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NEWS 2021 02

COVER STORY | PAGE 3

LiDAR and Autonomous Cars: No Conventional Solution

CONTENT

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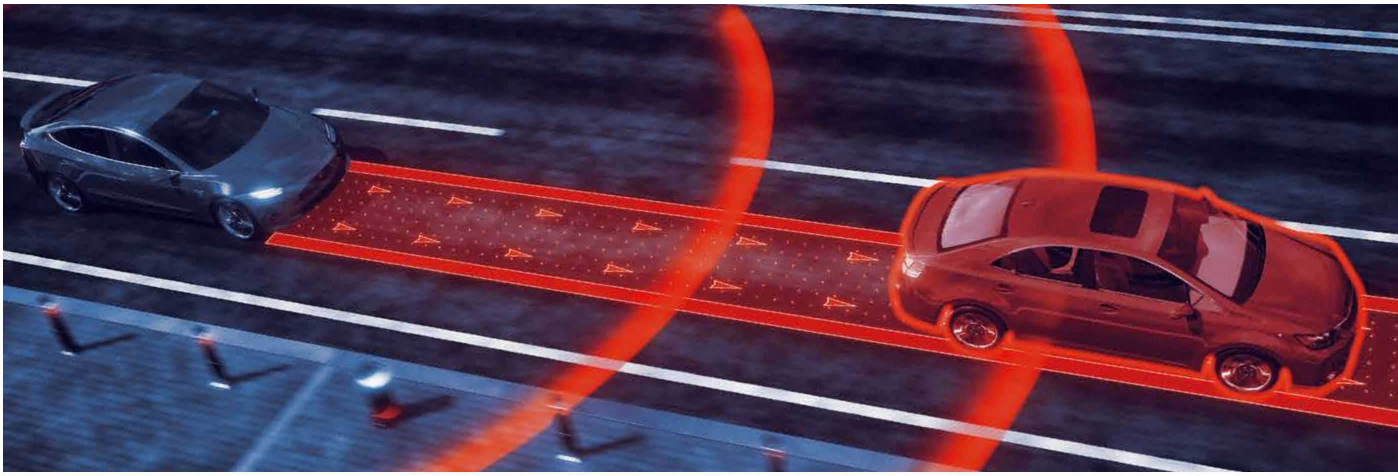


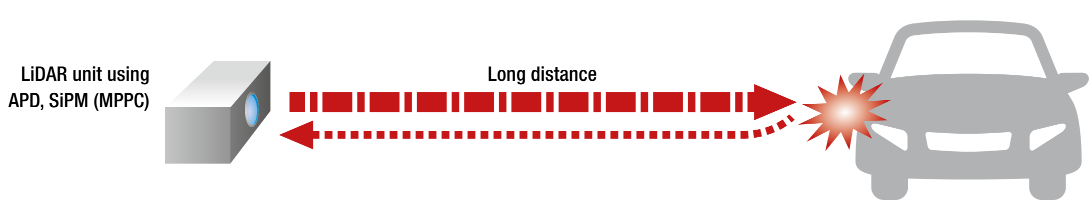
LiDAR and Autonomous Cars: No Conventional Solution

Since the first vehicle appeared on the road, safety remains one of the key topics in the automotive world. Many companies have been working on safety improvements for drivers and other road users. While the obligation to wear a seat belt was one of the major improvements for cars in previous years, today car manufacturers, automotive suppliers and many governmental funded projects are researching into new and improved safety systems. The key objective of such research is to minimize the impact, and number of severe and lethal accidents.

An important condition for totally safe and functional systems are sophisticated sensors and imaging processes that provide true-to-life images of the surroundings. Advanced Driver Assistance Systems (ADAS) are currently employing around a hundred sensors to provide functions such as lane departure warning or automatic distance control. Full accuracy and fast reaction times are essential in this field, even at high speeds and in unforeseen situations.

One of the most promising developments in recent years has been the use of LiDAR (Light Detection and Ranging) systems, an optical method aimed at measuring distances and speed. Unlike the related radar system, LiDAR sensors identify the environment by means of light only, which is detected by a photosensor. But not all LiDAR is the same, and not all photosensors are equal. Which technology is the most suitable is not always clear to the manufacturer and depends on the specific application. Our products extend to cover the entire range of LiDAR technologies. From design to manufacturing, we deliver standard and customized solutions with high-volume manufacturing capabilities.

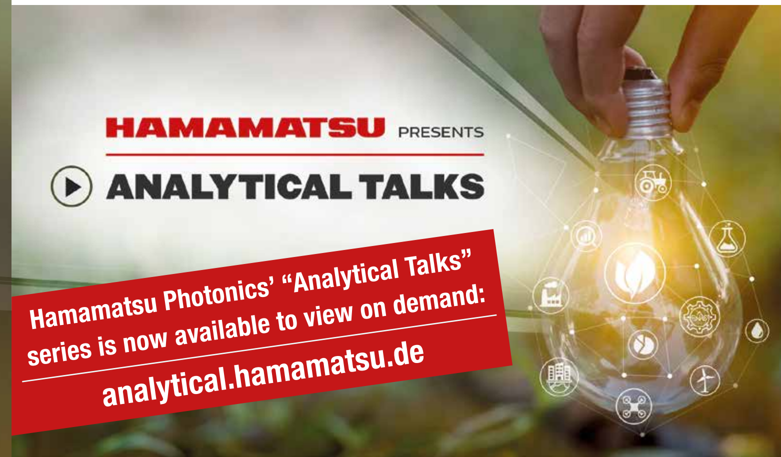
Read the full article here:
lidar.hamamatsu.eu



COMPANY NEWS

Talking Photonics

In “Analytical Talks,” experts from Hamamatsu Photonics take us on an exciting video tour of the technologies, the evolving application space, and the latest developments in the diverse world of optoelectronics!



EPISODE 1

Water Analysis – Photometry in the UV and VIS
Presenter: Jennifer Padberg

Why is Hamamatsu so active in water analysis?

The UNESCO World Water Assessment Program reported that two million tons of human waste are discarded into watercourses every day; clearly, keeping tabs on water quality remains critical – and we’re keen to play our part.

How does Hamamatsu serve this field?

We offer many different products suitable for water analysis applications – from simple photodiodes to sophisticated integrated spectrometer solutions. Notably, many of our customers in this space are OEM manufacturers of water analysis instruments – and we are passionate about using our expertise and insight to help find the right solutions for their specific applications.

Please tell us about a couple of recent innovations…

One standout product is our new – very compact – UV spectrometer. Despite its small size, it contains the latest CMOS image sensor to provide high sensitivity, high resolution, and robust UV measurements. Our small XeF modules are also worth a special mention because they include all necessary components (lamp, high-voltage power supply, trigger socket), which makes them really easy to use.

EPISODE 2

LIBS – Remote Analysis with the O-O-I Principle
Presenter: Dominik Kunert

For the uninitiated, what is LIBS?

Laser-induced breakdown spectroscopy (LIBS) uses a short pulse beam laser to create a micro-plasma. Within the plasma, electrons recombine with the ionized atoms and generate a unique spectrum, which allows substances to be identified at the element level. By combining such complex element information with artificial intelligence (AI) technology, it is possible to acquire highly accurate analytical information.


Dominik Kunert


Christoph Wöhnl


Moritz Fischer

And the O-O-I principle?

O-O-I stands for “online, onsite, insitu,” which highlights the clear benefit of LIBS: high-speed, noncontact, in-line inspections across a diverse range of substances, such as plastics, metals, and glass.

What are the key application areas?

LIBS is a promising technique for in-line inspections at many kinds of manufacturing sites. Some examples: i) in nuclear or thermal plants where exemplary rapid identification and measurement of hydrogen and other light isotopes is required; ii) in steel and iron manufacturing processes, where analytical equipment could not traditionally be installed nearby due to the extreme heat; iii) even in the recycling field, where accurate identification of mixed waste materials drives more efficient recycling.

EPISODE 3

Compact and Sophisticated – Mini-spectrometers Doing Big Business
Presenter: Christoph Wöhnl

You introduce MOEMS in your Analytical Talk...

Micro-opto-electro-mechanical systems – MOEMS – combine optical technology (including opto-semiconductor devices) and MEMS technology. Crucially, it makes it possible to integrate the components of a typical spectrometer into a compact module.

You also share details of TOKUSPEC…

That's right. TOKUSPEC supports our mini spectrometer portfolio – and it's free of charge for all customers. It can operate multiple devices simultaneously and its modern modular design allows the user to customize sections, such as the live data view, measurement settings, or the results window with multiple spectra. Additional functions include time lapse, background or reference image acquisition and the ability to set the calculation method round out the package.

EPISODE 4 – IR Sources – Hopping Through Technologies

Presenter: Dominik Kunert

Could you provide us with a brief IR 101?!

Infrared radiation (IR) is categorized as IR-A (780 nm to 1.4 µm), IR-B (1.4 µm to 3 µm), and IR-C (also known as far-IR; 3 µm to 1 mm). IR sources radiate measurable quantities of energy in the infrared region of the electromagnetic spectrum by applying electrical energy. Some molecules have unique vibrational interactions and therefore produce a spectral fingerprint. These tight absorption bands allow high-sensitivity measurements with high resolution down to ppt concentrations.

And what is Hamamatsu working on in the IR space?

We've got a lot going on in IR, but I can mention a handful of exciting developments. First, we have a new window glass material that shifts the cutoff wavelength of traditional XeF farther into the mid-infrared region. Second, we've developed an innovative graphene light source, which has high pulsing rate, low power consumption, and high brightness. Third, our new butterfly package for quantum cascade lasers – the premium class of IR source – reduces the financial burden.

EPISODE 5 – Beyond Human Vision

Presenter: Moritz Fischer

You focus on InGaAs in your Talk – what are they and why are they important?

InGaAs is a compound semiconductor of indium, gallium, and arsenide. Many of you will know that silicon is the material of choice for near-ultraviolet to near-infrared, but longer wavelengths of light cannot create an electric signal in silicon. This gap can be filled by InGaAs, which is capable of detecting light in the near-infrared range (900 nm to over 2500 nm).

What are the main applications of InGaAs sensors?

Near-infrared image sensors are often employed in advanced process analytical technology, which is an increasingly impor tant tool in many modern production plants.

Notably, for analytical applications, high sensitivity and low dark signal are critical – but these are usually weak points of InGaAs detectors. However, Hamamatsu's experience in this area makes us one of the highest quality suppliers of InGaAs detectors on the market today.

EPISODE 6 – Low Light Measurement – Fluorescence in the Analytical Field

Presenter: Jennifer Padberg

You focus on the challenges presented by fluorescence signals in your Talk – could you elaborate?

In general, fluorescence signals are weak and typically have a lifetime of several nanoseconds. To detect weak signals, optical sensors must be highly sensitive – sometimes even necessitating photon counting. Furthermore, sensors should have low dark counts, a wide dynamic range, and be fast enough to detect rapid signals.

And how is Hamamatsu rising to the analytical challenge?

We have a number of different optical sensors and light sources for fluorescent applications. But when it comes to the aforementioned challenge of weak and rapid signals, our avalanche photodiodes, multipixel photon counters, and photomultiplier tubes all really shine (no pun intended)! Hamamatsu has a broad portfolio and excels in providing customization options, so we are able to help our customers find the right sensor – whatever their specific application or challenge.

EPISODE 7 – With(out) a Trace – We Help You Find and Resolve Raman Signals

Presenter: Moritz Fischer

What are the main trends in Raman spectroscopy?

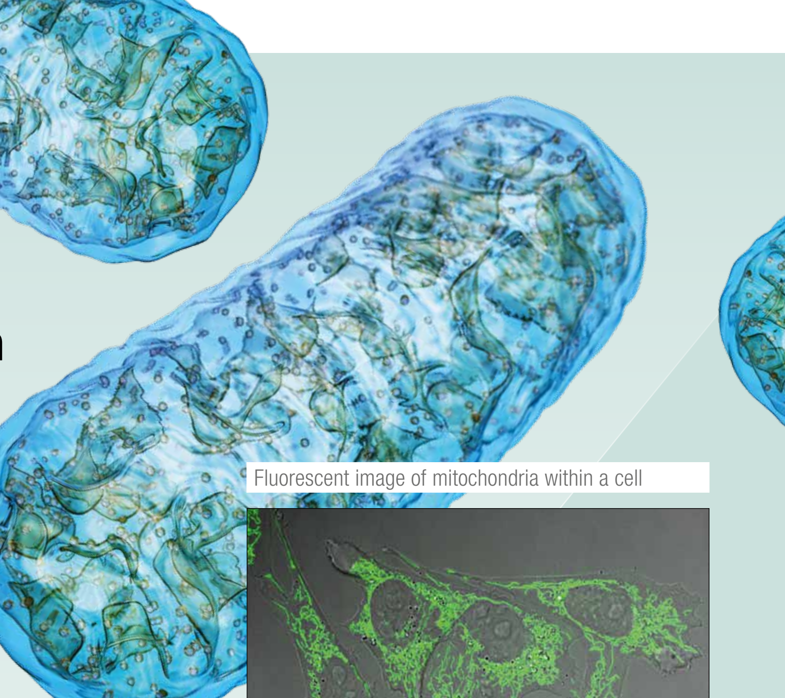
One important trend in Raman spectroscopy is miniaturization – to the point where it is now being introduced into application specific handheld devices. The optics in handheld devices are much smaller than in their lab-scale counterparts, but they still enable high precision Raman spectroscopy wherever you need it!

That said, one challenge in Raman spectroscopy – and a running theme in our Analytical Talk series – is the need to capture faint signals with sufficient signal-to-noise ratio. Furthermore, the spectral sensitivity must be sufficient to resolve narrow spectroscopic features.

And what is Hamamatsu's solution?

We've been busy developing semiconductor sensors and high-performance spectroscopic modules (with integrated excitation lasers) that enable our customers to quickly create Raman devices specifically for their measurement task. In short, we make it easy to design a Raman optical system!

Get the full tour from Hamamatsu's expert team by watching "Analytical Talks" – now available on demand: **analytical.hamamatsu.de**



Series Mitochondria

The Little Giants Inside a Cell That Maintain Life and Health

Commentary:
Hideo Tsukada, Ph.D.,
Central Research Laboratory, Hamamatsu Photonics K.K.

Part 1 What Exactly Are Mitochondria?

We will be taking up the topic of "Mitochondria – The little giants inside a cell that maintain life and health" over a total of 4 parts to give you a glimpse of these "intracellular organelles" from several different viewpoints. Most of you have at least seen the name "mitochondria" in junior high school science textbooks. Research in recent years has led us to understand that mitochondria play a much more important role than we thought in helping us lead healthy daily lives. Part 1 of this series gives a first look at mitochondria along with a brief review of related information. Part 2 gives a behind-the-scenes look at the development of the PET (positron emission tomography) probe developed at the Hamamatsu Photonics Central Research Laboratory. The PET probe measures mitochondrial functions within organisms by using PET. In Parts 3 and 4, we will show the results of actually using the PET probe for disease studies of the brain and peripheral organs.

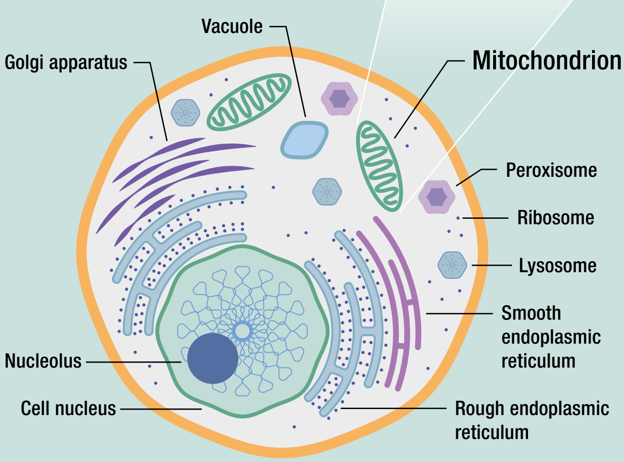


Figure 1: Mammalian eukaryotic cell

Fluorescent image of mitochondria within a cell

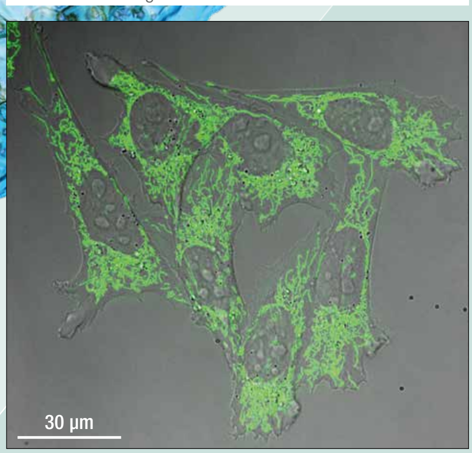
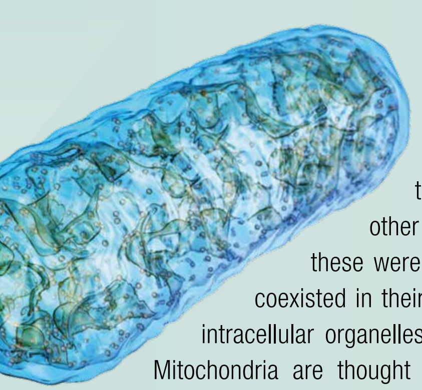


Figure 2: Mitochondria in a CHO K1 cell (obtained from JCRB cell bank, registration No. JCRB9018) visualized with the ORCA-Flash4.0 V3 digital CMOS camera C13440-20CU by expressing fluorescent protein in the cell. (Courtesy of Dr. Sayaka Kazami of the Central Research Laboratory, Hamamatsu Photonics K.K.)

Formation and Origins of Mitochondria

The human body is an aggregate of some 37 trillion cells. (Though some say without any particular basis in fact that the human body is made up of 60 trillion cells, a report by Eva Bianconi et al. in 2013 states the human body consists of some 37.2 trillion cells[1)]). A single cell, as shown in Figure 1, contains various highly-developed intercellular organelles such as nuclei, endoplasmic reticulums, and golgi apparatus. Mitochondria are one type of these intercellular organelles and are found in nearly all the cells that comprise our bodies. Mitochondria are each roughly 0.5 µm to 1 µm in diameter and a single cell contains a few dozen to several thousand mitochondria, which occupy about 10 % to 20 % of the volume of a cell. Descriptions found in textbooks may have illustrations such as in Figure 1 that show mitochondria in a shape resembling that of a rugby ball, but when actually observed under a microscope, mitochondria are flexible and constantly changing into filamentous or particulate shapes by fusion and fission according to the environment around the cell (Figure 2).



Though not well known, mitochondria differ widely from other intracellular organelles in that these were once separate organisms that coexisted in their host cell and transformed into intracellular organelles like chlorophyll in plant cells. Mitochondria are thought to have first originated about 2 billion years ago when a prokaryotic aerobic bacteria called “alpha-proteobacteria”, which has a function to produce large amounts of ATP (adenosine triphosphate) by using oxygen, was engulfed by the cytoplasm of a eukaryotic cell that was, until then, unable to utilize oxygen.

This so-called “endosymbiotic theory” is supported by the following three reasons[2)].

A first reason to support this theory is that intercellular organelles are formed within a single membrane structure, while mitochondria have a double membrane structure consisting of the inner and the outer membranes. Some types of aerobic bacteria have the same double membrane structure. Moreover, the lipids, proteins and other elements making up the mitochondrial membrane resemble the bacterial membrane, so the mitochondrial membrane likely stems from bacteria.

A second reason to support this theory is that our DNA which is the blueprint for our bodies can be found not only in the nucleus of the host cell but also in mitochondria, and also that this mitochondrial DNA more closely resembles bacterial DNA rather than nuclear DNA of the host cell. What’s more, the system for translating the protein from mitochondrial DNA information bears features close to that of bacteria. Incidentally, mitochondria currently contain only one-tenth of DNA derived from alphaproteobacteria. Assuming that the endosymbiotic theory is correct, it could have been because the host cell had robbed alphaproteobacterial of DNA in the process of symbiosis. The host cell likely had done this to prevent the incoming alphaproteobacteria from leaving the host cell and surviving outside it, by rewriting most of alphaproteobacterial DNA onto its own DNA information.

A third reason to support this theory is the point of mitochondrial fission. In contrast to cell division where the nucleus splits only at the time of cell division, mitochondrial fission occurs when it is necessary due to the environment and circumstances around the cell (semiautonomous proliferation), which seems to imply that mitochondria were organisms once independent from the host cell.

Diverse Mitochondrial Functions

The most essential function that the many mitochondria within the cell perform is producing the ATP energy source that is indispensable for maintaining cell functions and ensuring their survival. For that reason, mitochondria are often called the “powerhouse in the cell”. We consume foods containing various nutrients such as sugars, lipids and proteins in order to live. However, those nutrients obtained from food are still not directly usable as a power source within the cell. These nutrients must first undergo various processes for conversion to high-energy compounds of ATP to maintain the daily activities of the mass of cells that comprise our bodies.

ATP is produced through 5 types of mitochondrial complexes (MC) I to V on the mitochondrial inner membrane. In MC-I and MC-II, the coenzyme NADH (nicotinamide adenine dinucleotide hydrogen) and the succinate are respectively oxidized, which reduces the ubiquinone (Q) to ubiquinol. In MC-III, the ubiquinol is oxidized to reduce the cytochrome c (Cyto-c). In MC-IV, the cytochrome c is oxidized and then reduced to water by transferring electrons to oxygen molecules. In this process, a proton (H+) electrochemical gradient is generated on the mitochondria inner membrane. MC-V uses it as a driving force to phosphorylate ADP (adenosine diphosphate) to produce ATP (Figure 3).

Electron transport chain in the mitochondrial inner membrane

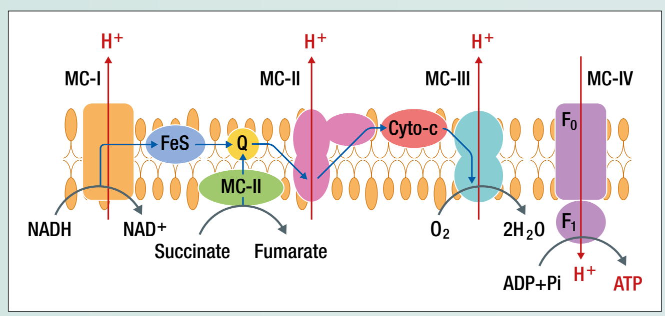


Figure 3: The electron transport chain in mitochondria consists of 5 types of complexes (MC-I to MC-V). The proton (H+) electrochemical gradient generated in the complexes MC-I, MC-III, and MC-IV is utilized in MC-V to produce ATP that serves as an energy source essential for the life and activities of the cell.

Oxygen is absolutely indispensable for the life and health of our bodies in the process of respiration that takes oxygen into the body and expels carbon dioxide from it. Oxygen taken into the body from the lungs at high oxygen partial pressure is absorbed by hemoglobin within the red blood cells and transported to all tissues and organs throughout the entire body. Oxygen released from the hemoglobin to the peripheral tissues at low oxygen partial pressure is taken into the mitochondria and utilized to produce ATP (aerobic metabolism shown in Figure 4), which in fact consumes approximately 95 % of the oxygen within the body. The carbon dioxide produced during this process is taken into the red blood cells, transported to the lungs and expelled from the body by respiration.

As mentioned earlier, mitochondria are present in virtually all cells of the body. One of the few exceptions to this is red blood cells. Red blood cells perform the specialized task of cramming as much hemoglobin as possible into a limited inner space of a cell for efficiently transporting oxygen and therefore exclude main intracellular organelles such as mitochondria and nucleus in the process of differentiation and maturation. However, ATP is also supposedly indispensable for red blood cells to maintain their life and activities, so what method is utilized to obtain ATP? Red blood cells produce the required ATP by utilizing another pathway called "anaerobic glycolysis" (Figure 4), although it is less efficient compared to aerobic metabolism by mitochondria. This "anaerobic glycolysis" pathway is utilized in producing ATP for cancer cells and inflammatory cells such as macrophages and microglia, and this topic is also scheduled to reappear from Part 2 onward.

How mitochondria contribute to ATP production

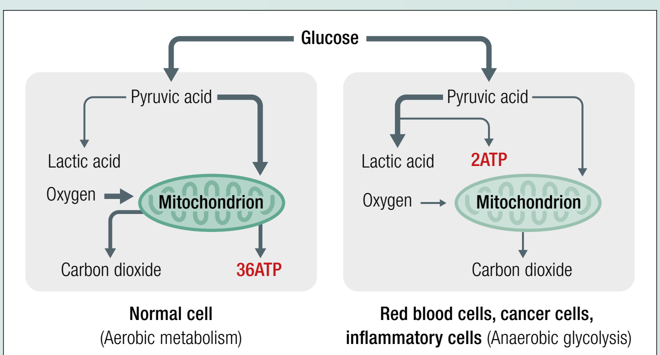


Figure 4: In contrast to normal differentiated cells that mainly rely on mitochondria to efficiently produce ATP; red blood cells, cancer cells and inflammatory cells produce ATP in an inefficient but rapid process mainly via the glycolytic pathway.

Besides producing ATP, mitochondria also play a huge role in "apoptosis" and even have a name like "apoptosis control tower." "Apoptosis" is a process of strictly controlled "programmed cell death" that causes morphological changes in the developmental process of multicellular organisms, removes cells that react to autoantigens in the immune system, and also eliminates dysfunctional cells like cancer cells. This is actively induced to keep the body in better condition. Apoptosis is often compared to the pathological cell death called "necrosis" that is often "long-term progressive" and discharges the internal contents of cells due to cell rupture, inducing inflammation around the affected area. However, apoptosis differs from necrosis in that it is a "short decisive battle" and does not induce inflammation since no contents are discharged from the cells. Apoptosis brings about cell death that does not damage the surrounding cells and tissues.

A mitochondrion contains "death substances" such as cytochrome c that induce apoptosis. Discharge of cytochrome c under healthy conditions is normally suppressed by apoptosis inhibitory proteins (Bcl-2, Bcl-xL) found within the mitochondrial outer membrane. However, when some type of death signal is received, several apoptosis promoting proteins (Bax, Bid, Bad, Bak, Bim) shift to the mitochondrial outer membrane, inducing the discharge of cytochrome c from the mitochondria into the cellular cytoplasm. Then, the activation of caspase 9 serves to activate apoptosis-related proteins (caspase-3, etc.) further downstream. This consequently induces a series of caspase cascades accompanied by distinct phenomena including cleaving of DNA, destruction of the lamin structure, and shifting the phosphatidyl serine to the cell membrane surface (Figure 5). Why this protein group that could cause cell death by just one wrong move in the process is localized only within the mitochondria is a mystery. One possible reason is that the mitochondrial outer membrane has a membrane permeability system for substances such as VDAC (voltage-dependent anion channel) that are regulated to make an instant response to changes in cell status.

Apoptosis – Programmed cell death

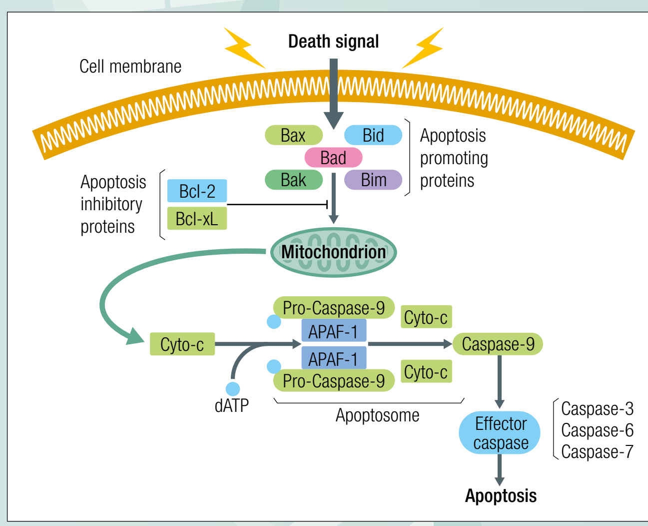


Figure 5: When a cell receives some type of "death signal" from outside the cell, the apoptosis promoting system, which has been suppressed by the apoptosis inhibitor system, becomes activated to discharge cytochrome c from the mitochondria and the cell processing system performs a series of actions via the caspase cascade.

Mitochondria and Reactive Oxygen Species

We have described the production of ATP that serves as an energy source essential for survival as well as apoptosis control that maintains the health of the cell. We also explained the crucial role that mitochondria play in maintaining the life and healthy function of cells and the aggregate of cells that are our bodies. However, these mitochondria are not always our friend and ally. We are now going to explain it by looking at another aspect of mitochondria as a source for producing ROS (reactive oxygen species).

ROS is a broad term for highly reactive chemical compounds formed from oxygen molecules in the air. ROS can oxidize the proteins, lipids, DNA and other components in living organisms, and is highly harmful to cells. However, if our bodies are infected by bacteria, a superoxide (a type of ROS), which is made by the ROS-producing enzyme system such as for neutrophils and macrophages, is effective in killing bacteria and therefore acts to protect the body. Superoxide is also used to kill cancer cells by way of natural killer cells that are one type of lymphocyte. These examples all serve to show the useful aspect of ROS in living organisms.

On the other hand, just as previously described in the paragraph on "Diverse mitochondria functions," mitochondria consume about 95 % of the oxygen we take into our bodies during breathing. That oxygen is used to produce ATP and about 0.1 % to 2 % of the oxygen in that process is used to produce ROS. So ROS is constantly produced from mitochondria in this way and if the cell functions are normal, an ingenious system can swiftly eliminate the produced ROS by using antioxidant enzymes (glutathione peroxidase and peroxiredoxin, etc.) and maintain a steady state of oxidoreduction or namely oxidizing and reducing.

However, when this balance between oxidation reaction and antioxidant reaction in the body deteriorates due to aging or sickness, "oxidative stress" occurs that tips the balance toward oxidation and provokes oxidative damage to proteins, sugars, lipids and DNA essential for cellular functions. The ROS produced from a mitochondrion also damages the mitochondrion itself, and the damaged mitochondria produce ROS in large amounts so that the damage expands even further in a chain process that amounts to a vicious cycle.

Moreover, the mitochondrial DNA forming the blueprint map for a portion of the protein comprising the mitochondria has no chromatin complex structure with histone proteins (Figure 6), and the DNA repair function is weak. There is a report that mitochondrial DNA cannot effectively cope with ROS and genetic mutations tend to easily accumulate in mitochondrial DNA when compared to nuclear DNA. It is somehow ironic that the process for producing ATP essential for our survival is also responsible for producing a material (ROS) that endangers our own cellular functions.

Two blueprints for mitochondria

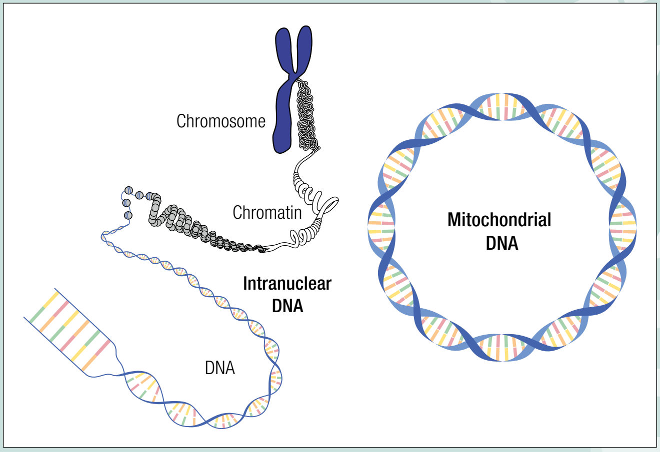


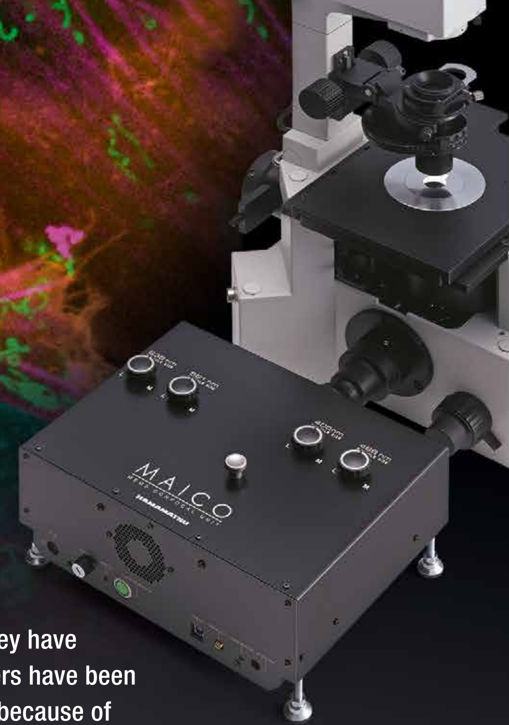
Figure 6: DNA is the blueprint of the proteins that comprise mitochondria. This DNA is present in 2 locations, one within the mitochondrion itself, and one within the cell nucleus. However, unlike intranuclear DNA, mitochondrial DNA has no chromatin structure that winds around the protein, so mitochondrial DNA of naked ring-like structure is easily susceptible to changes or mutations due to external damage.

Well, after the above description, were you able to easily get an understanding of the very important role mitochondria plays in cells and the human body holding those cells in order to maintain their health? Were you also able to see how cell dysfunctions are directly linked to all types of illnesses?

Next time, in Part 2, we plan to show you PET probes designed and developed at the Hamamatsu Photonics Central Research Laboratory. These PET probes are promising tools for discovering mitochondria dysfunctions or abnormalities while still in their early stage.

References

1. Eva Bianconi, et al., An estimation of the number of cells in the human body. Ann Human Biol. 2013;40:463-471.
2. Miraikan Science Communicator Blog "I can't live without you anymore! Mysterious relationship between mitochondria and cells" (Blog article posted by Sakiko Tanaka on December 21, 2018) https://blog.miraikan.jst.go.jp/articles/20181221post-68.html



Aiming at One MEMS Confocal Unit Installed In All Laboratories

Our High-speed, High-sensitivity and Compact Confocal Unit Will Rewrite the Conventional Wisdom of Confocal Microscopes

Confocal fluorescence microscopes are vital for the research of biological systems as they have high resolving power and can capture images in the depth direction. However, researchers have been unhappy with the fact that it is difficult to introduce them into each of their laboratories because of their high price. The MAICO® MEMS confocal unit made by HAMAMATSU eliminates that dissatisfaction and provides researchers and customers with that extra degree of convenience. In addition to its features of high speed, high sensitivity and compact design, the MAICO® is capable of simultaneous multiband observation without bleed-through.

MAICO™
MEMS CONFOCAL UNIT

We interviewed the three key persons who led development and creation of this product.

Project manager
Jiro Yamashita
Scientific Imaging Department, Systems Division

Electrical design
Takashi Mihoya
Scientific Imaging Department, Systems Division

Optical design
Shunsuke Matsuda
Optics Design Group, Product Design, Systems Division

The Concept of Eliminating Dissatisfaction Among Researchers

First, could you explain what a confocal microscope is?

Yamashita: The history of optical microscopes goes back a long way, and various observation techniques have been developed to date so far. What has been unable to be seen so far can now be observed, and this will contribute to the development of industry and research. Within this history, confocal microscopes are placed and regarded for their relatively new technology. Major features of our confocal unit are its high resolving power and is capability to produce optical sectioning images in the depth direction.

Matsuda: Confocal fluorescent microscopes are widely used in the field of biology as they can sharply observe samples. However, in almost all cases, they are installed as shared equipment in universities because of their high price. For this reason, they cannot be freely used in busy periods because everyone vies with each other to use them. We have heard this kind of complaint from lots of researchers.

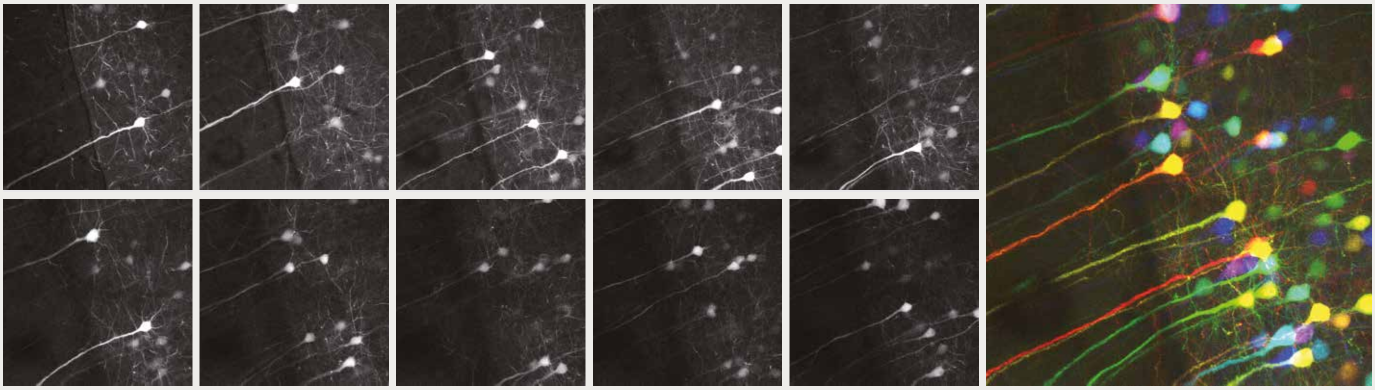
Yamashita: This prompted us to develop a compact confocal unit that can be attached to regular microscopes installed in individual laboratories to solve researchers' worries.

What is the product name MAICO® derived from?

Matsuda: It means "My Confocal." A confocal unit exclusively for me. We have come up with an advantage for researchers in laboratories – they can monopolize the unit for their own use.

Yamashita: We anticipated that a price tag of about five million yen would be affordable to laboratories, and began development with the absolute condition that the unit must fall within this price range. We wanted to achieve two things: the capability to attach the unit onto existing microscopes for use as a confocal microscope, and scalability from initial introduction in the minimum configuration so that it can be expanded in keeping with how research develops.

Imaging example: Z-section imaging of mouse brain



Sample and images courtesy of Dr. Christian Jüngst and Dr. Astrid Schauss (CECAD Imaging Facility, University of Cologne).
Image acquired (extracted) by moving the focal point on a fixed sample of a mouse brain in 5 μm increments, and integrated image made by coloring each Z-section.

So, you did not attempt to develop a confocal microscope, right?

Yamashita: We thought we could keep the price down and better contribute to the development of the market as a whole by developing a unit that allows existing microscopes to be used more effectively. This turned out to be the right approach, and for this we are held in high repute by researchers, our customers.

All Major Components Developed In-house

OK, then. I'd like to ask you about the development policy behind this product.

Mihoya: We studied whether or not there was a product in-house that we could use to make our product concept a reality. For the detector, the main part, we decided to use a photomultiplier module (simply referred to as "PMT" from here on) made by our Electron Tube Division which has a long track record in fluorescent measurement applications.

Yamashita: In addition to that, it was the MEMS mirror that had just been developed by the Solid State Division that greatly helped turn the MAICO® into a product. MEMS stands for Micro Electro Mechanical System, a system that comprises micro mechanical structures and electrical circuits integrated onto a semiconductor substrate. A MEMS mirror is a small electromagnet type mirror to which this technology is applied. MEMS mirrors are extremely small and relatively low-cost. So, we figured that we could achieve the compact size and low cost we were determined for if we used this as the scanning element.

Mihoya: Also, in consideration of the fact that the product would be connected to a microscope for use, preferably it should be usable in software for microscopes. So, we saw to it that MAICO® could be controlled by proven software applications used on digital cameras for microscopes. We thought that the hurdle to overcome using MAICO® would be considerably lower if we could use the same libraries as those used for controlling cameras.

Yamashita: A major feature of this product is the fact that we used proven main parts made using HAMAMATSU technology and the fact that everything from design through to manufacture of parts could be performed completely in-house to fully bring out the performance of these main parts. In-house production gave us a lot of freedom in design which made it easier to achieve target performance. Also, with regular confocal microscopes, the light sources and control units are in separate enclosures. On the MAICO®, however, these are all integrated into a single unit which helps make the product smaller.

Mihoya: The built-in laser source was one of our newly developed components. This also helped make the product compact and lower cost.

How did the laser source manage to achieve this?

Yamashita: If an existing laser light source is used, the light source is used by connecting to the main unit of the microscope with optical fibers. This is why the surroundings are a mess and the price increases. With our MAICO®, however, the laser light source could be designed in-house, which allowed us to achieve the minimum required structure and optimum arrangement.

Mihoya: Samples on confocal fluorescent microscopes are damaged if they are subjected to exciting light. To minimize the effect of this, exclusive modulation is applied to the laser in sync with operation of the MEMS mirror. As design began with the laser light source, we were able to incorporate optimized functions into confocal imaging at a low cost.

Did you encounter any particular hardships during development?

Matsuda: Realization of confocal optics by a MEMS mirror and a subunit structure in optical design was the hardest part. A MEMS mirror is a very small mirror having a diameter of about one millimeter. Even design in confocal optics is extremely difficult. You have to make sure that light is led in towards small mirrors such as this to achieve the required resolution. This is what we had the hardest time with.

Yamashita: We also experienced other hardships on top of that as we were aiming at a subunit structure. The MAICO® is supplied with all component parts required for each individual wavelength grouped together in separate subunits. Up to four subunits can be mounted on a single MAICO®, and each subunit has measurement functions for one specific wavelength.

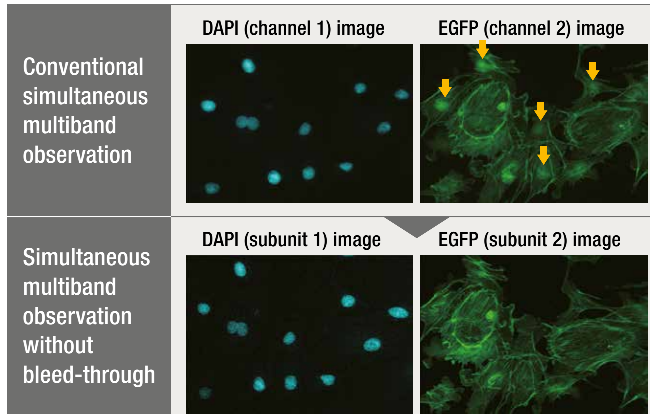
Matsuda: We had the idea of subunits from the outset, but how we should build the optical system was a cause of immense worry for us. In the end, we created the optical system by mounting four different confocal optical systems together. The adjustments for making this happen, however, were extremely difficult.

Our modular subunit structure makes adding extra channels easy

The subunit contains all the necessary components for single band fluorescence excitation and detection, including a laser source, a pinhole, and a detector.

Apparently, a feature of the subunit structure is that wavelengths can be increased by add-ons after purchase. Are there any other advantages?

Yamashita: By adopting a subunit structure, we have been able to prevent bleed-through or fluorescence leakage between detection channels. Conventionally, bleed-through occurred when attempts were made to observe multiple wavelengths simultaneously, and this made accurate measurement difficult. A subunit structure, though, allows light sources that go in and out to be designed independently. As a result, we managed to keep bleed-through to a minimum and make high light-receiving efficiency simultaneous multiband observation possible.



Conventional simultaneous multiband observation and simultaneous multiband observation by MAICO® (image produced by pseudo-color display). Up till now, DAPI fluorescence leaked into the EGFP image, and the shape of the nucleus also came out in the image. With the MAICO®, leakage is suppressed, and the fluorescent image for each fluorescent dye can be acquired.

Unexpected Negative Comments About the Evaluation Apparatus

Mihoya: When we asked users for their opinion of the evaluation apparatus, they told us that images were dark and samples were damaged a lot. The cause of this was insufficient sensitivity. We had been under the impression that sensitivity was sufficient as a PMT made by HAMAMATSU was used in the MAICO®. Yet, in actual fact, scanning of the MEMS mirror which moves at high speed had to be optimized. So, we modified the amplifier characteristics at the rear stage of the PMT and the signal sampling technique of the signal processing unit. The outcome of this was that we succeeded in improving sensitivity 10-fold and higher.

Yamashita: There was an unexpected by-product of enhanced sensitivity. The required sensitivity could also be realized by lowering laser output. Normally, confocal microscopes have to be used in a special room called a laser control area. As a result of being able to lower laser output, control areas were no longer needed.

Mihoya: Lasers are classified by output. Generally, confocal microscopes fall under laser class 3B. Initially, we were going to use the same class 3B laser. However, as a result of enhanced sensitivity, we were able to lower laser output, and so we could use a class 3R laser, a class of laser that meets one rank lower safety standard requirements.

Yamashita: It could be said that convenience was improved even further for customers as use of the product was not limited to laser control areas.

So, what you're saying is that as a result of pursuing sensitivity to meet customers' wishes, laser output was lowered and the product could ultimately be used anywhere.

Yamashita: Very much so!

Speedy and Stress-free

Mihoya: HAMAMATSU makes several types of MEMS mirrors. Of these, the raster scan type mirror moves extremely fast and thus achieves an outstanding frame rate.

How fast would that be?

Mihoya: When a microscope is set to maximum field of view, 19 frames can be produced in one second with the maximum being 76 frames per second.

Yamashita: A benefit of a faster frame rate is that you can now easily position and focus on a sample while viewing its image. On confocal microscopes that use existing galvanometer mirrors, the frame rate is slow. We have even heard stories of users preparing separate cameras for positioning and focusing. An attraction of MAICO® is that the phenomenon of samples moving at high speed can be imaged.

Which other microscope products made by other manufacturers can this product be attached to?

Matsuda: It can be attached to inverted microscopes made by other manufacturers. Though microscopes made by other manufacturers have their own specific differences, these are absorbed on the MAICO®. The quality of confocal microscopes is maintained while the differences are absorbed.

So, you knew the structure of the microscopes made by other manufacturers?

Matsuda: Actually, before MAICO®, I had supervised the development of products to attach to other manufacturers' microscopes. We were able to proceed relatively smoothly because of the knowledge of microscopes made by other manufacturers I had gained at the time.

Yamashita: Thanks to this know-how, MAICO® has successfully been designed to be attached to microscopes within a very short time.

Customer Reaction – Amazement

How did customers react after it was released?

Yamashita: We visited our customers and demonstrated the MAICO®. They responded very favorably. Many customers asked us half in doubt if you can really see a confocal point with the MAICO®, which has almost the same footprint as A3 sheet. Most of them were amazed that they could actually see it once they attached it to their microscopes and viewed a sample.

Matsuda: Ever since we put the product on the market in March, MAICO® has received one of the highest number of hits among the products introduced in the Product section of our company's web-site, and the company has received lots of inquiries. So, it was a successful launch for MAICO®.

From here on, what kind of product are you going to develop this into?

Yamashita: We are going to promote sales around the theme of "One MEMS Confocal Unit Installed In All Laboratories." This product provides users with lots of advantages – for example, it can be attached to existing inverted microscopes, it has good sensitivity, and bleed-through can be kept to a minimum. This is why it is getting lots of attention from customers, too.

Mihoya: We can also accommodate requests from microscope manufacturers and from manufacturers who develop and sell equipment that use confocal microscopes for OEM. We are also considering accommodating requests to incorporate MAICO® as part of the optical system for downsizing overall systems.

Yamashita: HAMAMATSU developed the MAICO® by integrating its extensive optical techniques. We hope that you all make use of the advantages that MAICO® offer in research and product development that use confocal microscopes.

ORCA®-Quest

Capable of Resolving 1, 2 and 3 Photons – The Ultimate ORCA®-Quest Camera for Low Light Measurement

Anticipating the Discovery of New Findings in Quantum Computing and Other Advanced Areas

The ORCA®-Quest qCMOS® Camera accurately measures the number of photons and performs imaging under ultimate minimal noise conditions. The resolving capability to measure the number of photons is due to the extensive design know-how of the development team that has, for many years, been engaged in noise reduction. Ahead of product release, we selected key opinion leaders in physics and related areas from around the world as prospective customers, and conducted a large-scale marketing survey. Just how did efforts to create a new market with the involvement of local subsidiaries in America, Europe and China bear fruit?

I interviewed the five central figures in charge of core project activities.

Product manager
Kunihiko Tsuchiya
Product Planning Group, Systems Division

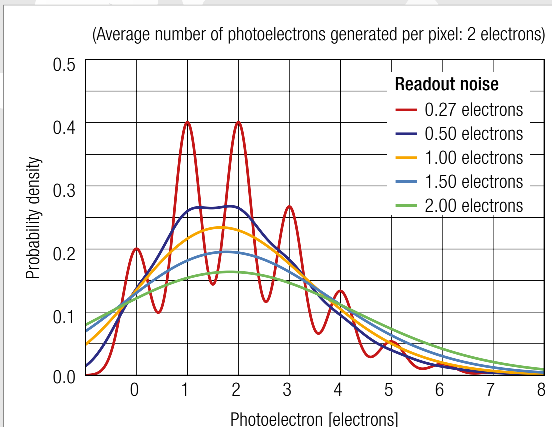
Overall project manager
Mao Nakajima
Scientific Imaging Department, Systems Division

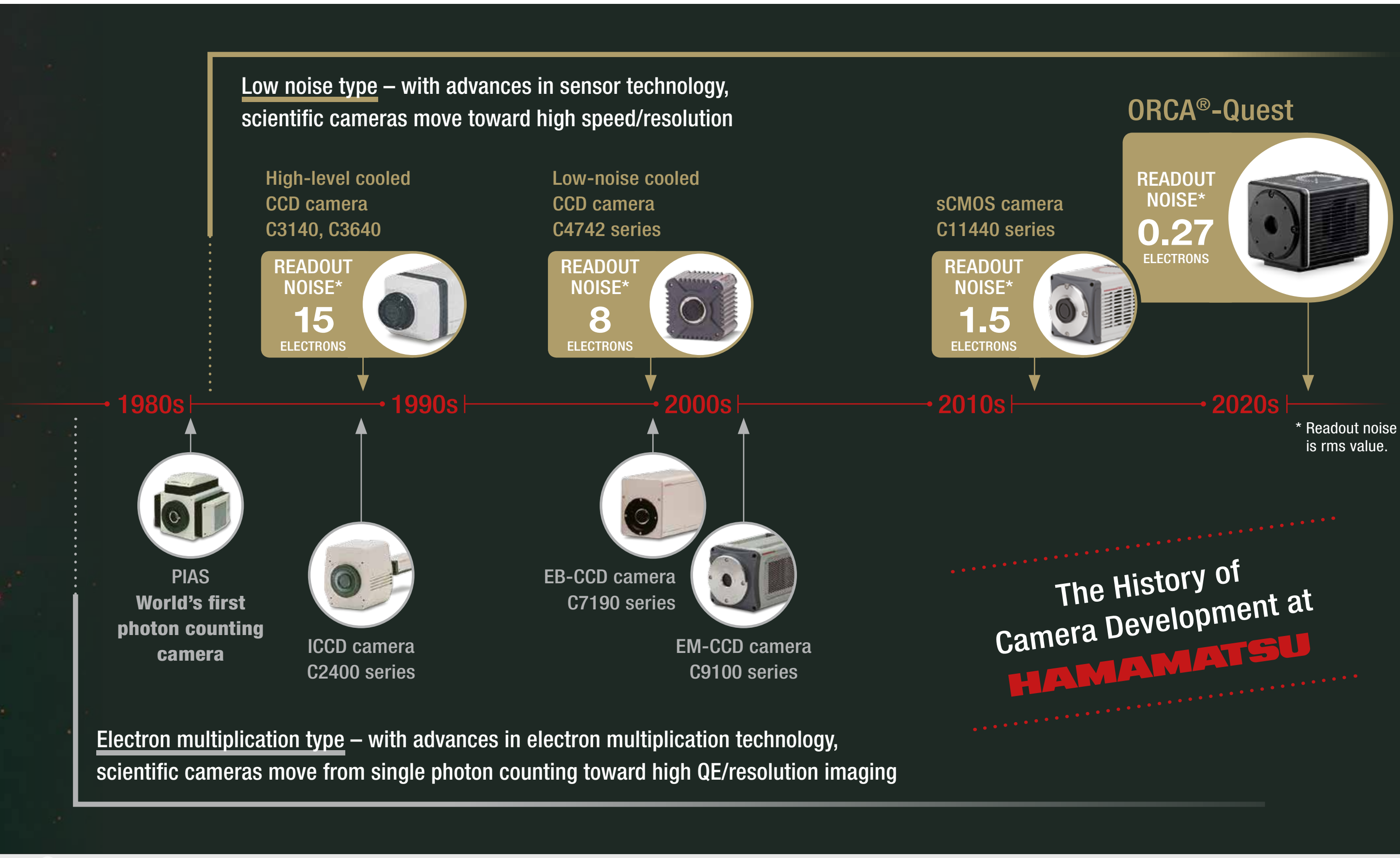
Domestic sales representative
Kenji Suzuki
Business Promotion Department, Systems Division

Camera design
Takuo Kameyama
Scientific Imaging Department, Systems Division

Camera design
Masaya Kyogoku
Scientific Imaging Department, Systems Division

Simulation data of photoelectron probability distribution





Innovation in Achieving Photon Number Resolving

Let's begin with the qCMOS® camera. Could you tell us what it is?

Nakajima: The "q" of the qCMOS® camera name is the first letter of "Quantitative." As advocated in our company's slogan "Photon is our business," our mission is to detect each single particle of light. Although this has been achieved even up till now by means of photon counting, strictly speaking measurement at the individual photon level has not been possible.

What do you mean by 'has not been possible?'

Nakajima: When photons are received by a sensor, noise inevitably occurs in the sensor and photon signals become buried. Up till now, in the design and development of cameras, we have focused on the reduction of noise. With this camera, we have succeeded in reducing noise to the utmost limit and accurately counting the number of photons. That is a huge difference from conventional sensors.

Tsuchiya: Being able to count the number of photons means that photons can be measured quantitatively. Because of that we acquired the qCMOS® trademark, and decided to release the camera onto the market as ORCA®-Quest equipped with the qCMOS® sensor.

How is ORCA®-Quest placed and regarded within the history of camera development at HAMAMATSU?

Tsuchiya: HAMAMATSU is a pioneer of cameras for weak light measurement. For the past 30 years or so we have led the world in putting onto the market photon counting cameras that have the sensitivity to detect single photons. This has led to continuous evolution in the number of pixels, readout speed, noise performance and other areas. As a result, we have put onto the market an EM-CCD camera that incorporates a mechanism inside the sensor that is capable of multiplying electrons by several 1000's.

Nakajima: In parallel with this, we have also been engaged in reducing the noise of sensors themselves without multiplying photons. CCD and CMOS imaging devices that convert light entering the lens to images have evolved, too. This has enabled each individual photon to be observed without the need for multiplication.

Tsuchiya: Because noise on the ORCA®-Quest we released onto the market this time has been reduced to its utmost limit, the camera is capable of resolving down to one, two and three photons in addition to measuring single photons without the need for multiplication. In other words, it is capable of spatial photon number resolving. For this, I think we can call it the ultimate type of camera for low light measurement.

Develop a Camera for Low Light Measurement That Excels EM-CCD Cameras!

EM-CCD cameras see photons by multiplying them. Whereas the ORCA®-Quest is able to count the actual number of single photons by eliminating noise to the utmost limit, can't it. Why is this kind of camera needed?

Nakajima: Because of market needs. If noise is low, what we have been unable to see so far becomes visible and what we have been unable to detect can be detected. In order to respond to these market expectations, we have continued to conduct development with our sights firmly set on noise reduction for the past ten years or so ever since CMOS was substituted for CCDs as the imaging device.

Kameyama: Development of qCMOS® began around 2017, about seven years after we had put onto the market a CMOS camera for scientific measurement. Around that time, EM-CCD cameras were used for detecting extremely low light. To exceed the performance of these cameras, development began with the aim of reducing noise further to increase the limit of sensitivity.

Nakajima: HAMAMATSU makes both EM-CCD cameras and CMOS cameras. To further respond to market needs and fulfill our roles as a pioneer of cameras for low light measurement, it was essential that we reduce noise to its utmost limit.

I see. OK, then. I'd like to hear about some technical aspects of ORCA®-Quest.

Kyogoku: Quality in low light measurement depends on the signal-to-noise ratio, namely, how much this ratio can be improved. The further noise reduction is improved, only signals remain. Being able to correctly measure only the signal component means that quantitative measurement is possible. Lowering noise to its utmost limit results in the ability to achieve quantitative measurement.

Earlier on you said that the number of photons can be counted. However, photon counting has been carried out for quite some time now. Right?

Kyogoku: Yes, we used to perform photon counting for counting the number of photons on conventional models of cameras, too. However, the count was basically either "0" or "1 or more." Even if the number of photons was two, ten or 100, that still meant that the count was "1 or more." In other words, this means that there were two types of measurement. As a result of producing the ORCA®-Quest, we could now see if the number of photons simultaneously entering the camera was two, ten or 100. Photon number resolving became possible, and we managed to achieve ultimate quantitativity.

Assembling Researchers in Physics and Related Areas From Around the World and Conducting a Market Survey

Which areas do you anticipate as markets where the advantages of photon number resolving can be demonstrated?

Tsuchiya: Our prime expectation is the field of quantum technology, and we anticipate, in particular, the area of quantum computing. On developing this new product, we appointed the most suitable project members at our domestic Sales Headquarters and at our local subsidiaries in America, Europe and China, and held discussions mainly with them. While conferring between our domestic Sales Headquarters and local subsidiaries, we chose key opinion leaders from among researchers around the world in areas related to physics and chiefly in quantum technology, and conducted on-line interviews with over 40 customers and researchers in Japan and overseas.

How were the results?

Tsuchiya: When coordinating schedules with all parties concerned, in particular, when dealing with personnel overseas, we often had to hold discussions late at night or early in the morning because of time differences, which made things tough. However, we felt that researchers and customers had great expectations for ORCA®-Quest. As a result of talking with people in charge at our local subsidiaries and interviewing key opinion leaders, our hope that the camera was ideal for research in quantum computing turned into a firm conviction – something that we had felt from the outset.

Specifically, what were their reactions?

Nakajima: Actually, there was a lot we did not know about the actual applications for photon number resolving, a feature of the product. And, yet, when we introduced them to this technology, we heard them comment "This is amazing. What is this? We could use this. I want to try out one."

Tsuchiya: One overseas customer who is conducting research into quantum computing told us that "Up till now, we could only tell that photons were present or not. It's really important for us that we can now identify if there are one or two." I think he probably said this with a gleam in his eyes.

Extending To Life Science, Astronomy and Other Fields

What other applications do you anticipate besides quantum computing?

Suzuki: Well, there's the field of life science. Let's think for a moment that our body moves by the chain transfer of small electrical signals or matter. These are imperceptible changes. ORCA®-Quest can count these minute changes as one photon, two photons or so forth. So, assuming this, there is the possibility that functions of the human body unexplained so far and functions that no-one has noticed so far can be noticed. We anticipate that research into life will be promoted further and that new knowledge will emerge.

Tsuchiya: We also look forward to the astronomy-related market, too. When there is a dark planet to the side of a bright planet, ordinarily, it cannot be seen. However, there are times when you want to observe planets around bright ones. This camera can reliably capture dark planets, too, so we feel that it can meet expectations in this market.

Suzuki: Then, there's the observation of auroras. The observation of auroras means observing the magnetic field surrounding the earth. GPS positional information becomes distorted when the magnetic field is strong. This is why airplanes apparently have to navigate with latitude lowered. As more and more vehicles will travel automatically from here on, GPS error will lead to serious accidents. This camera might be useful in avoiding these kinds of accidents, too.

Tsuchiya: Lucky imaging also is another application. When the night sky is photographed from the ground, atmospheric fluctuations might make images of fixed stars flicker. Clear images without the influence of flickering sometimes can be taken simply by releasing the shutter in short exposure time. The method of selecting just lucky images like these and positioning and overlaying them is called "lucky imaging." It has already been proved that ORCA®-Quest can be used in applications such as these.

Get more detailed information about the ORCA®-Quest on page 29

The Development Policy That The Design Dept. Steadfastly Stuck To Bore Fruit

Did you have any trouble during development?

Kyogoku: We did not experience any special hardships simply by conducting design as per normal. If anything, I suppose that we had no know-how about the sensor we were using for the very first time. We made evaluation apparatus on which various parameters could be controlled, and delved hard into how it would work while using the sensor. So, the process until we succeeded in producing an image could be described as hard work.

Kameyama: Noise is analyzed after the image is produced, however, this went smoothly. We have a track record in this area as we have already been developing cameras for ten straight years or so. You know from long years of experience where you should look if images shift or noise increases.

Suzuki: From our standpoint in Sales, a previous model of the ORCA®-Quest was put on sale in 2011, and since then, we have moved forward with product development at HAMAMATSU towards reducing noise. And, yet, many of our competitors have proceeded with sales with the emphasis on the high level of quantum efficiency. For this reason, this created a quandary for us in terms of sales as the notion of "a camera with high quantum efficiency being a good camera" prevailed in the marketplace.

What does "high quantum efficiency" actually mean?

Kameyama: A quantum efficiency of 100 % means that ten photons entering the sensor are converted to ten photoelectrons. If the quantum efficiency is 10 %, only one out of ten photons entering the sensor is converted to a photoelectron. This difference greatly affects sensitivity. However, if considered in the area of low light, we already knew that noise was a more important factor than quantum efficiency.

Nakajima: Even in advance simulations, it was evident that noise reduction affects camera performance the most. We heard that Sales was after quantum efficiency, but we were all in agreement in getting down primarily to reducing noise. As a result, we managed to not only achieve the ultimate in noise reduction but also to produce a high quantum efficiency of 90 %, as well.

Suzuki: As far as we in Sales were concerned, we were happy that the Design Dept. went ahead without changing their policy.

Riding the Wave of Research Into Quantum Computing To Develop Unexplored Markets

ORCA®-Quest is already anticipated for several markets, it seems. How do you think sales will be developed from here on?

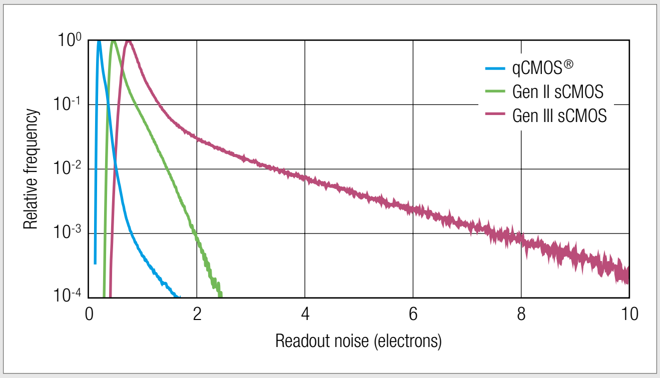
Tsuchiya: Although quantum computing has been reported in the news and various other media, in fact, it is still in its basic research stage. Yet, expectation for the practical application of quantum computing is very high. So, we anticipate that ORCA®-Quest will be used mainly in the field of research. I think I mentioned it earlier on but we took various steps to enable ORCA®-Quest to be accepted into the physics-related market before its development was completed. We proceeded with marketing so that people would buy the product as soon as it was released onto the market, and we included extra functions before its release as a result of interviews we conducted with researchers. We believe that these efforts resulted in earning considerable response in overseas markets before its release and that the effect of this will continue in the future, too.

Suzuki: It's the same in Japan, too. 2020 is called the First Year of the Quantum Era in Japan as this is the year that a quantum computer was first installed in Japan. Quantum-related research budgets started to increase from around the same time. ORCA®-Quest was completed just in time to ride this wave. From a sales perspective, the timing could not have been more perfect.

On the technical side, what are your aims from here on?

Nakajima: Up till now, we have been fully engaged in reducing noise. And, I feel that the continuation of this should be one of our technical aims. Also, there is still lots of room for improvement in quantum efficiency that I mentioned earlier.

Comparison of readout noise distribution between ORCA®-Quest and conventional cameras

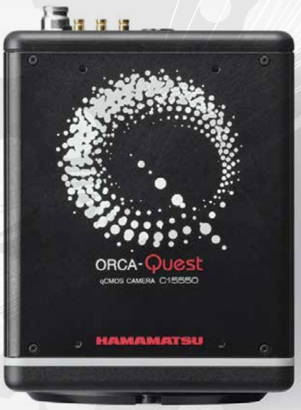


Kameyama: As for myself, my aim is to lower noise in all pixels as it is sometimes higher in some pixels while lower in others.

Kyogoku: I think improvements in speed should be added on to noise reduction. High sensitivity becomes necessary as the amount of light decreases the shorter the light sensing time becomes. ORCA®-Quest is amazing because of the ultra high-sensitivity that has been achieved. However, I think our next aim is to make the frame rate faster.

We Shall Raise the 'Torch of Pursuit' To Create Products That Illuminate The Way for Researchers

I heard that you thought through the design and logo mark used for ORCA®-Quest very carefully.



Suzuki: So that customers can use ORCA®-Quest in physics and related fields, we used the color black to minimize the light reflecting off the enclosure and a material with little gloss. The logo mark is on the top of the product. Together with those in charge at our local subsidiaries, we chose a logo mark from among over 30 candidates that would best convey a strong impression of ORCA®-Quest.

Nakajima: The product name "Quest" takes the initial "Q" of "Quantitative." The logo mark expresses the letter "Q" and combines an image of drops of light that express photons and an image of a torch lighting up researchers' field of research.

I see. So, the mark expresses the features of the product and the fields it will contribute to. OK, last of all, as a product manager could you give a message to our readers.

Tsuchiya: ORCA®-Quest is a camera for low light measurement and achieves the ultimate in noise reduction. I anticipate that it will find use in several markets, primarily in the field of quantum technology as best represented by quantum computing. However, 2-dimensional photon number resolving is a technology that did not exist up till now. In other words, I feel that this new technology has the latent potential to open up new areas of science. I look forward to receiving customer feedback for "visualizing what has been invisible" and "quantitatively measuring photons" in fields where observation and measurement have so far been impossible. Feel free to contact us about anything.

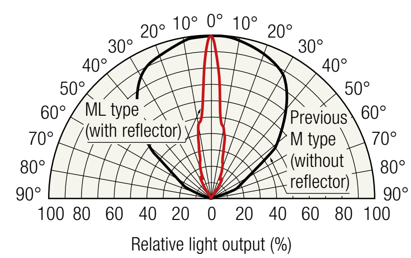
Mid Infrared LED
L15893-0330ML,
L15894-0390ML,
L15895-0430ML

Specifications

Parameter	L15893-0330ML	L15894-0390ML	L15895-0430ML	Unit
Peak emission wavelength*	3.3	3.9	4.3	μm
Spectral half width*	0.4	0.6	1.0	μm
Radiant flux*	2.6	2.4	1.4	mW
Forward voltage*	2.7	2.2	2.0	V
Rise time (max.)		1		μs

* I_F = 80 mA, QCW mode

Directivity



Distance between LED and photodiode
= 3 cm: ML type (with reflector)
= 5 cm: M type (without reflector)

With Reflector
Peak Emission Wavelength:
3.3 μm, 3.9 μm, 4.3 μm

The L15893-0330ML, L15894-0390ML and L15895-0430ML are mid infrared LEDs with a peak wavelength of 3.3 μm, 3.9 μm, and 4.3 μm respectively, manufactured using Hamamatsu unique crystal growth and process technologies. These are suitable as light sources mounted in gas detectors.

Differences from the previous product

Compared to the previous product (without reflector type), about 10 times higher radiation intensity is achieved.
(Distance between LED and photodiode: approx. 17 mm)

Features

- High output
- Narrow directivity
- Low power consumption

Application

- Gas detection (CH_4, CO_2)

NEW OPTO-SEMICONDUCTOR PRODUCTS

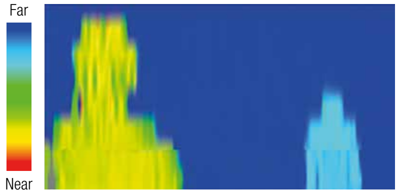
Distance Area Image Sensor S15743-01WT, S15744-01WT

Left: S15743-01WT
Right: S15744-01WT

Specifications

Parameter		S15743-01WT	S15744-01WT	Unit
Number of effective pixels (H × V)		128 × 8	320 × 20	pixels
Pixel size (H × V)		20 × 50		μm
Pixel pitch	H	20		μm
	V	146.5		

Imaging examples



Using S15743-01WT (distance image)

Commercial camera (visible image)

Back-illuminated Type, NIR-enhanced, Measures the Distance to an Object by TOF Method

The distance image sensors are designed to measure the distance to an object by TOF (time-of-flight) method. When used in combination with a pulse modulated light source, these sensors output phase difference information on the timing that the light is emitted and received. Distance data can be obtained by performing calculation on the output signal with an external signal processing circuit or on a PC.

Features

- High sensitivity in the near infrared region
- Chip size package (CSP)

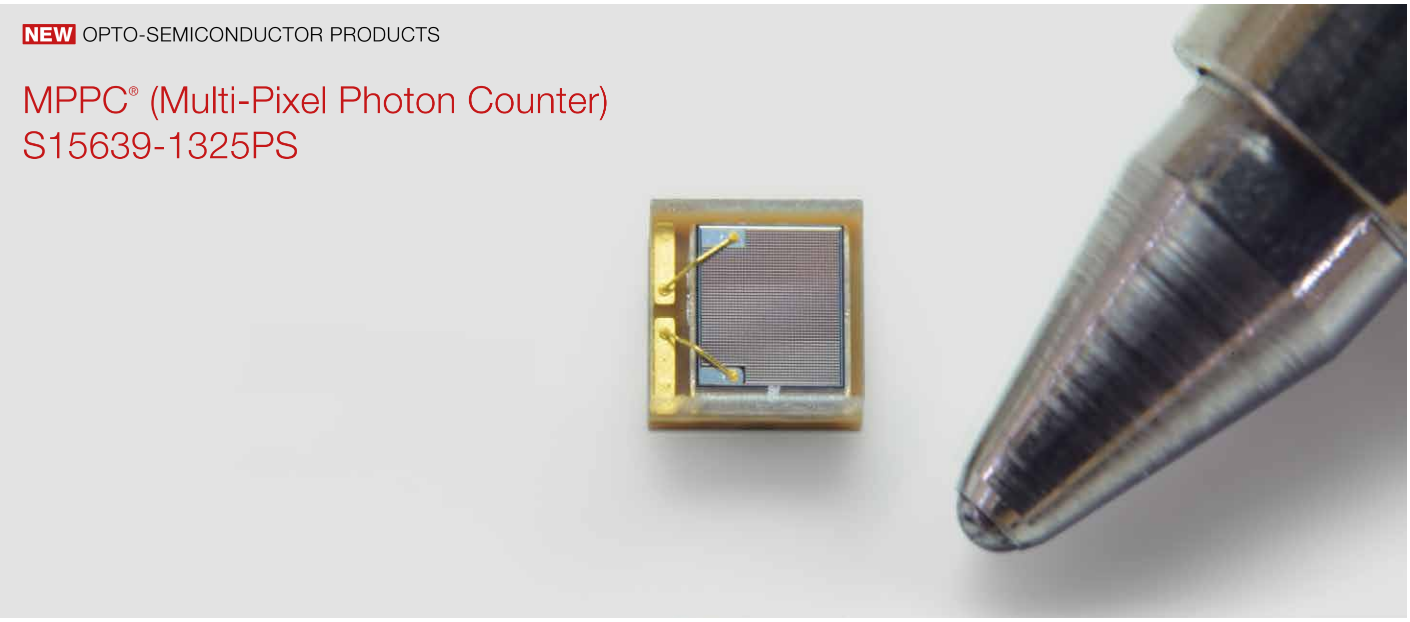
Applications

- Touchless operation
- Obstacle detection
- Shape recognition
- Motion capture

Evaluation kits

The evaluation kits are available for the S15743-01WT and S15744-01WT distance area image sensors (with the sensor). Contact us for detailed information.

MPPC® (Multi-Pixel Photon Counter) S15639-1325PS

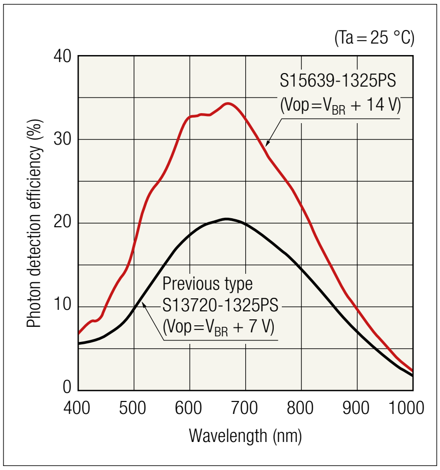


Specifications

Parameter	Specifications	Unit
Effective photosensitive area (H × V)	1.3 × 1.1	mm
Pixel pitch	25	µm
Number of pixels	2120	–
Photon detection efficiency (λ = 905 nm)	9	%
Breakdown voltage	42	V
Dark count rate*	700	kcps
Crosstalk probability	6	%
Afterpulse probability	1 max.	%
Gain	1.7×10^6	–

* Threshold = 0.5 p.e.

Photon detection efficiency vs. wavelength



NIR-enhanced MPPC for LiDAR

This MPPC achieves high detection efficiency in the near infrared region that is used in LiDAR (Light Detection and Ranging).

Differences from the previous product

Compared to the previous product S13720-1325PS, the detection efficiency at the wavelength of 905 nm is increased from 7 % to 9 %.

Features

- High photon detection efficiency: 9 % (λ = 905 nm)
- Low afterpulse probability: 1 % max.

Applications

- Automotive LiDAR
- Industrial distance measurement

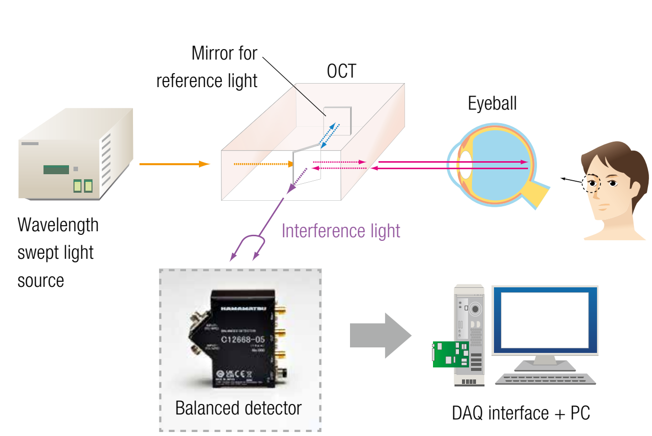
Balanced Detector C12668-05/-06

Specifications

Parameter	C12668-05	C12668-06	Unit
Built-in element	InGaAs PIN photodiodes		–
Optimal wavelength band*1	1.0	1.3	µm
Frequency bandwidth (-3 dB)	0.1 to 800		MHz
Common-mode rejection ratio	30		dB
Conversion impedance (50 Ω)	29		kV/A
Supply voltage	± 12		V
Dimensions (W × H × D)*2	18 × 70 × 63		mm

*1 Wavelength at which multiple reflections can be reduced the most
*2 Excluding connectors in the output section

Image of ophthalmologic examination



Balanced Detectors With Reduced Multiple Reflections

These are differential amplification type photoelectric conversion modules containing two Hamamatsu photodiodes with balanced characteristics. The photodiodes are connected in a direction that cancels out each photocurrent.

The minute difference in light levels is treated as a displacement signal, converted into an electrical signal, and output. These products can be applied to optical coherence tomography (OCT) used in ophthalmologic examinations and the like.

Differences from the previous product

Compared to the previous products C12668-01/-02 (DC to 200 MHz) and -03/-04 (DC to 400 MHz), high-speed response of 0.1 to 800 MHz is achieved.

Photosensor Module H16200-40, H16201-40

Left: H16200-40
Right: H16201-40

Specifications

Parameter	Specification	Unit
Spectral response range	300 to 740	nm
Quantum efficiency at 520 nm (typ.)	45	%
Effective photocathode area	ϕ5	mm
Input voltage	+11.5 to +15.5	V
Maximum output signal current	40	µA
Gain (typ.)*	1.0×10^6	–

* Control voltage +0.8 V

Wide Dynamic Range PMT Modules With High Sensitivity in Visible Range

The H16200-40 and H16201-40 are PMT modules that incorporate a GaAsP photocathode metal-package PMT with high sensitivity to visible light and a high-voltage power supply circuit. The maximum output signal current is improved from 2 µm to 40 µm, achieving a wider dynamic range. When used in microscopy applications, these PMT modules allow measuring samples with different brightness without changing the control voltage (gain).

Features

- Wide dynamic range: Maximum output signal current 40 µA
- High sensitivity: GaAsP photocathode
- Compact

Applications

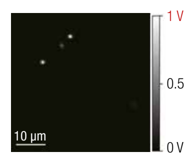
- Laser microscopy
- Flow cytometry

Comparison of imaging examples

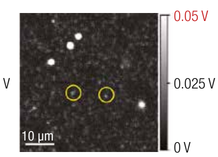
Samples: 1 µm and 0.2 µm beads

H16201-40

The wide dynamic range allows imaging dim beads and bright beads simultaneously without changing the voltage.



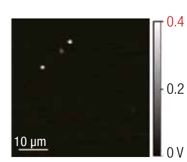
40 µA, 650 V, 10^4[V/A], LPF: 1 MHz



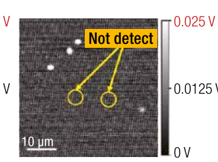
40 µA, 650 V, 10^4[V/A], LPF: 1 MHz

Conventional type

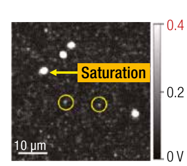
The dynamic range is narrow, so it's necessary to change the voltage in response to the size of the beads.



2 µA, 450 V, 10^5[V/A], LPF: 1 MHz



2 µA, 450 V, 10^5[V/A], LPF: 1 MHz



2 µA, 650 V, 10^5[V/A], LPF: 1 MHz

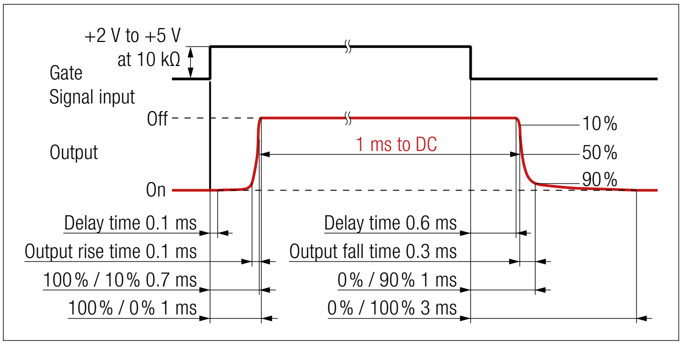
Courtesy of Keisuke Isobe and the academic-industrial partnership among RIKEN Center, Kyoto University, and HPK

Photosensor Module H12056-40

Specifications

Parameter	Specification	Unit
Spectral response range	300 to 740	nm
Quantum efficiency at 520 nm (typ.)	45	%
Effective photocathode area	ϕ5	mm
Input voltage	5	V
Maximum input current	10	mA
Maximum output signal current	40	μA
Gate width	1 ms to DC	–

Gate characteristics



Gated PMT Module With High Sensitivity in Visible Range

The H12056-40 is a PMT module that incorporates a GaAsP photocathode metal-package PMT with high sensitivity to visible light, a high-voltage power supply circuit, and a gate circuit. The gate function protects the PMT from excessive light such as excitation light irradiating a sample.

Features

- Gate function: 1 ms to DC
- High sensitivity: GaAsP photocathode
- Compact

Application

- Laser microscopy

Photosensor Module H16146-110

Specifications

Parameter	Specification	Unit
Spectral response range*	230 to 700	nm
Effective photocathode area	ϕ8	mm
Input voltage	5 (USB bus power)	V
Maximum output voltage of current-to-voltage amplifier	+4	V
Frequency bandwidth of current-to-voltage amplifier	DC to 20 k Hz	–
Current-to-voltage conversion factor	1	V/μA
AD converter sampling rate	200	kHz
AD converter resolution	16	bit

* Other spectral response ranges available

Equipped With a USB Interface Capable of Controlling the Signal Output and Supply Voltage

The H16146-110 photosensor module contains a metal-package PMT, a high-voltage power supply circuit, a voltage-divider circuit, an output current-to-voltage conversion circuit, and an AD converter. The H16146-110 has a USB interface that is easier to handle, unlike pin/cable outputs.

Features

- Equipped with USB interface
- Digital signal output
- Digital control of supply voltage
- Operates on USB bus power

Application

- Low-level-light measurement

HAMAMATSU PHOTON IS OUR BUSINESS

NEW ELECTRON TUBE PRODUCTS

Photosensor Module
H14603, H14950, H14951, H14953

Left: H14950
Center: H14951
Right: H14603, H14953

Specifications

Parameter	H14603	H14950	H14951	H14953	Unit
Effective photocathode area	ϕ8				mm
Input voltage	±5	+15	+15	±15	V
Output type	Voltage/cable	Current/pin	Current/cable	Voltage/cable	–

Suffix	Spectral response range (nm)	Photocathode type
-100	300 to 650	Super bialkali
-103	185 to 650	Super bialkali
-200	300 to 650	Ultra bialkali
-01	300 to 870	Multialkali
-04	185 to 870	Multialkali
-20	300 to 920	Extended red multialkali

Miniature Metal-package PMT Modules

These metal-package PMT modules are integrated with a high-voltage power supply circuit and a voltage divider circuit. The volume of these PMT modules is about one-half that of our conventional products (H10720, H10721, H11900 and H11901 series), and so will help downsize light measurement equipment.

Features

- +15 V operation, current output type
- ±5 V/±15 V operation, voltage output type
- Low power consumption

Applications

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

Photosensor Module H14990-100-02

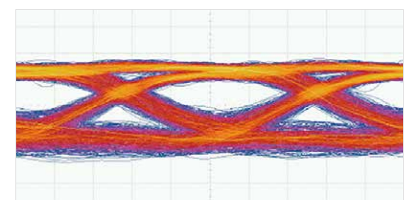
Left: H14447
Center: H14990-100-02
Right: H14600-100

Specifications

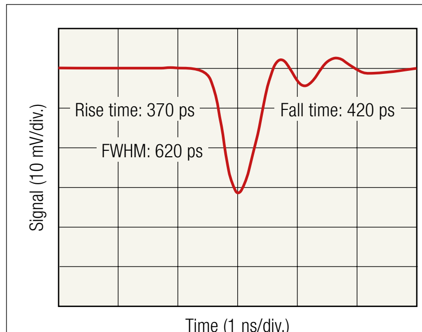
Parameter	Specification	Unit
Spectral response range	300 to 650	nm
Effective photocathode area	ϕ8	mm
Input voltage	+5	V
Maximum input current	3.2	mA
Maximum output signal current*	100	μA
Rise time	370	ps
FWHM	620	ps

* Control voltage +0.8 V

Eye pattern (0.8 Gbps)



Time resolution (typ.)



Allows 0.8 Gbps-class Communications High-speed Response Small Photomultiplier Tube Module

The H14990-100-02 is a current output type metal-package PMT module incorporating a high-voltage power supply circuit. The H14990-100-02 features fast time response, high gain and large photosensitive area, making it useful for high-speed underwater optical communications. Our lineup also includes the H14600-100 with lead pin output and the H14447 with an effective photocathode area of 25 mm diameter capable of 1 Gbps class communications.

Features

- High speed response: up to 0.8 GHz
- Wide photosensitive area of 8 mm diameter despite its small size
- Low power consumption

Applications

- Optical communication
  - Movie streaming
  - High-definition image/movie transfer

NEW ELECTRON TUBE PRODUCTS

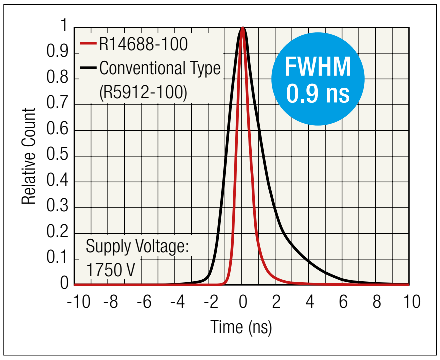
8 inch (202 mm) Head-on Type Photomultiplier Tube R14688-100

Specifications

Parameter (typ.)	Specification	Unit
Spectral response range	300 to 650	nm
Quantum efficiency at 390 nm (typ.)	35	%
Photocathode type	Super bialkali	–
Effective photocathode area	ϕ190	mm
Gain (typ.)*	1.0 x 10^7	–
T.T.S. (FWHM) (typ.)	0.9	ns

*Supply voltage 1750 V, at 25 °C

T.T.S. (Transit Time Spread)



Fast Time Response and High Gain

The R14688-100 is an 8-inch diameter photomultiplier tube ideal for high energy physics experiments. The R14688-100 offers a time resolution (T.T.S.) of 0.9 ns which is more than 2.4 times better than our conventional product (R5912-100) with a T.T.S. of 2.2 ns. Its excellent time response is promising for a wide range of applications in scientific research.

Features

- High time resolutions(T.T.S.): 0.9 ns
- High gain: 1.0×10^7

Application

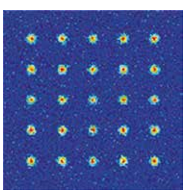
- High energy physics

NEW SYSTEMS PRODUCTS

ORCA®-Quest qCMOS® Camera C15550-20UP

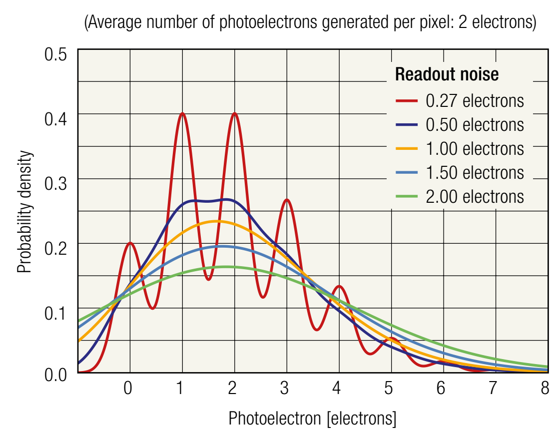
Simulation image of neutral atoms

Observing the fluorescence of trapped ions and neutral atoms contributes to the research of quantum computing and quantum simulation.



Rb atom	@780 nm
Number of atoms	5 × 5
Atomic emission	2000 photons
Background	5 photons
Magnification	20 × (NA: 0.4)
Distance between each atom	5 μm

Simulation data of photoelectron probability distribution



Realization of photon number resolving by low readout noise

In order to count these photoelectrons, camera noise must be sufficiently smaller than the amount of photoelectron signal. Conventional sCMOS cameras achieve a small readout noise, but still larger than photoelectron signal, making it difficult to count photoelectrons. Using advanced camera technology, the ORCA®-Quest counts photoelectrons and delivers an ultra-low readout noise of 0.27 electrons rms (@Ultra quiet scan), stability over temperature and time, individual calibration and real-time correction of each pixel value.

The World's First Camera That Achieved Photon Number Resolving

This is the world's first qCMOS® (Quantitative CMOS) camera that realizes Photon Number Resolving with ultimate low noise performance. It develops new applications in a wide range of fields such as biology, physics, astronomy and quantum research.

Features

- Spatial photon number resolving capability
- Low readout noise: 0.27 electrons rms
- Low dark current: 0.006 electrons/pixel/s (max cooling)
- High QE: 90 % (Peak QE)
- High pixel number: 4096 (H) × 2304 (V), 9.4 megapixels
- High speed readout: 120 frames/s (4096 × 2304)

Applications

- Quantum technology
- Astronomy
- Raman spectroscopy
- Cell luminescence imaging
- X-ray / neutral atom imaging
- PL imaging

NEW SYSTEMS PRODUCTS

PHEMOS®-X Emission Microscope C15765-01

The PHEMOS®, Now Future Proofed

The PHEMOS®-X is a high-resolution emission microscope that pinpoints failure locations in semiconductor devices by detecting weak light emissions, heat emissions caused by defects and internal waveforms from working samples.

Features

- New laser scan system supporting static and dynamic analysis
- High accuracy stage designed for precise positioning
- New macro lens with high resolution
- New user friendly analysis software for multiple analyses

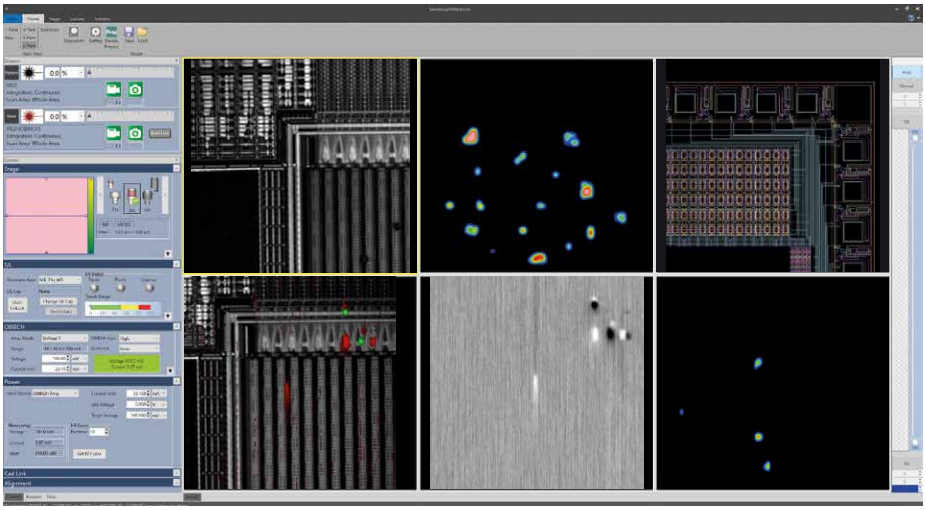
Applications

- Localization of defect site and analyzing functional errors inside semiconductors

Specifications

Parameter		PHEMOS®-X	PHEMOS®-1000 (Conventional product)
Light source		5 ports	3 ports
Stage resolution		XYZ 0.05 µm	XY 1.0 µm, Z 0.2 µm
Repeat accuracy		±1 µm	±4 µm
Macro lens	Photo detection	1.35 ×, NA = 0.40	0.8 ×, NA = 0.40
	Photo stimulation		1.0 ×, NA = 0.03

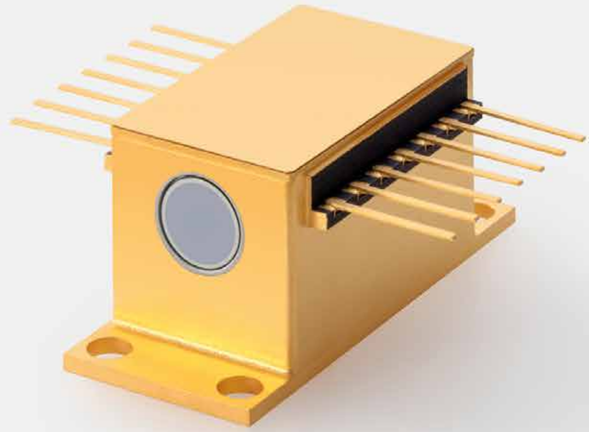
Analysis software



New analysis software displays multiple analysis results and has excellent operability.

NEW LASER PRODUCTS

Quantum Cascade Laser L12004-2190B-G/-E, L12005-1900B-G/-E



Specifications

Items	L12004-2190B-G/-E	L12005-1900B-G/-E	Unit
Wavenumber	2190	1900	cm^{-1}
Radiant power (min.)	15		mW
Threshold current (max.)	0.4		A
Target gas (e.g.)	Carbon monoxide (CO)	Nitric oxide (NO)	–

Quantum Cascade Laser is Now on New Compact and Lightweight Package

Quantum cascade laser (QCL) is expanding in the field of Mid-infrared laser absorption spectroscopy.
Spectroscopy with a QCL has many advantages, in particular the achievable sensitivity of the measurements.

Differences from the conventional products

The power saving of QCL chip has resulted in a volume ratio of approx. 1/5 and a mass ratio of approx. 1/10 compared to conventional HHL packages, enabling the laser to be mounted on compact and lightweight equipment.

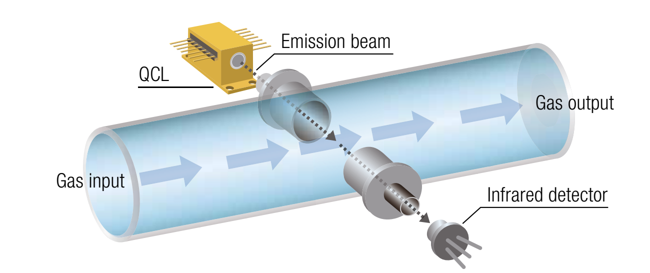
Features

- Mid-infrared (4 μm to 10 μm) semiconductor laser
- DFB laser ideal for gas-analysis application
- Lens built-in types (/-E) are also available

Application

- Trace gas analysis

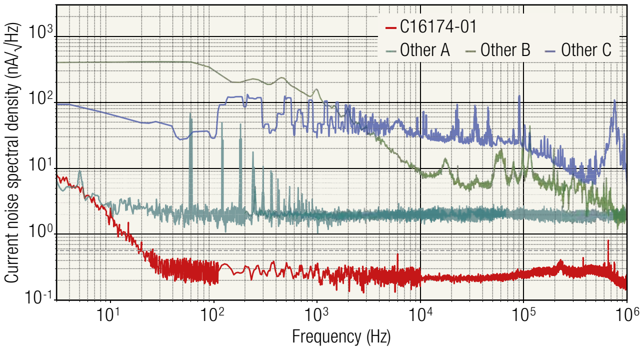
Gas measurement image



Accessory

CW controller C16174-01
CW controller is a power supply unit for CWQCL, and it controls QCL and TEC by USB communication. C16174-01 would support to improve the peformance of your laser spectroscopy as it has a superior low noise characteristics.

Comparison of noise characteristics in output current



NEW LASER PRODUCTS

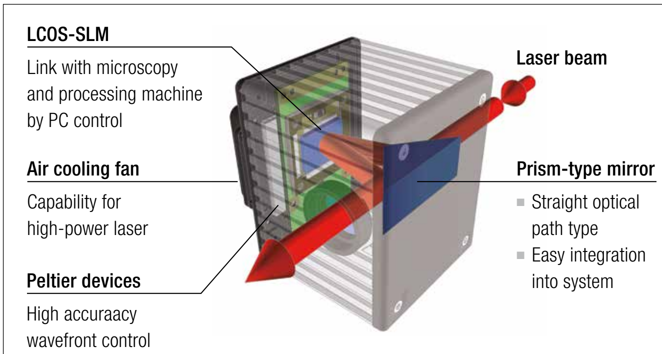
Wavefront Shaper C15789 Series

Specifications

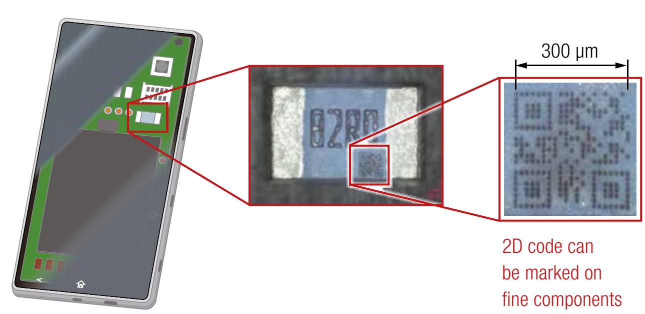
Type. no	Corresponding wavelength	Unit
C15789-04M	460 to 560	nm
C15789-02	750 to 850	nm
C15789-12	850 to 1000	nm
C15789-03	1000 to 1100	nm

Please contact us separately for other wavelengths

Pseudo transmissive optical



2-D code marking machining



Wavefront Control Modules Suitable for Laser Processing and Microscopic Observations

Wavefront control module for easy beamforming. The pseudo-transmission configuration, makes it easy to connect to optical systems such as laser processing equipment and microscopes. In addition, since it is equipped with a design library and application of phase data for beamforming as standard, it is possible to add a computer hologram creation function, etc. to the software.

Feature

- Easy connection to optical components/systems

Applications

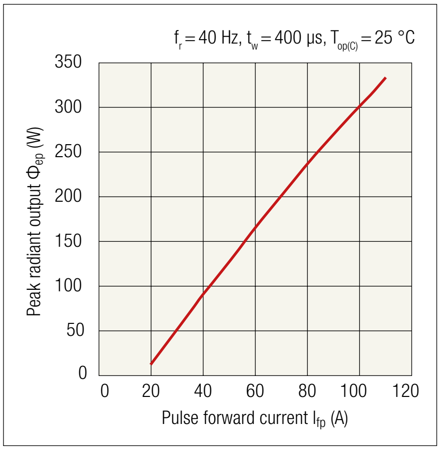
- Optical beam shaping
- Aberration correction
- Repair/trimming
- 3D simulataneous multipoint laser beam generation

Pulsed Laser Diode Bar Module L13459-01

Specifications

Items		Specification	Unit
Center emission wavelength		798±3	nm
Operating current		100	A
Operating voltage		6.5	V
Threshold current		16	A
Beam-divergence angle	Horizontal	11	° (degrees)
	Vertical	26	

Peak radiant output – pulse forward current (ex.)



High Density Laser Beam Owing to Narrow Stack Pitch

This is a laser diode (LD) bar module with a peak radiant power of 300 W and 798 nm wavelength. By stacking the LD bars at a narrow pitch, a high-density laser beam can be realized. In addition, the use of passive cooling method, which does not require chillers, increases the flexibility of designing when assembling equipment.

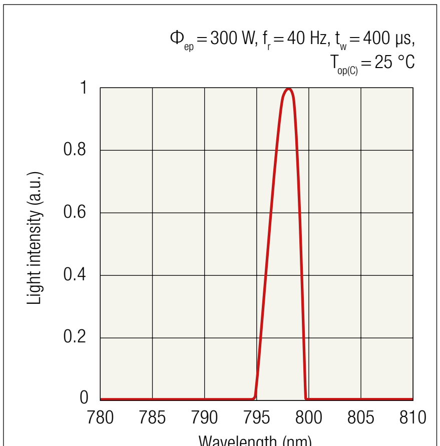
Features

- Peak radiant power: 300 W
- Wavelength: 798 nm
- Passive cooling
- High density laser beam

Application

- Pumping of solid state laser

Emission spectrum (example)



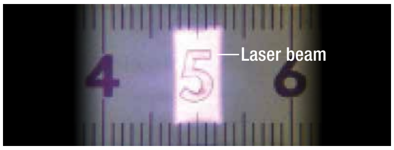
DDL Coaxial Unit A15185 Series

Left: DDL Coaxial unit A15185-11N
Right: DDL Expansion unit A15185-000-B

Product configuration example

1. DDL L14133 series
   Radiant power 2.5 kW/5.0 kW
2. Irradiation unit A14132-BD
   Uniform delivery and various radiation ranges configurable
3. DDL coaxial unit A15185 series
   Mounting of thermometer and CCD camera is possible

Coaxial observation image taken with CCD camera



Laser was irradiated onto a ruler placed at the focus point (processing point)

Coaxial Observation Cameras and Thermometer Fitting Accessories for DDLs Ideal for Laser Processing

A coaxial unit that allows thermometers and a CCD camera to be mounted onto a direct diode laser (DDL) ideal for hardening and annealing. Mounting a thermometer enables temperature measurement during machining, enabling control of temperatures during quenching and annealing.

Features

- Coaxial observation
- Coaxial temperature measurement

Applications

- Metal processing (hardening, annealing, cladding, brazing)
- Pumping of solid state laser

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