HAMAMATSU
PHOTON IS OUR BUSINESS
NEWS 2018 01

COVER STORY PAGE 3

Photonics for advanced car technologies

Content

Optical devices contributing to diverse advanced technologies to assist in **safe, reliable, convenient, and comfortable car driving**

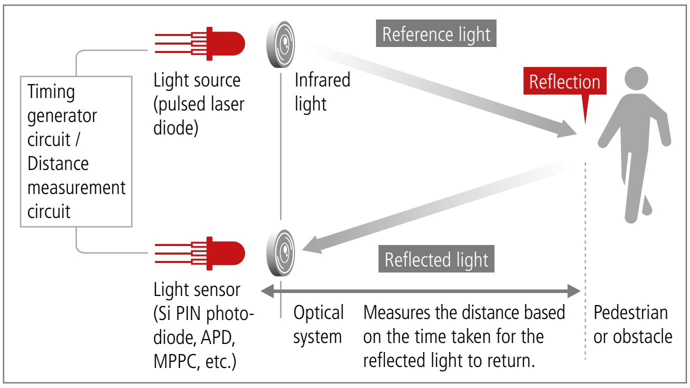
Applying the distance measurement (obstacle detection) principle to collision avoidance and self-driving

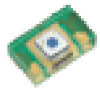
Collision avoidance system

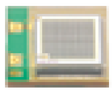
A collision avoidance system in a car automatically activates the brake when the car gets too close to an object such as a pedestrian or obstacle.

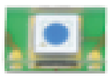
Auto-cruise or self-driving system

An auto-cruise or self-driving system maintains the constant speed set by the driver without him having to keep pressing the accelerator pedal. These systems utilize a sensing technology called LiDAR (Light Detection and Ranging) to measure distances such as the distance to the car ahead and distance for safely controlling the car. The LiDAR uses a pulsed laser diode and a sensor such as a silicon PIN photodiode. The laser diode emits infrared light (reference light) onto an obstacle ahead or around the car and the sensor detects the light (reflected light) returning from the obstacle. The distance from the car to an object can be found by measuring the time taken for the reflected light to return.




APD

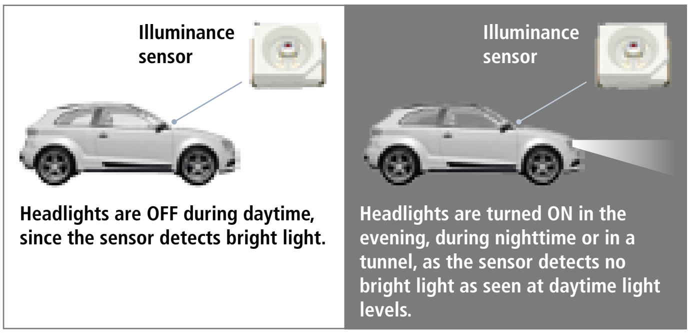

MPPC


Si PIN photodiode


Pulsed laser diode

Detecting the ambient light level for smart auto headlights and auto anti-glare rearview mirrors

Smart auto headlights respond to the ambient light level to automatically turn the headlights of a car on or off. An illuminance sensor mounted near the dashboard monitors the brightness outside the car and turns on the parking lights or headlights when the brightness drops below a certain light level. Auto anti-glare rearview mirrors also have an illuminance sensor that automatically adjusts the mirror reflectance when it detects intense light (high beam headlights) from a rear-approaching car at night, so that the driver is not dazzled by the headlight glare.




Illuminance sensor

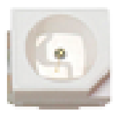

Si photodiode

SMART CAR

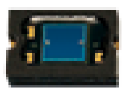
Photonics is also used here!

Detecting raindrops for automatic windshield wiper control

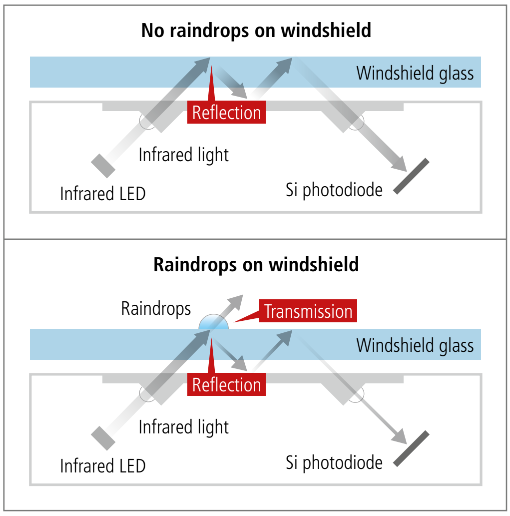
When there aren't any raindrops on a car windshield, infrared light emitted from an infrared LED reflects from the front surface of the windshield and is detected by a silicon photodiode. When there are raindrops on the car windshield, infrared light passes through the raindrops and less light is reflected and detected by the silicon photodiode. Making use of this principle, a silicon photodiode detects whether or not there are raindrops (water droplets) on the windshield. When raindrops on the windshield are detected, the windshield wipers automatically start while also automatically adjusting their speed according to the amount of the light detected by the silicon photodiode which indicates whether the rain is light or heavy.



Infrared LED



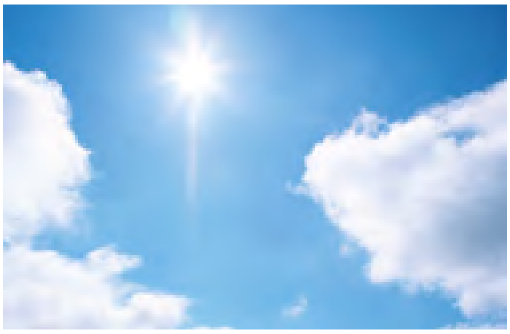
Si photodiode



Sunlight sensing (auto air conditioner)

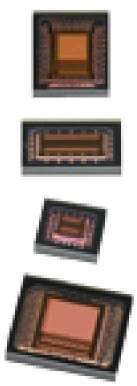
Auto air conditioners for cars use various sensors to detect conditions such as temperatures inside and outside the car and the amount of sunlight. Based on such information, the air conditioner controls the blow temperature and air flow rate and it also switches air vents on or off to keep the temperature inside the car at the set level. Sunlight sensors incorporating a silicon photodiode are used to detect the amount of sunlight.

Sunlight sensor



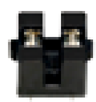
HMI (human-machine interface)

A human-machine interface or HMI is a general term for the system, equipment and software that help a human operator to operate a machine or the device to inform the operator of the current status and results. In the case of automobiles, the HMI is utilized to operate the steering wheel and instrument panel. Optical encoder modules and Schmitt trigger circuit photo ICs are used to detect the steering wheel angle, and range-finding image sensors are applied to recognize various operations by gestures.



Distance image sensors

Schmitt trigger circuit photo IC



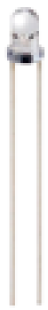
Optical encoder module

Cover Story

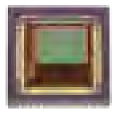
Photonics is also used here!

Driver monitor

A vehicle driver monitor uses a near-infrared video camera to capture images of a driver's face and analyzes the orientation of the driver's face and the degree of eye opening in real-time. If the driver does not look forward or close his or her eyes for a certain period of time, the driver monitor triggers an alert to the driver to assist in safe driving and prevent inattentive driving such as dozing while driving. CMOS area image sensors and infrared LEDs are used to capture near-infrared images of the driver's face.



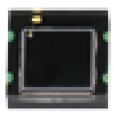
Infrared LED



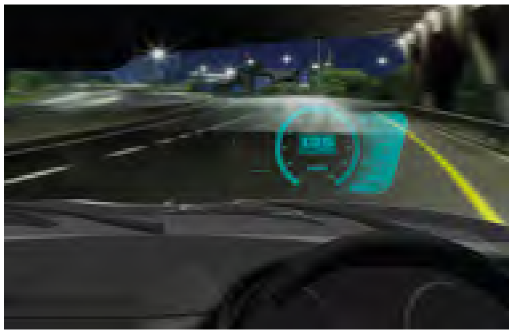
CMOS area image sensor

Head-up display

A head-up display or HUD is a safe-driving support system that displays information such as speedometer and car navigation data on the windshield or transparent panel in front of the driver, allowing him or her to view such information while keeping his or her line of sight on the road ahead. Silicon PIN photodiodes are used to adjust the light level of images displayed on the head-up display.



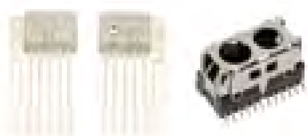
Si PIN photodiode



Information communication

Multimedia information including the video and audio data we enjoy in a car is sent via a wire harness or optical fiber cable between various devices such as a display, in-car camera, audio player, and speakers. Light emitter and receiver photo ICs are used for such information exchange through optical links using optical fibers. Light emitter and receiver modules are also used for VICS (Vehicle Information and Communication System) that utilizes FM multiplex broadcasting and beacons to enable a car navigation system to receive real-time road traffic information such as traffic jams and regulations.

Light emitter and receiver modules for VICS



Light emitter and receiver photo ICs for optical links

Creating a market for laser hardening

Beam-homogenizing DDL with excellent energy-saving characteristics, capable of uniform processing over a large area

The field of laser processing also known as laser cutting or laser machining using semiconductor lasers has been steadily expanding. Hamamatsu has been working to open up the market in the laser processing field by developing Direct Diode Lasers (DDL) that use a unique optical system to directly focus a beam from a semiconductor laser without using an optical fiber. At Hamamatsu, we are increasing our product lineup to support applications including laser welding and laser hardening on even larger surface areas. DDL are convenient to use at manufacturing sites and production lines as they don't need optical fibers. As a result, we have also developed a unique irradiation unit (beam-homogenizing optical system A14132 series) designed specifically to smooth out the DDL light distribution. We plan to offer this product as a high energy efficiency light source ideal for laser hardening equipment.

We talked to 5 staff members involved in developing this product. Now let's hear about the background leading to the release of this product.

Interviewees (from the left)

Omiya Takenori, Business Promotion Group, Laser Promotion Division

Uchiyama Takayuki, Compound Semiconductor Fabrication Center

Miyajima Hirofumi, Manufacturing Group, Laser Promotion Division

Matsuura Masaki, Manufacturing Group, Laser Promotion Division

Watanabe Masaki, Compound Semiconductor Fabrication Center

R&D Interview

No.1 Energy-saving performance – directly focused semiconductor laser

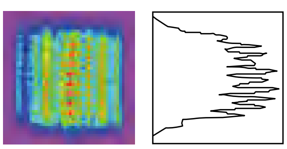
Lasers are becoming more and more widely used in industrial production processes such as cutting and welding. First of all, can you explain the current state of the laser processing market?

Miyajima: Currently, fiber lasers have about half the market share, and CO_2 lasers and solid-state lasers occupy the remaining half. The market share held by semiconductor lasers is still small, but we think that to the contrary there will be large growth especially in promising applications such as resin welding and soldering.

Omiya: At Hamamatsu, we have been conducting research into semiconductor lasers for pumping energy into solid-state lasers to make laser fusion a reality. As another application that directly utilizes the output from semiconductor lasers, we have developed a laser product named "DDL" for laser processing that is much more efficient than other processing methods up to now. DDL consists of an array of high-power LD (Laser Diode) bars combined with an optical system. Our first DDL was released in 2004 for application fields such as welding and thermal treatment. DDL offers very high energy-saving performance compared with other light sources used in the same applications, and also has a simple structure and compact design due to the use of a small micro-channel heatsink with high cooling efficiency.

Previous model

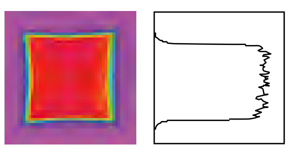
DDL L11585 series with aspect ratio variable optical system attached.



The above is an extreme example showing irregularities in intensity stemming from the emission point of each LD.

NEW model

DDL L11585 series with irradiation unit (beam-homogenizing optical system) A14132 series mounted.

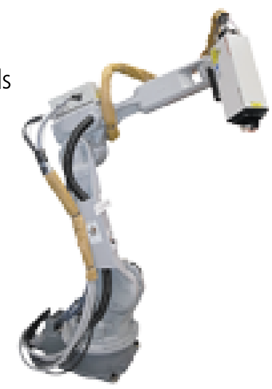


Irregularities are smoothed by the beam-homogenizing optical system we developed in-house.

What is the biggest difference compared to other similar products?

Miyajima: Most laser light sources use an optical fiber routed to the processing point. In contrast to this, DDL generates a laser beam near the processing point and directly focuses the beam onto the processing point. This avoids damaging the optical fiber from excessive bending or twisting.

Omiya: Our recent DDL model is designed to be even more compact than earlier models and so can be held by the manipulator of a compact 6-axis robot to perform welding tasks. DDL has a simple structure and is an ideal laser for industrial applications where high reliability and minimal maintenance are required. DDL is already in use mainly for automobile manufacturing in various countries throughout the world.



Opening up a new market to utilize high performance

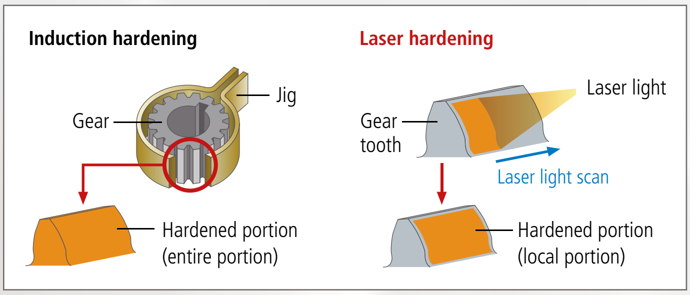
Semiconductor lasers are now becoming quite common in the welding field, aren't they?

Omiya: Yes, they are. However, fiber lasers are also becoming more compact so competition is tough in the welding field. This prompted us to begin opening up another application field where the advantages of DDL can be fully utilized, for example laser hardening. In this field, users want laser processing with low distortion and less thermal impact. Therefore, we started improving our DDL to meet user needs for laser hardening.

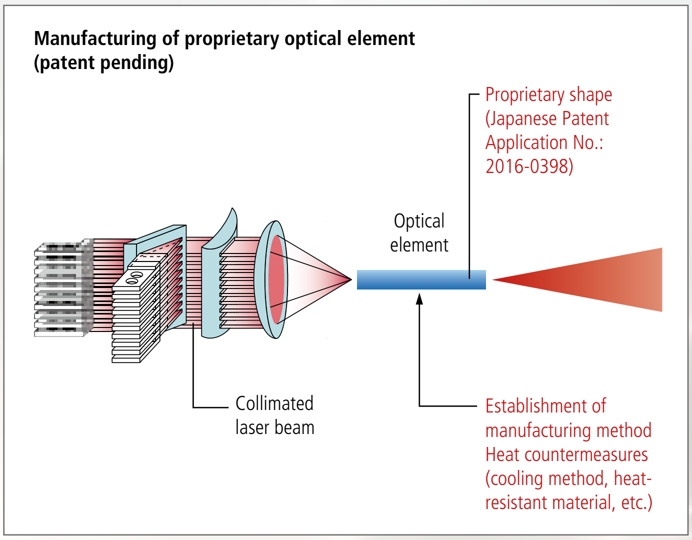
Uchiyama: DDL produces a high output beam in an elongated pattern which is suitable for welding but not for laser hardening that requires processing a specific large area. To flexibly expand the beam pattern in both horizontal and vertical directions we developed a laser hardening optical system option for DDL.

So, you started opening up the laser hardening market …

Watanabe: Yes. However, the laser hardening optical system we first developed did not work well enough. To put it another way, DDL is like a bundle of laser pointers designed to emit a very large amount of energy. These arrayed light beams create no problems when focused on a small point as in the case of laser welding. However, when the



Applications	High-frequency	Laser
Distortion	Large	Small
Cooling	Required	Not required
Jig (coil)	Required	Not required
Hardening depth	Special jig is required for each product	Easy changeovers
Heating	Deep	Shallow
Post-processing	Entire portion	Local portion



light beams are expanded to irradiate a larger area such as for laser hardening, the light intensity uniformity is poor, which causes uneven heating and makes for unstable processing quality.

Miyajima: Most light sources currently used for laser hardening are fiber lasers. In a fiber laser, light is reflected many times within the fiber so the output beam becomes uniform and easy to form as needed.

So the advantage that DDL does not need an optical fiber becomes a disadvantage from a viewpoint of uniform light intensity?

Watanabe: Yes, in order to solve this problem, we decided to develop in-house a beam-homogenizing optical system (A14132 series) to smooth out the light beams without using an optical fiber. Since beam-homogenizing optical systems using an optical fiber are already on the market, just trying to do what everyone else was doing would not lead us to any great breakthroughs.

So you have developed a unique beam-homogenizing optical system. What kind of structure does it have?

Watanabe: Simply stated, it is like a poorly-made kaleidoscope. When you look into a kaleidoscope, you'll see various patterns and colours linking and changing one after the other. If a mirror used in the kaleidoscope is distorted, the patterns on the mirror are also distorted. We tried smoothing out the laser beams in this same way by linking and distorting them so that all the light becomes soft and blurred.

What did you do to make all the light soft and blurry?

Watanabe: For example, when you twist a square bar at its middle position, the surface of the twisted portion is curved inward. If light strikes the curved surface, it reflects and spreads outward. This gave us a hint about how to obtain the right amount of light blurring. Twisting the bar too much makes the curved surface too big, which scatters the light away. In contrast, if twisted too loose, the light does not mix sufficiently. So we had a hard time finding just the right condition.

Did you find the optimal condition while making prototype models?

Watanabe: We first studied the problem using computer simulations. After obtaining some guidelines for the optimal condition, we decided to actually fabricate a beam-homogenizing optical system from glass and consulted various glass processing manufacturers for help. However, we soon ran into a brick wall, as fabricating such a unique optical system involved many challenges, and we could not therefore find a manufacturer willing to take on the job. After consulting with our own glass processing department we found that the desired optical system could be fabricated without difficulty by using existing equipment and in-house glass processing machines.

R&D Interview

Highly rated by end users even from the early developmental stage

So you have completed a beam-homogenizing optical system for DDL optimized for laser hardening. What can you offer customers with this system from now on?

Matsuura: Our current beam-homogenizing optical system (A14132 series) is designed to attach to the second-generation DDL L11585 series. The L11585 series is available in two types: a 2 kW and a 4 kW type. We will propose combining our beam homogenizer with a 2 kW type for users who don't need high power, and combining with a 4 kW type for users who need high power.

Omiya: One outstanding feature of our beam-homogenizing optical system is that the users themselves can select a beam pattern according to their applications. For example, our lineup includes 5 aspect ratio converter units from 1:1 to 1:5, and 4 types of condenser lenses. This combination of both converter units and lenses allows selecting up to 20 beam patterns. Users can easily swap aspect ratio converter units and condenser lenses as needed to match the processing task.

Uchiyama: We are also developing a coaxial unit with temperature monitoring and a visible guide light unit which can be attached as an option. Besides standard beam patterns we also welcome custom requests for even larger beam patterns.

How was the customer response?

Omiya: We displayed product samples at a domestic laser-related exhibition held in April, 2017 and got a much better response than expected. Even though the products were still in the developmental stage, we got high ratings from end users and also from system integrators who specialize in building up on the DDL to offer their customers a complete system. We were very happy to receive such positive feedback at such an early stage of development.

Uchiyama: Unlike conventional techniques such as induction hardening, laser hardening causes almost no warping or distortion during hardening and requires no cooling. We propose that our customers use our beam-homogenizing DDL as a new, high-stability light source for laser hardening. Laser hardening has many advantages, for example, it does not need any post-processing, and therefore will offer users an eco-friendly process.

Matsuura: DDL uniformly radiates homogenized light. By making use of this feature, we can find a wide range of applications for DDL in addition to laser hardening such as laser cladding, wafer surface heat treatment in semiconductor manufacturing, and pumping for solid-state lasers.

Establishing this new technique to create new markets

What are your plans moving forward?

Uchiyama: Many customers are requesting us to shorten the tact or cycle time by irradiating laser light over an even larger surface area. This requires higher output power than the present level. To respond to this request, we have started working on improving the power ratings of our beam-homogenizing optical system. At the same time, to boost output power, we intend to further increase the output from the current 4 kW type DDL.

Omiya: The laser hardening technique is not yet popular and few people know that there are now lasers ideally suited for laser hardening. Usually, it takes time for a new processing technique to become widely known, especially since the reliability rating method differs from conventional techniques.

Uchiyama: When hardening the gear of a mechanical part normally subject to wear, the entire gear is hardened by the conventional technique and the reliability is defined based on processing results for the entire gear. However, the actual portion subject to wear is only the gear teeth. So quality can be verified if the gear teeth are properly hardened. Laser hardening is effective enough to harden gear teeth. However, the current definition of reliability established for the conventional technique acts as a barrier that prevents companies from using laser hardening which only processes the gear teeth. To spread use of laser hardening, we think it is essential to review these quality standards.

Miyajima: Moving forward we plan to verify what type of laser hardening is most ideal in terms of laser power, beam pattern, and size of processed objects. To achieve this we will work with our users and system integrators in a long process of trial and error, which will enable us to firmly establish our new laser hardening processing technique.

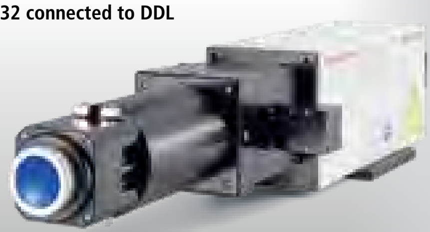
Irradiation Unit A14132 Series

Ideal for laser hardening applications

homogenized beam pattern allows heating in any desired area

Hamamatsu has developed a beam-homogenizing optics system as the irradiation unit for the Direct Diode Laser (DDL) L11585 series. Connecting this unit in front of the L11585 series model gives a uniform, no speckle beam pattern. The focused beam size can be varied by changing the aspect ratio conversion unit and condenser lens unit in combination.

A14132 connected to DDL



Differences from conventional products

This unit can transform a spiky beam profile into a uniform top-hat beam profile.

Features

- Uniform beam profile ideal for laser hardening and heat treatment process
- Beam pattern for heat input control
- Varying beam aspect ratio

Application

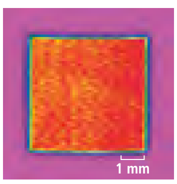
- Metal processing (quenching, cladding), thermal treatment

Specifications (when connected to L11585-04)

Parameter		Value	Unit
Oscillation mode		CW (continuous wave operation)	-
Light output power		2	kW
Oscillation wavelength		940	nm
Beam spot size	Vertical*1	2.5 ±0.5 to 25±0.5	mm
	Horizontal*1	2.5 ±0.5 to 25±0.5	mm
Cooling method		Water cooling (deionized water)	-
Cooling water temperature		25	deg. C.
Weight		Approx. 15 (excluding cooling water)	kg
Dimensions (W x H x D)		Approx. 906 x 150 x 130 (excluding projecting parts and base)	mm

*1 By changing the direction of aspect ratio conversion unit, we can vary focusing beam size vertically and horizontally.

Beam pattern example

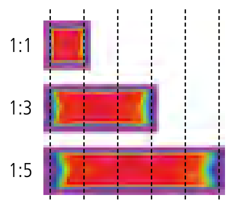


Data of 5 mm x 5 mm

2 kW output when using a 1:1 aspect ratio conversion unit and an F200 condenser lens

Beam lineup

Beam ratio	Condenser			
	F100	F120	F160	F200
1:1	2.5 mm x 2.5 mm	3.0 mm x 3.0 mm	4.0 mm x 4.0 mm	5.0 mm x 5.0 mm
1:2	2.5 mm x 5.0 mm	3.0 mm x 6.0 mm	4.0 mm x 8.0 mm	5.0 mm x 10.0 mm
1:3	2.5 mm x 7.5 mm	3.0 mm x 9.0 mm	4.0 mm x 12.0 mm	5.0 mm x 15.0 mm
1:4	2.5 mm x 10.0 mm	3.0 mm x 12.0 mm	4.0 mm x 16.0 mm	5.0 mm x 20.0 mm
1:5	2.5 mm x 12.5 mm	3.0 mm x 15.0 mm	4.0 mm x 20.0 mm	5.0 mm x 25.0 mm



Company News

Hamamatsu Photonics K.K. to acquire Energetiq Technology Inc. of Woburn, Massachusetts, U.S.A.

Company name: Hamamatsu Photonics K.K.
Stock listing: Tokyo Stock Exchange First Section
Stock code: 6965 URL: http://www.hamamatsu.com/ir/index.html
Representative: Akira Hiruma, President and Chief Executive Officer
Contact: Tadahiko Shimazu, Director and General Manager of Accounting Div.

Hamamatsu Photonics K.K. announces an agreement to acquire Energetiq Technology Inc. (EQ) a manufacturer of Laser Driven Light Sources (LDLS™), and Extreme Ultraviolet (EUV) light sources. The agreement, if consummated, will bring Energetiq into the consolidated group of companies that are owned by Photonics Management Corp (PMC), of Bridgewater, NJ (USA). Hamamatsu Photonics K.K. owns 100 % of the shares of PMC. The consideration for the deal is $ 42M plus company cash.

There has been a growing demand for light sources with high brightness in the Ultraviolet region. With high brightness sources, semiconductor wafers can be quickly and more accurately inspected for properties such as thickness and pattern accuracy. With the advent of thinner design rules for semiconductors, it is anticipated that there will be a significant demand for ultra-short wavelength EUV light sources for inspection and metrology in support of EUV photolithography.

EQ's LDLS have the required high brightness for semiconductor metrology applications. In addition, EQ's EUV light sources have become the workhorse of the EUV community.

Hamamatsu has a long history of developing and marketing light sources such as the xenon lamp and mercury xenon lamp for semiconductor inspection. The addition of EQ's technology and production ability will help to expand Hamamatsu's capabilities and product offerings.

Hamamatsu, as one of the only companies in the world that offers light sources, solid state and electron tube based detectors and systems, plans to utilize the combined technologies of both companies to speed development of new, value added products. These products may have value in diverse areas, including environmental analysis. Hamamatsu envisions a future where the combined technologies of the companies will result in new and exciting product offerings.

Transaction Details

The transaction will be conducted through a merger between a special purpose subsidiary of PMC, and EQ pursuant to Delaware Corporation Law. PMC has established Photonic Energy Subsidiary, Inc. (SPC) in Delaware as a vehicle to facilitate the merger. The merger will be accomplished by way of a reverse triangular merger resulting in EQ as the surviving company and SPC being dissolved.

Upon merger, shares of EQ will be converted into the right to receive cash consideration. Shares of SPC, owned by PMC, will be converted into common share of EQ. PMC will thus own all shares of EQ after the merger and EQ will become a wholly-owned subsidiary of PMC.

Shareholders from which the shares are being acquired

There are 95 shareholders in total of Energetiq Technology, Inc. consisting of management, employees and corporations. It is the management's decision not to disclose a profile of shareholders. None of the shareholders have any capital, personnel and business relations with Hamamatsu Photonics K.K. and PMC.

Outlook for the future

It is expected that there shall be no material effect due to the Transaction on the consolidated financial outlook of Hamamatsu Photonics K.K. for the fiscal year ending September 30, 2017.

Hamamatsu Photonics shines at Photonics West 2018

SPIE Photonics West, the biggest trade show in the photonics industry, was held in San Francisco, California, from January 30 to February 1. There, we introduced many new products at our booth and presented several talks at the conferences.

SPIE. PHOTONICS WEST

Diverse products for automotive LiDAR
This year, we highlighted technologies for LiDAR that play a role in ADAS (advanced driver assistance systems) and autonomous vehicles. A major section of our booth exhibited a wide variety of sensors for distance measurement – including photodiodes, avalanche photodiodes, silicon photomultipliers (or MPPC), and distance image sensors – as well as other components such as MEMS mirrors and laser diodes. To showcase these products' capabilities, we had several demos throughout the booth that featured combinations of sensors, mirrors, and laser diodes.

Ever-expanding silicon photomultiplier (SiPM) lineup
Our lineup of SiPMs (called MPPC) is continually expanding, and at Photonics West, we unveiled a number of new types. These include NIR-enhanced SiPM modules, whose sensitivity extends to 1,000 nm; SiPMs with a 600 nm peak sensitivity (compared to our conventional 450 nm peak); and low-cost types that feature a hole-wire bonding structure.

Other new products
We also displayed new light sources and a CMOS camera, just to name a few. Our new light sources included xenon flash lamps whose emission range encompasses the UV to mid-infrared regions. Our new camera called ORCA-Spark is an affordable CMOS camera for routine microscopy applications.

Conference presentations and workshops
At our conference presentations, the attendees were treated to a preview of our products currently in development such as InGaAs SPAD (single-photon avalanche diode) arrays, silicon SPAD arrays, and InGaAs MPPC. Our other talks covered topics related to laser processing, terahertz light sources, and microscopy.

We also held free workshop sessions where the attendees learned about photodetector selection and Raman spectroscopy.

Re-scan + ORCA-Flash4.0 V3
plug-and-play super resolution confocal microscopy

Re-scan Confocal Microscopy
The Re-scan Confocal Microscopy (RCM) technology provided by Confocal.nl is a major step towards the accessibility of cutting-edge confocal microscopy for any bioimaging based research institution. The concept, implemented as an add-on module for any existing research grade microscope, allows robust confocal imaging with superior performance in terms of resolution, contrast and light-efficiency. The optical module – simply coupled via C-mount between the microscope and the camera – contains two scanning units for beam-steering instead of one as in most confocal microscopes. The first scanning unit scans the excitation light across the sample and directs the fluorescence light towards the pinhole, as in any descanned confocal technique. As opposed to standard confocal microscopy, the optical path does not end behind the pinhole with the detector. The beam of fluorescence light is directed to the second scanning unit instead, which projects the image onto a camera. On the one hand, this gives the opportunity to add additional magnification to the system by doubling the speed of the second scanning unit, thereby improving the resolution of the system up to a factor of $\sqrt{2}$ effectively circumventing Abbe's diffraction limit without additional computation or sacrificing contrast.

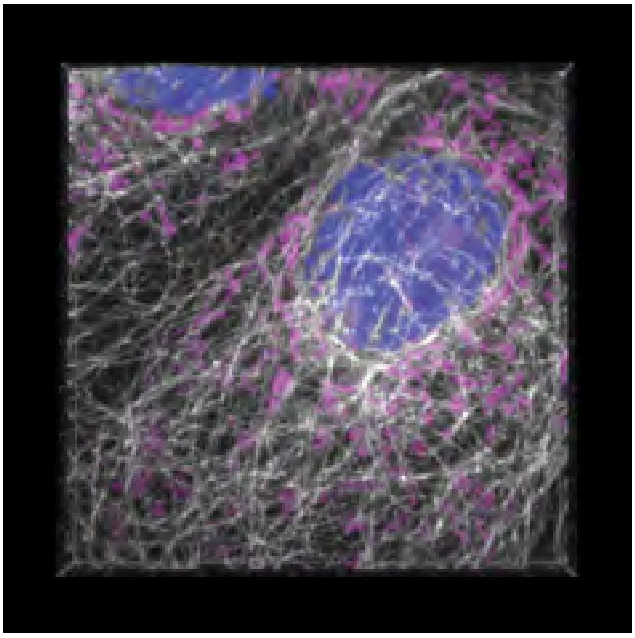
Observing fine structures with ideal resolution and contrast
On the other hand, the ability to detect confocal images with a modern camera results in additional advantages compared to the standard detection with a photomultiplier tube (PMT). In comparison to PMTs, modern sCMOS cameras show nearly double the quantum efficiency. When comparing this fact with a standard confocal microscope of comparable resolution (with a pinhole of 0.5 Airy Units), the SNR improvement of the RCM technology over conventional confocal microscopy reaches a factor of 4 [1].

Detecting faint signals with the ORCA-Flash4.0 V3
The ORCA-Flash4.0 V3 is a perfect solution for this integral part of the RCM. Of course it provides a very high quantum efficiency of 82 % peak, but images are not defined in terms of quantum efficiency. A more reliable metric of image quality is the image SNR (see box). While the image SNR will always be limited by the shot noise of the available signal, every measurement process will add additional noise to the

$$\frac{QE \cdot S}{\sqrt{QE \cdot (S+B) + \sigma_{rn}^2 + \mu_I \cdot t_{exp} + (PRNU \cdot QE \cdot (S+B))^2 + DSNU^2}}$$

Image Signal to Noise	
QE:	Quantum efficiency
S:	Signal (in photons)
B:	Background (in photons)
σ_{rn}:	Readout noise (in electrons rms)
μ_I:	Dark current (in electrons/pixel/second)
t_{exp}:	Exposure time (in seconds)
PRNU:	Photo Response Non-Uniformity (in percent)
DSNU:	Dark Signal Non-uniformity (in electrons)

The image signal is determined by the signal intensity and the quantum efficiency. For the image SNR, the noise sources have to be accounted for. In high signal (or optical background), the noise is mostly composed of shot noise $\sqrt{QE \cdot (S+B)}$ and the PRNU. As optical background is a minor issue in confocal techniques like the RCM, minimizing the readout noise σ_{rn}, the dark current shot noise $\sqrt{\mu_I \cdot t}$, the DSNU and PRNU maximizes the SNR in all light levels and therefore enables observing the faintest structures.



Cos7 cells imaged with the RCM. Nucleus is displayed in blue, microtubuli in grays and mitochondria in violet. The width of the volume is 45 µm. The confocal stack was rendered using ClearVolume [3].

shot noise, reducing the final image SNR. This additional noise is composed of the readout noise of the detector, as well as the dark current shot noise. The additional noise limits the SNR in the regime where the signal is very low and the the quantum efficiency limits the SNR in high signal conditions. While the dark current shot noise can be neglected in many situations when the exposure time is short, confocal techniques like RCM require exposure times in the range of 1s to 4s. The dark current shot noise is defined as $\sqrt{\mu_I t_{exp}}$ with μ_I being the dark current and t_{exp} being the exposure time, meaning the dark current shot noise scales with $\sqrt{t_{exp}}$.

The ORCA-Flash4.0 V3 has a very low readout noise of 0.8 e^- median (1.4 e^- rms), but also an exceptional low dark current of 0.06 e^-/px/s (0.006 e^-/px/s at maximum cooling), resulting in an additional dark current shot noise with a 1s exposure of only 0.2 e^- (0.1 e^- at maximum cooling).

To avoid any further non-uniformity in the image, which might limit the information content of the experiment, each camera is individually calibrated to minimize the dark signal non-uniformity and the photo response non-uniformity inherent in CMOS image sensors [2].

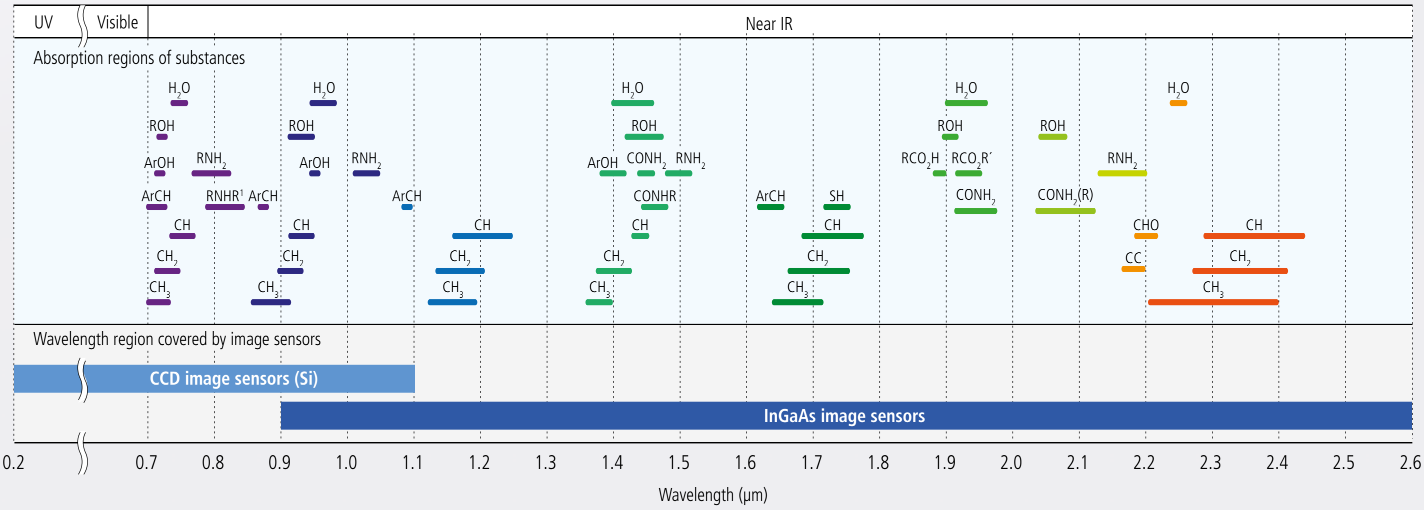
The combination of the RCM with the ORCA-Flash4.0 V3 is an ideal all-around solution, whether you are interested in a high performance system to observe faint structures with good SNR up to a resolution of 170 nm, or simply want an affordable, easy-to-use plug-and-play confocal system.

[1] De Luca, Giulia, et al. "Re-scan confocal microscopy (RCM) improves the resolution of confocal microscopy and increases the sensitivity." Methods and applications in fluorescence 5.1 (2017): 015002.
[2] European Machine Vision Association. "EMVA Standard 1288, Standard for Characterization of Image Sensors and Cameras." Release 3 (2010): 29.
[3] Royer, Loic A., et al. "ClearVolume: open-source live 3D visualization for light-sheet microscopy." Nature methods 12.6 (2015): 480.

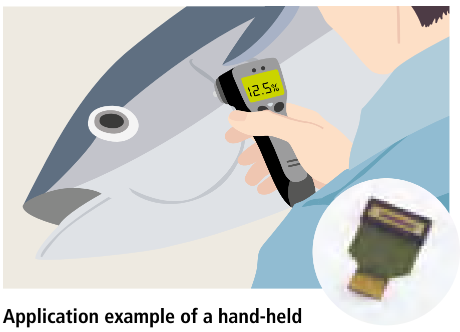
InGaAs linear image sensor

Expanding the possibilities of near-infrared light spectroscopy and making components more visible

Near-infrared light spectroscopy is a method of measuring components by making use of when near-infrared light is applied to a measured object, the absorbed wavelengths differ depending on the substances. It is an analysis method that takes advantage of its non-destructive, non-contact characteristics and is used in a wide range of fields including physicochemical measurements and industrial measurements. Hamamatsu produces InGaAs image sensors for the near-infrared region as detectors for near-infrared light spectroscopy. The expanding product lineup offers a wide variety of types including different number of pixels and pixel sizes, various waveform types, up to a cutoff wavelength of 2.6 μm using unique production technology. These products expand the possibilities of near-infrared spectrophotometry where demand will increase in the future in food component analysis and other applications.



Development of a compact, low-cost sensor – bringing near-infrared spectroscopic measurement closer to practical application



Application example of a hand-held measuring instrument

InGaAs linear image sensors are useful because of their sensitivity in the near-infrared region. However, they are expensive and large and are used for high-end applications. Particularly non-destructive, non-contact infrared spectroscopic measurements have been performed mainly at the laboratory level. The G13913 series was developed as a new device for making these measurements possible on-site and in real-time.

A back-illuminated structure (128 pixels, 256 pixels) was employed to make the sensor smaller and to reduce current consumption. The spectral response covers a range from 0.95 to 1.7 μm. The miniaturization of the device expands its application to hand-held professional component measuring instruments and other applications used outside the laboratories.

Cutoff wavelength: up to 2.6 μm – supports long spectral ranges suitable for foods

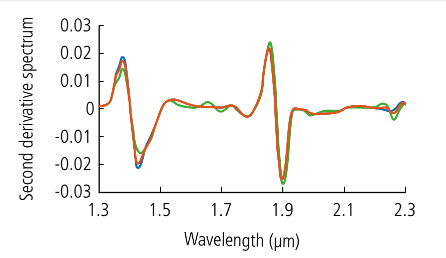
With the advancement in food processing technology and globalization of trade, we are able to obtain various types of foods, but at the same time, fraudulent claims of origin, dilution, and other frauds are becoming a problem, and consumers are becoming increasingly concerned about food safety. In light of this situation, the new food indication laws in Japan require the indication of items that are of primary concern to consumers such as allergens and nutritional composition. As a result, there is a growing demand to make component analysis, which was previously performed in laboratories, more available to producers, wholesalers, distributors, retailers, and consumers by making measurements easier and non-destructive. The G11475 to G11478 series are InGaAs linear image sensors that are suitable for near-infrared analysis of foods. They support spectral ranges up to 2.6 μm. This spectral range contains absorption regions originating from carbohydrates, proteins, and lipids. InGaAs linear image sensors make it possible to perform more accurate measurements and analysis. The wafer production of InGaAs photosensors that have a cutoff wavelength exceeding 1.7 μm is highly difficult, and there are not many manufacturers producing them. Hamamatsu utilizes its unique crystal growth technology to stably produce highly accurate and original InGaAs wafers, and offers a diverse product lineup with different supported wavelengths.

Verification

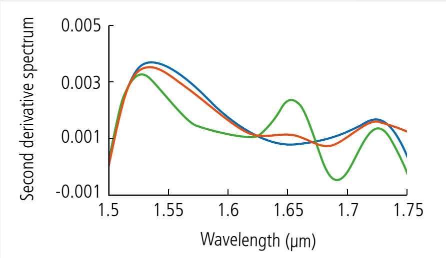
Example of acquiring the optical spectrum of water, sake, and beer using a spectrometer equipped with an InGaAs image sensor and measuring the light absorption characteristics based on alcohol content

<Measurement system> mini-spectrometer: C11118GA (installed image sensor: InGaAs, 0.9 to 2.55 μm, 256 ch), gain: low, integration time: 12 μsec (integration time adjusted so that the A/D count is 60,000 at reference measurement), light source: halogen, cell: 1 mm thick, <measurement> Hamamatsu Central Research Laboratory

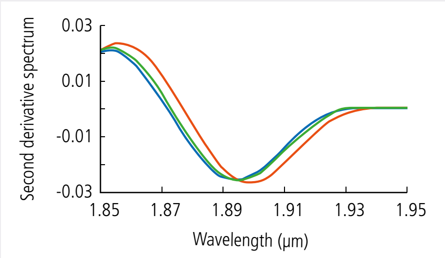
Water — Sake — Beer



Wide range spectrum from 1.3 μm to 2.3 μm



Spectral changes can be seen in the 1.5 μm to 1.75 μm range due to the differences in the alcohol concentration.



Spectral changes can be seen near 1.9 μm due to moisture caused by the differences in the alcohol concentration.

Meeting specific component analysis needs

Hamamatsu will continue to develop products that meet a variety of needs. The G14237-512WA InGaAs linear image sensor for Raman spectroscopy is one such example. It is said that 1,064 nm excitation Raman spectrophotometry will make possible the detection and identification of medicine and hazardous substances that were difficult to be measured by conventional means. Raman spectrophotometry, which detects low-level light, requires integration over a long time period. As such, on the G14237-512WA, the cutoff wavelength on the long-wavelength side has been reduced from the standard 1.7 μm to 1.45 μm to suppress dark current. Further, for the high-speed type that is used in foreign object detection and other sorting applications, the G14006-512DE with a cutoff wavelength of 1.9 μm has been added to the product lineup. It is also suitable for numerous applications including the food and agricultural sectors.

InGaAs Linear Image Sensors

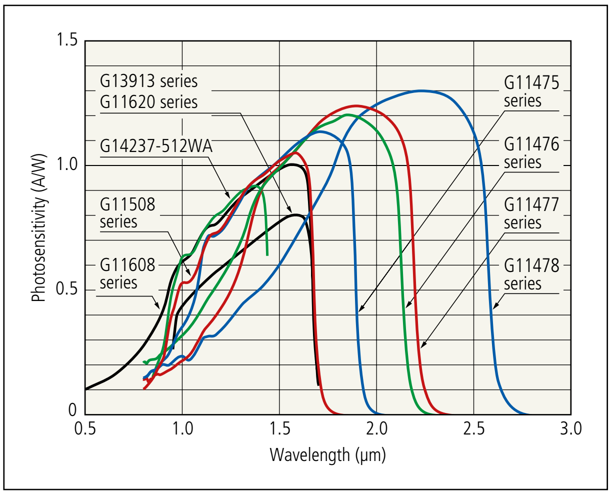
Extensive product lineup suitable for analysis applications

These InGaAs linear image sensors have been designed for near-infrared spectrophotometry. Hamamatsu Photonics offers an extensive product lineup supporting a spectral response range of 0.5 to 2.55 µm.

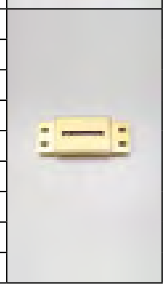
Recently added to the lineup are the low dark current G14237-512WA for performing Raman spectrophotometry using a 1064 nm LD and the compact, low-cost G13913 series designed for portable analytical instruments.

In addition, the G11475/G11476/G11477/G11478 series, which are long-wavelength types with a cutoff wavelength of 1.7 µm or longer, feature improved data rates and better linearity characteristics at high gain than the previous products.

Spectral response (Typ. Tchip = 25 deg. C.)



Lineup

Type No.	Cooling	Spectral response range (nm) 0.5 / 1.0 / 1.5 / 2.0 / 2.5	Pixel height (µm)	Pixel pitch (µm)	Number of pixels	Photo
G11608-256DA	Non-cooled	0.5 to 1.7	500	50	256	
G11608-512DA				25	512	
G9203-256D		0.9 to 1.7		50	256	
G9204-512D				25	512	
G11620-128DA		0.95 to 1.7	500	50	128	
G11620-256DA					256	
G11620-256DF				25	256	
G11620-512DA					512	
NEW G13913-128FB			250	50	128	
NEW G13913-256FG				25	256	
G11508-256SA	One-stage TE-cooled (Tchip = -10 deg. C.)	0.9 to 1.67	500	50	256	
G11508-512SA				25	512	
G11620-256SA		0.95 to 1.67		50	256	
G11620-512SA				25	512	
NEW G14237-512WA	Two-stage TE-cooled (Tchip = -20 deg. C.)	0.85 to 1.4	500	25	512	
NEW G11475-256WB		0.9 to 1.85	250	50	256	
NEW G11475-512WB				25	512	
NEW G11476-256WB		0.9 to 2.05		50	256	
NEW G11477-256WB		0.9 to 2.15		50	256	
NEW G11477-512WB				25	512	
G12230-512WB		0.9 to 2.15		25	512	
NEW G11478-256WB		0.9 to 2.55		50	256	
NEW G11478-512WB				25	512	

NEW

MEMS-FPI Spectrum Sensor C14272

Introducing a new wavelength type – ultra-compact spectrum sensor for near-infrared light

The MEMS-FPI spectrum sensor C14272 is an ultra-compact sensor that houses a MEMS-FPI (Fabry-Perot Interferometer) tunable filter that can vary its transmission wavelength depending on the applied voltage and an InGaAs PIN photodiode in a single package. The C14272, a new type added to the lineup, has a spectral response range of 1.35 to 1.65 μm. Along with the previous C13272-02 (spectral response range: 1.55 to 1.85 μm), it is suitable for installation in compact instruments for simply measuring material absorbance.

Features

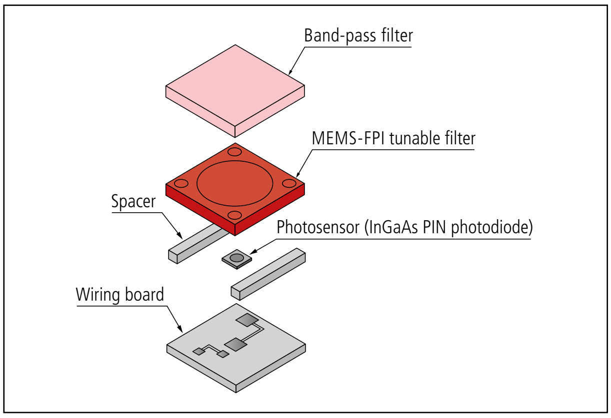
- Built-in Hamamatsu InGaAs PIN photodiode single element chip
- Spectral response range: 1.35 to 1.65 μm
- Spectral resolution: 18 nm max.
- Ultra-compact: TO-5 package
- Ultra light: 1 g
- Hermetically sealed package: High reliability in high humidity environment
- Built-in thermistor
- Built-in band-pass filter for cutting off wavelengths outside the spectral response range
- An evaluation circuit C13294-02 is available (sold separately)

Application

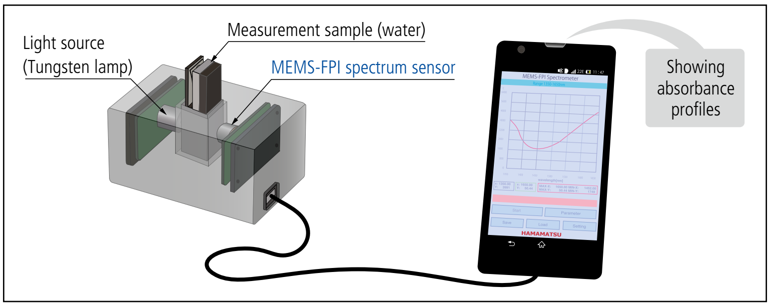
- Portable spectrophotometers

C14272

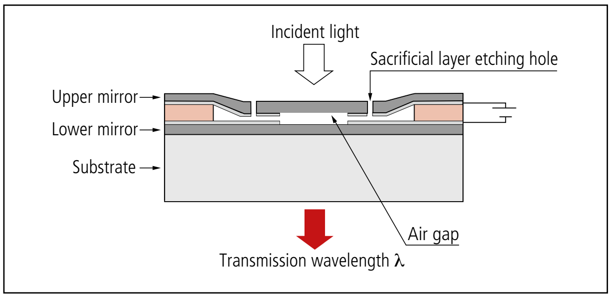
Spectrum sensor structure



Application example (spectrometry)



Tunable filter cross section



Specifications (compared with the previous type) Ta = 25 deg. C.

Parameter	NEW C14272	C13272-02	Unit
Spectral response range	1.35 to 1.65	1.55 to 1.85	μm
Spectral resolution (FWHM) max.	18	20	nm
Photosensitive area (photosensor)	φ300	φ100	μm

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

Si PIN Photodiode S13773

NEW

Photodiode for LiDAR and other high-speed applications

The S13773 is a Si PIN photodiode with sensitivity in the visible to near-infrared range, and is compatible with lead-free solder reflow. It features high-speed response and is suitable for distance measurement laser monitoring.

Features

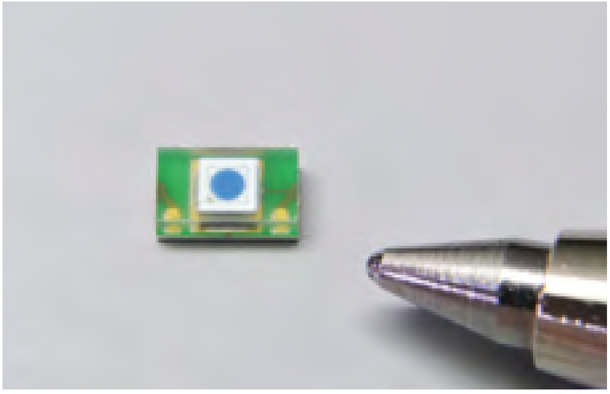
- High-speed response: 500 MHz (V_R = 10 V)
- Surface mount type
- High reliability (wide temperature range)
- Photosensitive area: φ0.8 mm

Applications

- Distance measurement laser monitor
- Light monitor (from visible to near-infrared region)

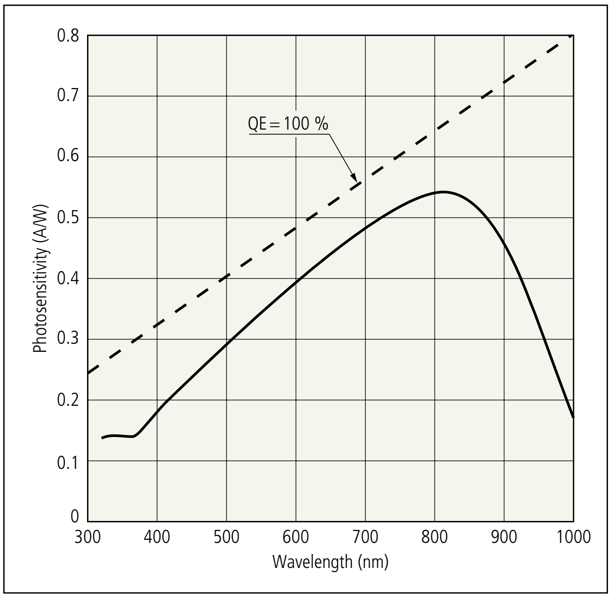
Specifications

Parameter	Condition	Value	Unit
Reverse voltage	-	20	V
Power dissipation	-	0.2	W
Operating temperature	No dew condensation	-40 to +100	deg. C.
Storage temperature	No dew condensation	-40 to +100	deg. C.
Soldering conditions	JEDEC level 2a	Peak temperature: 260 deg. C.	-



S13773

Spectral response (Typ. Ta = 25 deg. C.)



NEW

Photodiode Arrays with Amplifiers S13885/S13886 Series

Sensitivity approx. 4 times (Cf = 0.125 pF) that of the previous product

The S13885/S13886 series are photodiode arrays with amplifiers having a phosphor sheet for X-ray detection. Improvement in the signal processing IC chip has achieved higher sensitivity. A long and narrow image sensor can be configured by arranging multiple arrays in a row.

Features

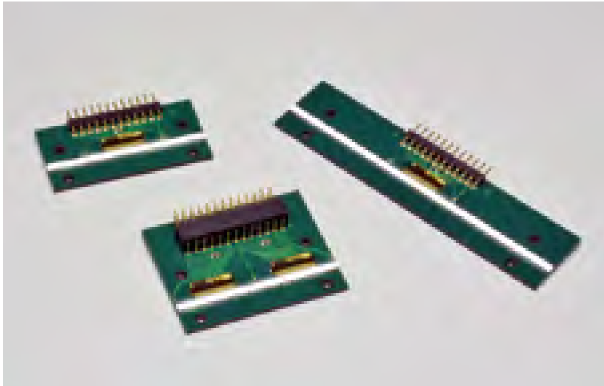
- Sensitivity: Approx. 4 times that of the previous product
- Low noise: 800 e^- rms (previous type: 3,000 e^- rms)
- Low dark current
- Data rate: 1 MHz max.
- Simultaneous integration method by using a charge amplifier array
- Integrated timing generator allows operation at two different pulse timings
- Detectable energy range: 30 k to 100 keV

Applications

- Line sensors for X-ray detection
- Long and narrow line sensors

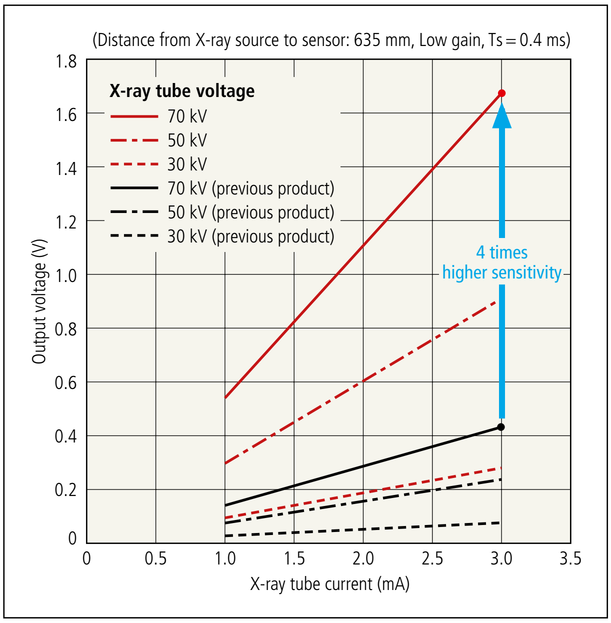
Specifications

Parameter	S13885-128G	S13885-256G	S13886-128G	Unit
Image size	51.2 x 0.6	51.2 x 0.3	102.4 x 0.8	mm
Number of elements	128	256	128	-
Element size	0.3 x 0.6	0.1 x 0.3	0.7 x 0.8	mm
Element pitch	0.4	0.2	0.8	mm
Scintillator	Phosphor sheet			-



S13885/S13886 series

X-ray output example (S13885-128G)



Xenon Flash Lamp/Module for Broad-Wavelength Infrared Light Source

NEW

Broad-wavelength infrared light source – ideal for high-precision quantitative and qualitative analysis

Emits a continuous spectrum from 160 nm to 7,500 nm ideal for a wide range of inspection, measurement, and analysis. Compared to conventional thermal type light sources such as halogen lamps, xenon flash lamps generate less heat and provide instantaneous high peak output making them ideal for applications where high accuracy is required.

Features

- High output
- Long life
- Intense continuous spectrum
- No warmup required
- Low heat generation: Causes less thermal damage to sample
- High stability

Applications

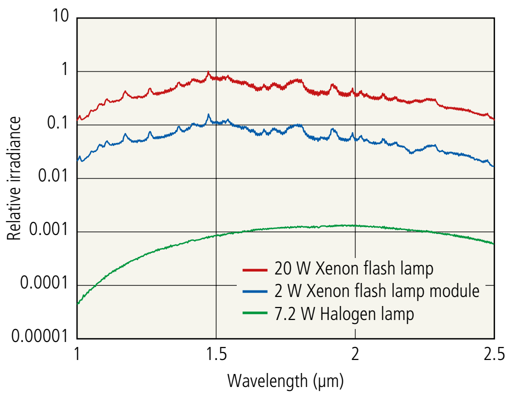
- Food product inspection
  - Food sorting
  - Food analysis (sugar content, lipid, moisture measurements)
  - Foreign matter inspection
- Gas measurement and analysis
  - Multiple gas detection (CH_4 (methane), C_3H_8 (propane), CH_3OH (methanol), etc.)

Xenon flash lamp/module

Specifications

Parameter	2 W type	20 W type	Unit
Spectral distribution	160 to 7,500		nm
Main discharge voltage variable range	400 to 600	400 to 1,000	V
Maximum average input (continuous)	2	20	W
Light output stability (typ.)	0.5		% CV
Guaranteed life	1 x 10^8 to 1 x 10^9		flashes

Spectral distribution (typ.)



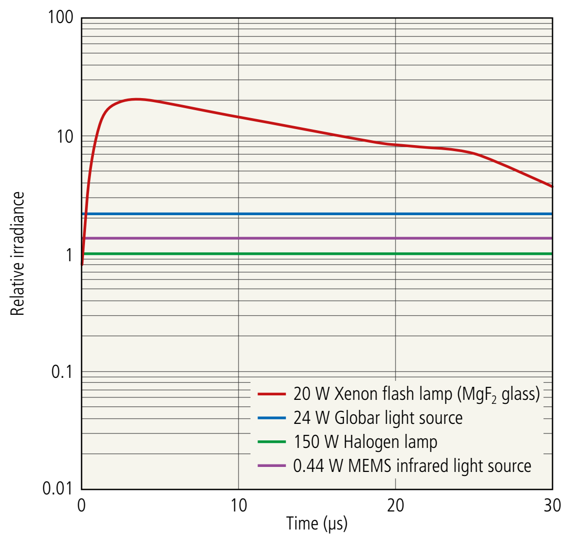
Measurement conditions

Detector:
Spectrometer NIRQuest512-2.5 made by Ocean Optics (Slit width: 25 μm, integration time: 1 ms)

Optical fiber:
MF11L1 made by Thorlabs (Core diameter: 100 μm, InF3 transmission wavelength range: 0.3 μm to 5.5 μm)

* Light output depends on detector sensitivity.
Use this data as a reference for comparison with other infrared light sources.
* Light output of halogen lamp is corrected to peak irradiance of xenon flash lamp (flash duration: Approx. 6 μs)

Emission pulse waveform (typ.) (Wavelength at 7 μm)

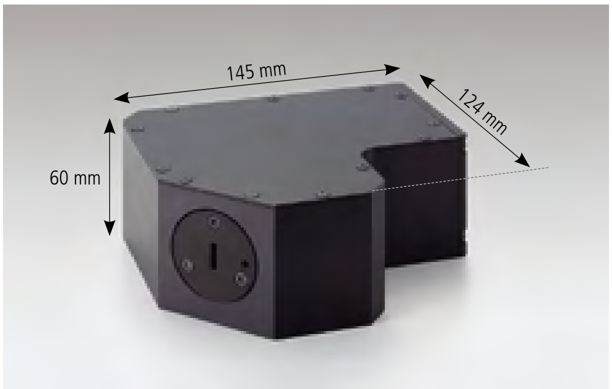


NEW

High Sensitivity Compact Spectrometer A13658

Ideal for simultaneous multi-wavelength spectral intensity measurements

The A13658 is a compact polychromator with high diffraction efficiency designed for 16-channel linear multianode PMTs (H11459, H12310, H13197, H13964). When combined with one of these PMTs, the A13658 allows simultaneous spectral intensity measurements at 16 wavelengths using a multi-branch fiber bundle and is also ideal for spectrum measurement using a microscope.



A13658

Features

- Compact: 40 % cubic volume of the current product (A10766)
- High diffraction efficiency

Applications

- Flow cytometer
- Microscope

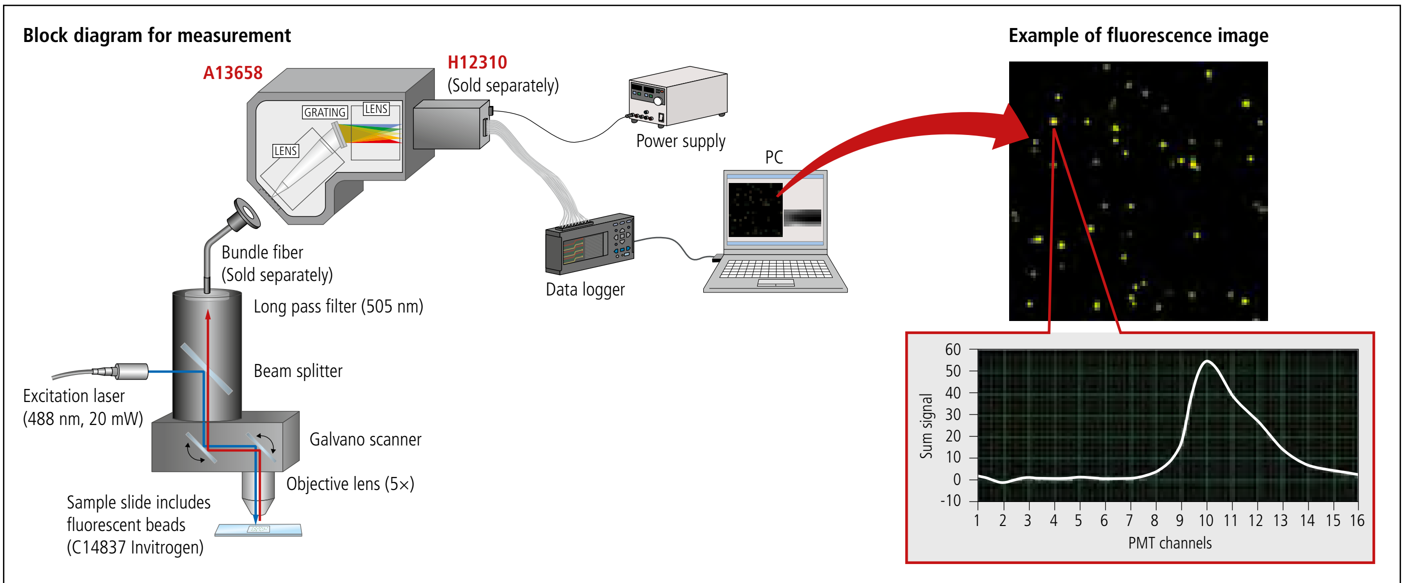
16ch Linear array multianode PMT
PMT designed to enable simultaneous multi-channel measurements with high speed and high sensitivity

Specifications

Parameter	Specification	Unit
Spectral response range	418 to 817	nm
F value (NA)	2.5 (0.2)	-
Dispersion*1	26	nm/mm
Input slit size	0.8 x 7	mm

*1 Dispersion is defined when 644 nm is adjusted at the center channel of PMT. The unit of dispersion is used as nm/mm. Because of 1 mm channel pitch of PMT, its dispersion is as same unit of nm/ch.

Example of laser scanning measurement of fluorescent beads



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

High Voltage Power Supply Module C13890-15

NEW

UL approved (UL60601-1)

The C13890-15 is a PC-board mountable high-voltage power supply module that provides an output of -1,250 V/0.6 mA and UL approved one. Compared to the current product (C4900/-01 and C10673/-01), the C13890-15 operates with a wider input voltage range and operating ambient temperature range. It is also possible to directly replace the C13890-15 with them as both products have an identical pin assignment.

C13890-15

Input voltage

C13890-15: +11 V to +16 V
C4900, C10673: +15 V±1 V
C4900, C10673-01: +12 V±0.5 V

Operating ambient temperature range

C13890-15: -10 deg. C. to +60 deg. C.
C4900/-01, C10673/-01: 0 deg. C. to +50 deg. C.

Features

- Wide input voltage range and operating ambient temperature range
- Low ripple/noise
- Compact, light weight
- High stability
- Low power consumption

Application

- Photomultiplier tube operation

Specifications

Parameter	Specification	Unit
Input voltage	+11 to +16	V
Maximum output voltage	-1,250	V
Maximum output current	0.6	mA
Ripple / noise (p-p)*1	38	mV
Operating ambient temperature*1	-10 to +60	deg.C.
Weight	29	g

*1 At maximum output voltage/current

NEW

Thermal F1 Emission Microscope C14229-01

Non-destructive electrical failure analysis system for packaged devices

Thermal F1 is a thermal emission microscope equipped with a high sensitivity InSb camera that indicates abnormal heat generated inside a semiconductor device. Its single function and small size with user friendly software are suitable for initial analysis for quick defect localization.

Specifications

- High sensitivity thermal detector (InSb) with motorized stage and 5 lens turret controlled through software
- Objective lens for IR (0.29x, 0.8x, 4x, 8x) and NIR 5x for probing
- Thermal lock-in unit with power supply voltage selectable

Features

- High sensitivity thermal camera with lock-in function
- Windowing function up to 2,000 fps
- Optimally designed IR optics with probing camera unit
- Stitching function for large field of view

Applications

- Short-circuit of metalization
- Abnormality of contact holes
- Microplasma leakage in oxide layer
- Oxide layer breakdown
- TFT leakage/Organic EL leakage

C14229-01

Femtosecond Streak Camera FESCA-100 C11853-01

NEW

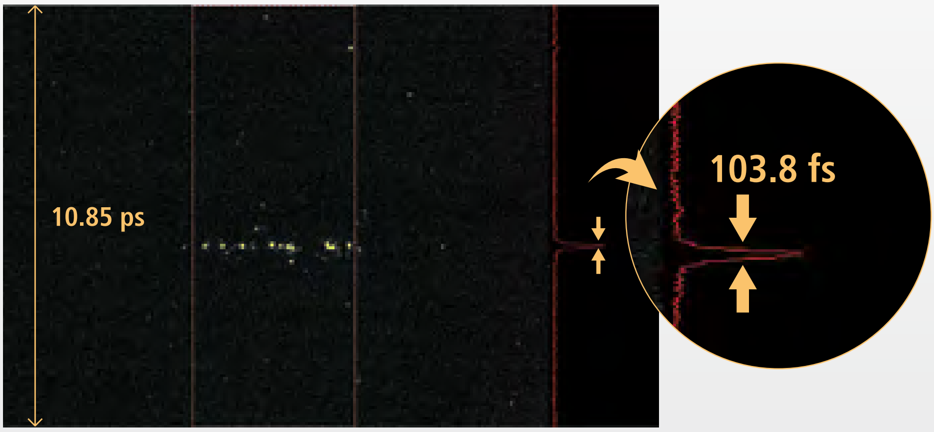
Measurement of light phenomena with 1×10^{-13} second (100 femtoseconds) is possible!

Features

- 100 femtosecond temporal resolution (typ.)
- Simultaneous measurement of light intensity on both the temporal and spatial axis
- Real time analysis is possible with the dedicated readout system

Applications

- Measurement of electron bunch for synchrotron and LINAC applications
- Analysis of the ultrastructure of laser waveform along optical waveguides
- Diagnosis of femtosecond lasers



Streak image and intensity profile of light pulse from Ti:Sapphire laser measured with the FESCA-100

Measurement of single ultrafast phenomena with high temporal resolution (100 femtoseconds)

NEW

Pulsed Laser Diode (PLD) L11854-323-51

Delivers a peak output power more than 75 W at 905 nm

This product is a multimode laser that emits a high power beam from an emitting area of 230 µm x 10 µm. Applications include light sources for LiDAR, laser rangefinders, security, monitoring and surveillance. This product comes in a standard TO-5.6 can package but is also available in other can packages.

Differences from conventional products

Delivers a peak output power more than 75 W at 905 nm.

Features

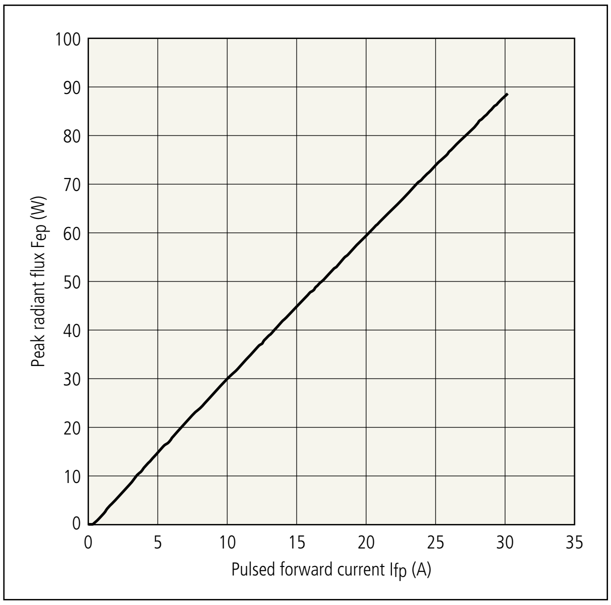
- Peak output power ≥75 W
- Peak emission wavelength 905 nm
- Emitting area size: 230 µm x 10 µm

Applications

- Laser rangefinders
- Security
- Measuring instruments

L11854-323-51

Radiant flux vs. Forward current (Typ.) ($T_{op(c)}$ = 25 deg. C.)



Photonic Crystal Surface Emitting Laser Diode (PCSEL) L13395-04

NEW

High-power, surface-emitting semiconductor laser with narrow pulse and high beam quality

This product is a surface-emitting semiconductor laser with a photonic crystal structure that features a narrow spot beam pattern (narrow beam spread angle, circular shape) and a narrow spectral linewidth. The photonic crystal is an optical nanostructure having a periodic refractive index distribution with dimensions nearly equal to the light wavelengths. In this product, light is amplified and diffracted by the photonic crystal grown in the vicinity of a light amplification layer called an active layer, and the amplified light is output as a laser beam in a direction perpendicular to the surface. Even with a large area, this laser allows a stable resonance action and so delivers a high quality beam with a narrow radiant angle.

L13395-04

Differences from conventional products

Semiconductor laser that delivers beam quality equivalent to a solid-state laser.

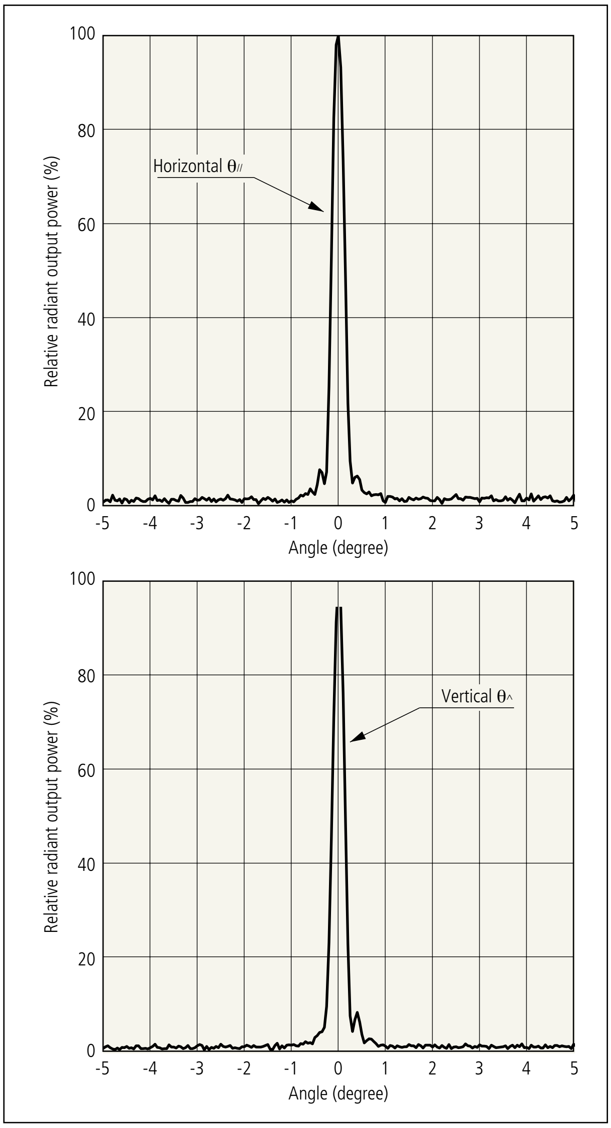
Features

- Narrow beam spread angle: under 1 deg.
- Narrow spectrum line-width: under 1 nm
- Temperature coefficient at peak wavelength: 0.08 nm/deg. C.

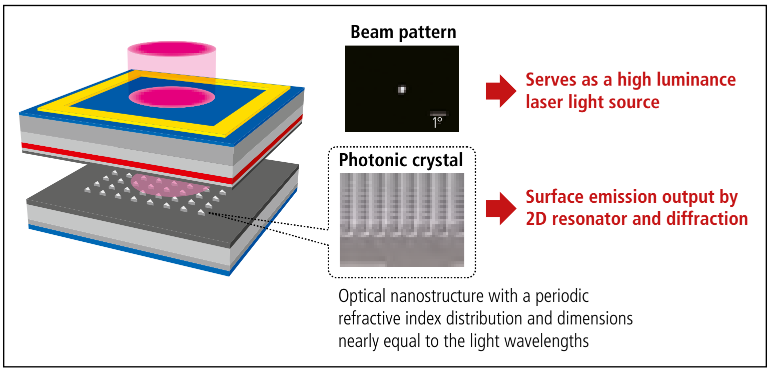
Applications

- Pumping source for solid-state lasers
- Light source for frequency conversion
- Fine processing
- Object sensing
- Spectroscopic analysis

Directivity (Φ_e = 150 mW, $T_{op(c)}$ = 25 deg. C.)



Principle



NEW

TO-8 Pulse Driver C14277-01/-02

Pulse driver for quantum cascade laser

The C14277 series is an OEM pulse driver circuit board designed to pulse drive a pulsed quantum cascade laser (TO-8 package QCL). The C14277 series is designed for installation into other equipment and does not work on its own. An external trigger type and internal trigger type are provided.

Differences from conventional products

Compact and lightweight design ideal for installation into equipment.

Features

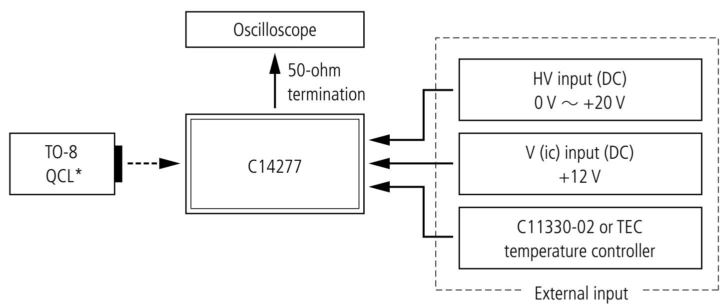
- Designed to mount a TO-8 package QCL
- Adjustable pulse width and repetition frequency (external trigger signal required for C14277-01)
- Low noise, high stability
- Designed for installation into equipment

Application

- Trace gas analysis

C14277-01/-02

Setup example



- External trigger is required for the C14277-01.
- Aspherical ZnSe lens unit A11331-0xH cannot be attached to this product.

* Quantum cascade laser is sold separately.

Global Exhibitions 2018

USA

April 2018

ADAS Sensors
April 4-5 2018, Detroit, MI US

The Vision Show
April 10-12 2018, Boston, MA US

AACR
April 14-18 2018, Chicago, IL US

Corrosion
April 15-19 2018, Phoenix, AZ US

Defense & Security
April 17-19 2018, Orlando, FL US

May 2018

Radtech
May 7-9 2018, Chicago, IL US

CLEO
May 15-17 2018, San Jose, CA US

Pathology Infomatics Summit
May 21-24 2018, Pittsburgh, PA US

NSI
May 22-23 2018, Rogers, MN US

June 2018

ASMS
June 3-7 2018, San Diego, CA US

Digital Pathology Congress USA
June 26-27 2018, New York City, NY US

Sensors Expo
June 27-28 2018, San Jose, CA US

July 2018

Semicon West
July 10-12 2018, San Francisco, CA US

August 2018

Optics and Photonics
Aug 21-23 2018, San Diego, CA US

September 2018

WMIC
Sept 12-15 2018, Seattle, WA US

FiO
Sept 19-20 2018, Washington, DC US

Label Expo
Sept 25-27 2018, Rosement, IL US

Saftey Pharmacology Society Annual Meeting
Sept 30-Oct 3 2018, Washington, DC US

Europe

April 2018

ECHNO
April 11-14 2018, Rome, Italy

Fysica
April 13-18 2018, Utrecht, Netherlands

Elekronik i fordon
April 12-13 2018, Gothenburg, Sweden

ISPF2
April 16-18 2018, Gothenburg, Sweden

Paint Expo
April 17-20 2018, Karlsruhe, Germany

A&T 2018
April 18-20 2018, Torino, Italy

8th International Symp. on Sentinel Node Biopsy in Head and Neck Cancer
April 20-21 2018, London, UK

Photonics Europe
April 23-26 2018, Strasbourg, France

Analitika Expo
April 24-26 2018, Moscow, Russia

Control
April 24-27 2018, Stuttgart, Germany

CAM Workshop
April 25-26 2018, Halle, Germany

Cyto Conference
April 28-May 2 2018, Prague, Czech Republic

May 2018

AKL
May 2-4 2018, Aachen, Germany

ADH
May 11-13 2018, Mannheim, Germany

Optatec
May 15-17 2018, Frankfurt, Germany

PSND – International Workshop
May 15-17 2018, Jülich, Germany

TEC
May 17 2018, Warsaw, Poland

LIMS2018
May 17-18 2018, Frascati, Italy

Technology HUB 2018
May 17-19 2018, Milano, Italy

SU2P Annual Symposium
May 21-22 2018, Glasgow, Scotland

SPS IPC Drives Italia 2018
May 22-24 2018, Parma, Italy

ElektronikExpo
May 23 2018, Västerås, Sweden

102. Jahrestagung der DGP
May 24-26 2018, Berlin, Germany

Pisa Meeting 2018
May 27-June 2 2018, La Biodola, Italy

Optics & Photonics 2018
May 28-30 2018, Jyväskylä, Finland

Ipack Ima 2018
May 29-June 1 2018, Milano, Italy

ECDP (14th European Digital Pathology Congress)
May 29-June 1 2018, Helsinki, Finland

ENOVA
May 30-31 2018, Toulouse, France

June 2018

Neutrino
June 4-9 2018, Heidelberg, Germany

ELMI
June 5-8 2018, Dublin, Ireland

14th European Functional Drug Screening Symp.
June 7 2018, Basel, Switzerland

ECNDT
June 11-15 2018, Gothenburg, Sweden

Achema
June 11-15 2018, Frankfurt, Germany

IC Biomedical Symposium
June 14 2018, London, UK

Histologica
June 15-16 2018, Oberhausen, Germany

SENSE TechForum
June 21-22 2018, Geneva, Switzerland

Nuclear Photonics
June 24-29 2018, Brasow, Romania

Laser Precision Microfabrication
June 25-28 2018, Edinburgh, Scotland

Sensor und Test
June 26-28 2018, Nuremberg, Germany

Frontiers in Bioimaging
June 27-28 2018, Glasgow, Scotland

Agri Food Innovation Event
June 27-28 2018, Venlo, Netherlands

ConCar Expo
June 27-28 2018, Berlin, Germany

SLAS Europe
June 27-29 2018, Brussels, Belgium

Fluorescent Biomolecules and their Building Blocks
June 30-July 2 2018, Glasgow, Scotland

July 2018

dXCT Conference 2018
July 2-3 2018, Nottingham, UK

OPTIQUE
July 3-6 2018, Toulouse, France

ESRIC Summer School
July 16-20 2018, Edinburgh, Scotland

August 2018

8th Single Molecule Localisation Microscopy Symp.
Aug 27-30 2018, Berlin, Germany

SINDEX
Aug 28-30 2018, Bern, Switzerland

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