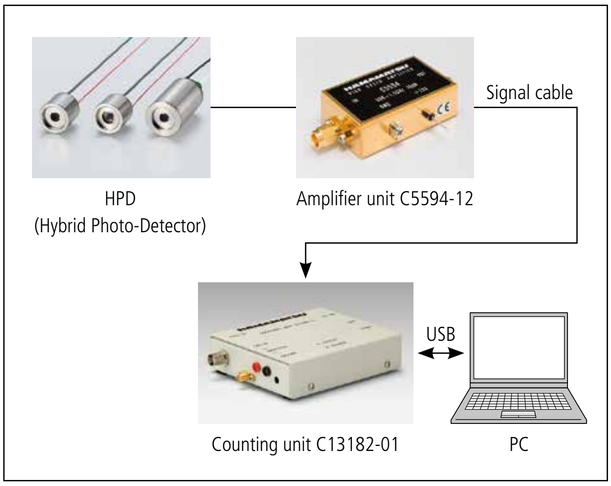
HPD: R10467U-40 Count linearity



C13182-01 Internal block diagram



Setup example



NEW

Photomultiplier Tube Cooler C12473

Cooling capability of 25 deg. C. (ΔT)

The C12473 is a forced air-cooled thermoelectric cooler designed for 25 mm (1 inch) diameter head-on photomultiplier tubes.

Differences from previous products

Compact, easy-to-handle cooler is now available for the first time for 25 mm (1 inch) head-on photomultiplier tubes.

Features

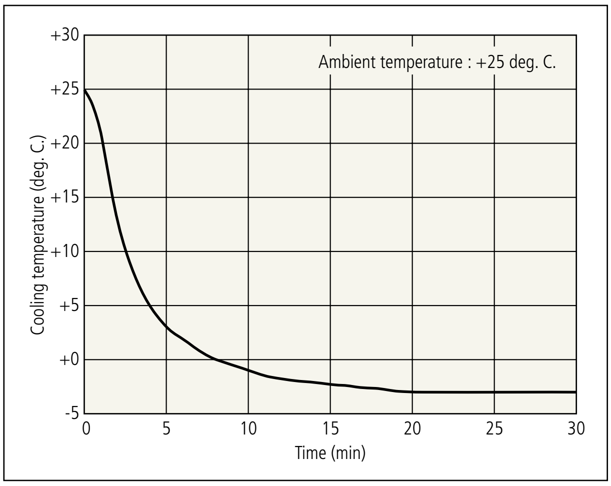
- Cooling capability: 25 deg. C. (ΔT)
- Time to reach stable cooling: 30 minutes
- Compact size
- Built-in temperature sensor

Applications

- Low-light-level measurements
- NOx measurements

C12473

Cooling characteristics



Specifications

Parameter	Specification	Unit
Cooling method	Thermoelectric cooling (Peltier module)	-
Heat dissipation method	Forced air cooling	-
ΔT (minimum)	25	deg. C.
Time required to reach thermal equilibrium	Approx. 30	minutes
Applicable photomultiplier tubes (sold separately)	R1924A, R3550A, R1925A, R5070A, R11265-100, R11265-200, R11265-300, R11265-20	-

Medical Life Science Drug Discovery Measurement Analytical Semicon Prod. Optical Comms Security Industry ND inspection Academic Res.

High-Voltage Power Supply Module C13145-01

NEW

High-voltage power supply module with 8 channel outputs

The C13145-01 is a high-voltage power supply module for photomultiplier tubes designed for mounting into equipment and providing 8-channel outputs (1,000 V at 1 mA per channel).

Differences from previous products

Provides independent 8-channel voltage outputs each of which is separately adjustable. The outputs can be controlled by external input (0 to +5 V) or by just adjusting the internal variable resistors.

Features

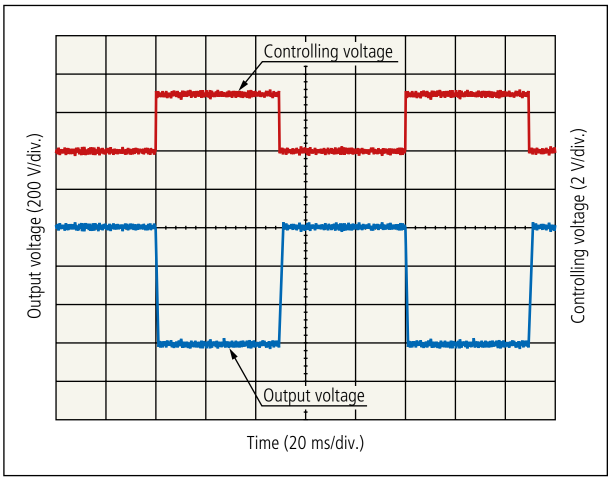
- 8 channel outputs
- -1,000 V/1 mA output
- High-speed response
- Low ripple/noise

Applications

- Equipment using multiple photomultiplier tubes (flow cytometers, microscopes, etc.)

C13145-01

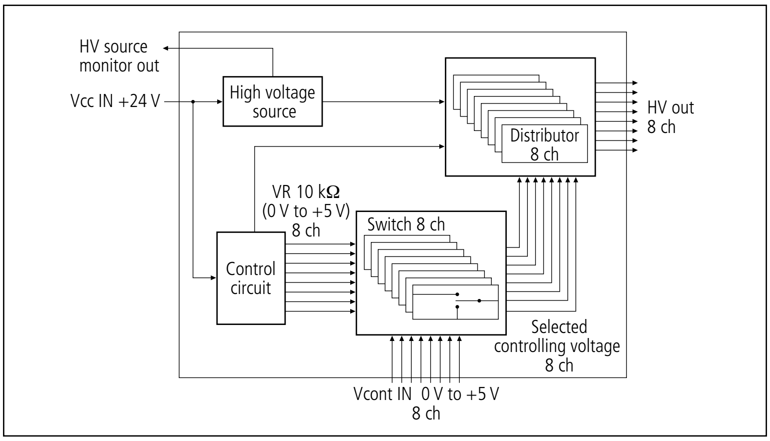
Time response characteristics



Specifications

Parameter	Specification	Unit
Input voltage	+24	V
Maximum output voltage	-1,000	V
Maximum output current	1/ch	mA
Ripple/noise (p-p)	20	mV
Output voltage rise time	5	ms

Time response characteristics



InGaAs Camera C14041-10U

NEW

High sensitivity in the near infrared region from 950 nm to 1700 nm

C14041-10U

The C14041-10U is an InGaAs camera with high sensitivity in the near infrared region from 950 nm to 1,700 nm. It has a USB 3.0 interface port which supports 14 bit image acquisition and exposure time adjustment. This makes the C14041-10U ideal for use in a wide range of applications including internal inspection of silicon wafers and devices, laser beam alignment and evaluation of solar cells.

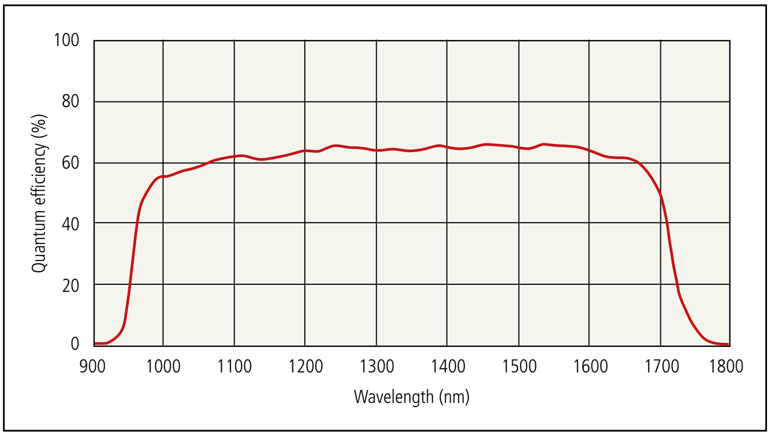
Features

- High sensitivity in the near infrared region from 950 nm to 1,700 nm
- 320 x 256 pixels
- Low noise and high stability with cooling
- High image quality rolling shutter mode and the global shutter mode capable of simultaneous exposure to the entire screen mounted
- Frame rate of approx. 216 frames/s (rolling shutter mode)

Applications

- Internal inspections of silicon wafers and devices
- Evaluation of solar cells
- Evaluation and analysis of optical communication devices
- EL/PL image acquisition

Spectral response



W-VIEW GEMINI-2C Image Splitting Optics A12801-10

NEW

Simultaneous dual color imaging with super resolution performance

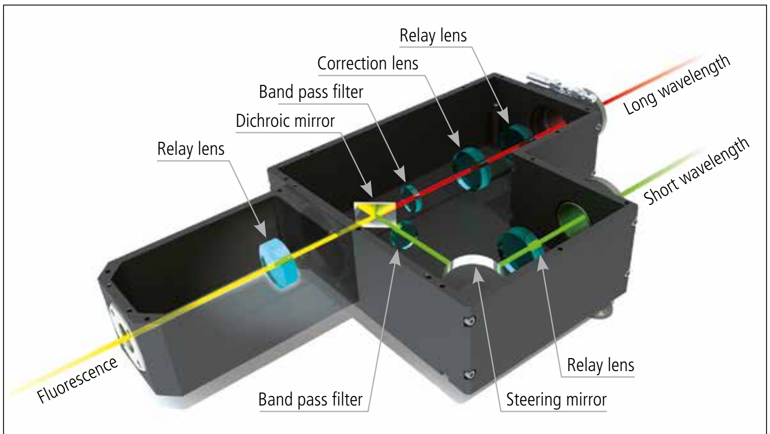
The W-VIEW GEMINI-2C is an image splitting optics for microscopes which provides one pair of dual color light images separated by a dichroic mirror onto two cameras. With the newly designed lenses, color shift of dual images due to chromatic magnification aberration and optical distortion are minimized to the single pixel level. The W-VIEW GEMINI-2C demonstrates ample performance for simultaneous dual color imaging in super resolution microscopy.

Features

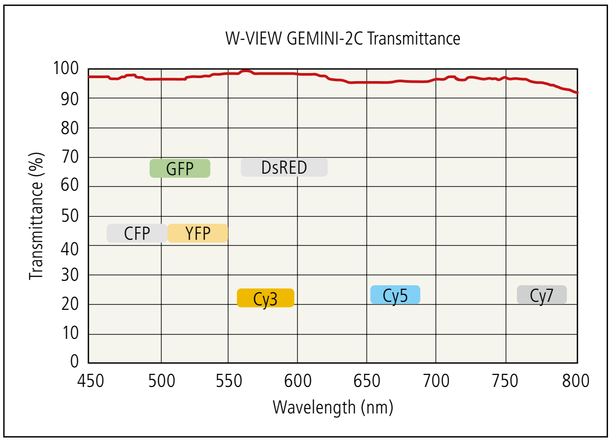
- Simultaneous dual color imaging in super resolution microscopy
- High uniformity
- User-friendly alignment
- Single pixel level color shift
- PSF engineering (Option)

A12801-10

Conceptual diagram of light passage



Spectral Response



ORCA®-Flash4.0 V3 Digital CMOS Camera C13440-20CU

NEW

Realized breakthrough scientific imaging with high speeds and resolution

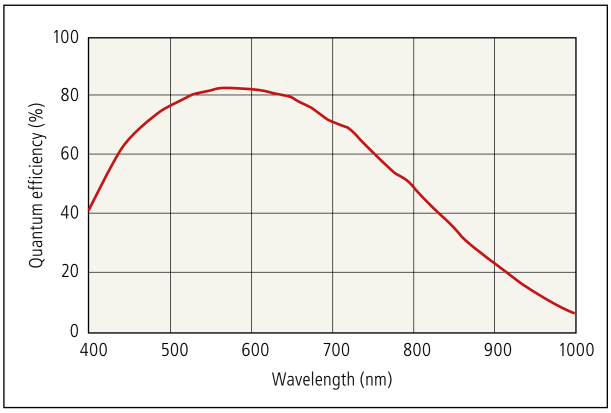
The ORCA-Flash4.0 series are the cameras that realized simultaneously low camera noise, high resolution, and high speed readout with the scientific CMOS sensors. Our ORCA-Flash4.0 V3 has additional functions such as high contrast mode to improve displayed image quality and others, which can be used in various application fields such as fluorescence live-cell imaging, food internal inspection, X-ray imaging and so on.

C13440-20CU

Features

- High quantum efficiency 82 % (Peak QE)
- Low noise
  - 0.8 electrons (Slow scan mode, 30 frames/s)
  - 1.0 electrons (Standard scan mode, 100 frames/s)
- High speed readout
  - 100 frames/s (Camera Link)
  - 80 frames/s (USB 3.0/8 bit)
  - 53 frames/s (USB 3.0/12 bit)
- High resolution 4-megapixel

Spectral response



Flexibility for Customized Data Control

Like its predecessors, each ORCA-Flash4.0 V3 is capable of both USB 3.0 and Camera Link output. In addition, the ORCA-Flash4.0 V3 offers data reduction through user-controllable look up tables (LUT) for 12 or 8-bit output. These two choices, combined with region of interest selection, enable you to fine tune acquisition speed and image data requirements.

Specifications

Region of Interest*1	Output Bit Depth	Camera Link frames per second*2	USB 3.0 frames per second*2
2,048 x 2,048	16	100	40
	12	100	53
	8	100	80
2,048 x 1,024	16	200	80
	12	200	106
	8	200	160
2,048 x 512	16	400	160
	12	400	212
	8	400	320
2,048 x 8	16	25,655	9,329
	12	25,655	12,827
	8	25,655	17,103

*1 Pixels centered on chip, horizontal x vertical
*2 In standard scan mode

Global Exhibitions 2017

USA

April 2017

SPIE Defense & Commercial Sensing
April 9-13 2017, Anaheim, CA

InPrint
April 25-27 2017, Orlando, FL

May 2017

BIOMEDevice
May 3-4 2017, Boston, MA

CLEO
May 4-19 2017, San Jose, CA

Pathology Informatics Summit
May 22-24 2017, Pittsburgh, PA

June 2017

ASMS
June 4-8 2017, Indianapolis, IN

CYTO
June 10-14 2017, Boston, MA

Sensors Expo
June 27-29 2017, San Jose, CA

July 2017

Digital Pathology Congress USA
July 11-12 2017, Chicago, IL

Semicon West
July 11-13 2017, San Francisco, CA

August 2017

SPIE Optics & Photonics
Aug 6-10 2017, San Diego, CA

September 2017

PRINT
Sept 10-14 2017, Chicago, IL

CAMX
Sept 11-14 2017, Orlando, FL

World Molecular Imaging Congress
Sept 13-16 2017, Philadelphia, PA

ASTRO
Sept 24-27 2017, San Diego, CA

Europe

April 2017

EACTA
April 19-21 2017, Berlin, Germany

Technology HUB 2017
April 20-22 2017, Milano, Italy

UKP
April 26-27 2017, Aachen, Germany

CAM Workshop
April 26-27 2017, Halle, Germany

2nd joint SFBD/SBCF meeting
April 26-29 2017, Lyon, France

May 2017

A&T 2017
May 3-5 2017, Torino, Italy

Elektronik i fordon
May 9-10 2017, Gothenburg, Sweden

Vårmöte i patologi
May 9-12 2017, Malmö, Sweden

IPAC
May 14-19 2017, Copenhagen, Denmark

Mirsens
May 15-17 2017, Wroclaw, Poland

TEC
May 18 2017, Warsaw, Poland

Optics & Photonics Days 2017
May 19-21 2017, Oulu, Finland

SPS-IPC Drives Italia 2017
May 23-25 2017, Parma, Italy

43rd European Congress of Lymphology (ESL)
May 26-27 2017, Stuttgart, Germany

E-MRS
May 26-29 2017, Strasbourg, France

PSMR 2017
May 29-31 2017, Lisbon, Portugal

Sensor und Test
May 30-June 1 2017, Nuremberg, Germany

UK Space Conference
May 30-June 1 2017, Manchester, England

Les Journées COFREND
May 30-June 2 2017, Strasbourg, France

June 2017

118. Jahrestagung der DGaO
June 6-10 2017, Dresden, Germany

IoT – Internet of Things Event
June 7-8 2017, Eindhoven, Netherlands

automation & electronics
June 7-8 2017, Zurich, Switzerland

Chii
June 7-8 2017, Graz, Austria

Smart Manufacturing Summit
June 7-8 2017, Orly, France

FDSS USERS MEETING
June 8 2017, Chilly Mazarin, France

2. Histologica
June 9-10 2017, Oberhausen, Germany

ICNIRS
June 11-15 2017, Copenhagen, Denmark

Photonics Event
June 14 2017, Veldhoven, Netherlands

Congrès AFH
June 22-23 2017, Nantes, France

101. Jahrestagung der Dt. Gesellschaft für Pathologie
June 22-24 2017, Erlangen, Germany

25. Jahrestagung der Arbeitsgemeinschaft Dermatologische Histologie (ADH)
June 23-25 2017, Stuttgart, Germany

Laser World of Photonics
June 26-29 2017, Munich, Germany

July 2017

Microscience Microscopy Congress (MMC)
July 3-6 2017, Manchester, England

8th NDIP
July 3-7 2017, Tours, France

ConCarExpo
July 5-6 2017, Berlin, Germany

19th IUPAB & 11th EBSA Congress
July 16-20 2017, Edinburgh, Scotland

August 2017

Microscopy Conference 2017
Aug 21-25 2017, Lausanne, Switzerland

September 2017

ECP
Sept 2-6 2017, Amsterdam, Netherlands

17th Congress of the European Society for Photobiology
Sept 4-8 2017, Pisa, Italy

MAF15
Sept 10-13 2017, Bruges, Belgium

Abercrombie Meeting 2017
Sept 12-13 2017, Oxford, England

MipTec
Sept 12-14 2017, Basel, Switzerland

XNPIG2017
Sept 12-15 2017, Zurich, Switzerland

Herbsttagung Pathologie
Sept 14-16 2017, Casineum Velden, Austria

48. Jahrestagung der DGPRÄC
Sept 14-16 2017, Graz, Austria

Electronica
Sept 14-16 2017, New Delhi, India

ENOVA
Sept 19-21 2017, Paris, France

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