

Sep. 2023

HAMAMATSU
PHOTON IS OUR BUSINESS

Devices for Gas Measurement

Supporting Gas Analysis with Optical Devices



Optical Gas Measurement

Features of optical-based measurement

Gas detection through optical absorption is generally approached by using infrared (IR) light or ultraviolet (UV) light. Thanks to their unique absorption wavelengths, the density of gases can be measured easily through molecular absorption. The absorption of the vibrating gas molecules increases particularly in the infrared region, making it ideal for measuring various gases. After selecting the suitable device, according to the targeted absorption gas and its surrounding environment, the optical method is by far the most optimal for high-speed response, high-accuracy, and long life gas measurement. As an expert in photonics technology and in the creation of optical devices, Hamamatsu Photonics presents you a wide-range of light sources and detectors perfectly suited for the measurement of gas.

IR

Absorption spectroscopy based on "intramolecular vibration"



- Great light absorption efficiency
- Superior gas selectivity
- Superior maintainability due to less sensitivity deterioration

UV

Absorption spectroscopy based on "electron transitions"



- Greater heat resistance
- Greater resistance to background light
- Does not overlap with absorption wavelengths of water

Main advantages of optical based technology compared to other sensing technologies for gas measurement

Comparable technologies	Advantages of optical gas measurement
Electro-chemical type detection	<div>High-speed response</div> <p>The rapid response of an optical sensor makes it suitable for real-time gas monitoring. It enables higher accuracy measurement by integrating and averaging the large number of data per unit time.</p>
MOS type detection	<div>High precision</div> <p>Optical gas detection is less affected by coexisting gases and water vapor since it detects the specific absorption wavelength of each gas; high selective detection is performed with optical gas measurement.</p>
Catalytic type detection	<div>Long life</div> <p>Contactless detection with optical measurement contributes to make the sensor a robust system while avoiding deterioration. Therefore, the frequency of maintenance will be reduced.</p>

Technologies for optical gas measurement

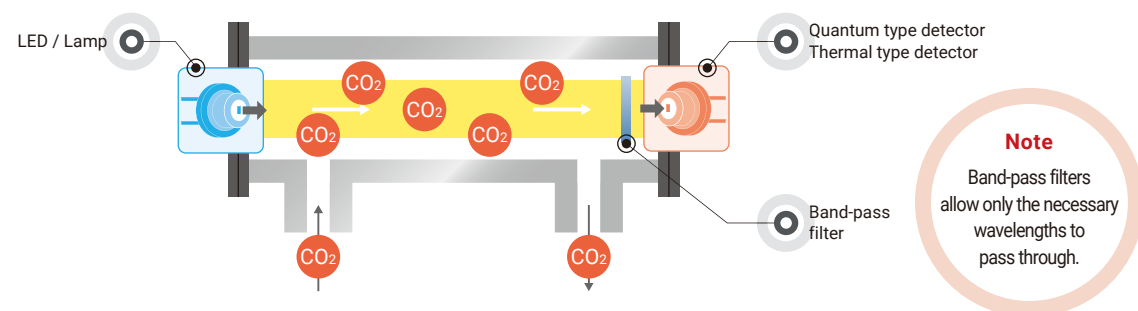
Method	Features	Wavelength	Measured objects	Light sources	Detectors	Details
NDIR	Compact, inexpensive, superior maintainability	IR	Specific gas	LED Lamp	Quantum type detector Thermal type detector (with band-pass filter)	P04
FTIR	Optimal for analysis of complex gases and organic compounds	IR	Specific gas Complex gas	Lamp	Quantum type detector Thermal type detector	P05
TDLAS	Trace gas measurement with high throughput	IR	Single molecule of gas	Laser	Quantum type detector	P06
DOAS	Simple structure, wide selection of wavelengths	UV to IR	Specific gas Complex gas	Lamp	Quantum type detector	P07



NDIR (Non-Dispersive Infrared)

Compact, inexpensive, superior maintainability

NDIR (Non-Dispersive Infrared) detection method uses an optical filter to extract and detect only the wavelengths required for gas measurement. This method offers superior reliability and maintainability due to a simple detection principle, which uses no moving parts. Mostly containing cost-effective optical parts, it is non-dispersive and does not use image sensors. High cost-performance optical parts are used in many measuring devices, including but not limited to portable safety (explosive gas detection) devices and fixed environmental measurement devices.



■ Applications

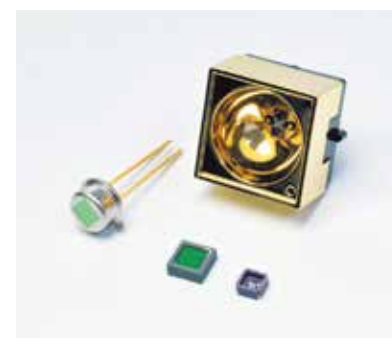
CO₂ measurement in hydroponics farms
Measuring CO₂ concentration required for photosynthesis.



Portable gas sensor
Gas leak detection at factories and other work sites.



■ Recommended products



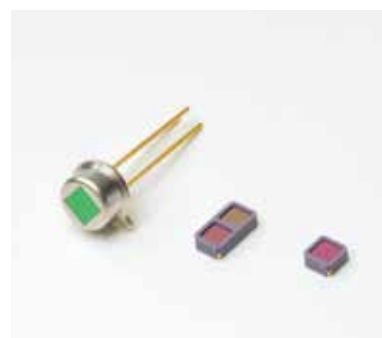
Mid infrared LEDs
L15893, L15894, L15895 series

- High output
- Three types available: for CO₂, CH₄, or reference light
- Surface mount types are also available



Xenon flash lamps
L13651 series and others

- Instantaneously high-peak output
- Low-heat generation
- Continuous spectrum: UV to MIR



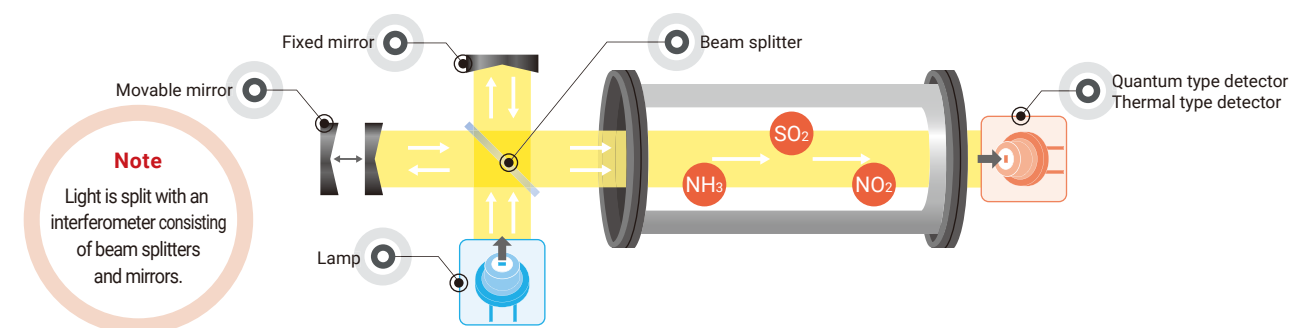
InAsSb photovoltaic detectors
P16112/P16612/P16849 series
(with band-pass filter)

- Equipped with a band-pass filter supporting CO₂ and CH₄
- Two-element types are available
- Surface mounted types are also available

FTIR (Fourier Transform Infrared Spectroscopy)

Optimal for analysis of complex gases and organic compounds

FTIR (Fourier Transform Infrared Spectroscopy) acquires spectral information with arithmetic processing from an interference signal (interferogram), which is generated by an interferometer, structured from beam splitters and mirrors. Because it can be used to obtain wide-band spectral information, it is suitable for measuring gases with a wide absorption band such as volatile organic compounds (toluene, benzene, chlorofluorocarbons, etc.). It can also measure complex gases with a wide range of absorption wavelength peaks.



■ Applications

Vehicle exhaust gas test
Concentration analysis of complex gas in vehicle exhaust gas.



Flue gas monitor
Analysis of complex gases emitted from factories and the like.

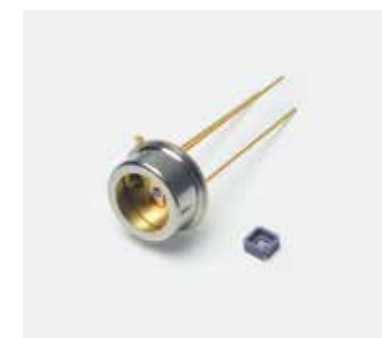


■ Recommended products



InAsSb photovoltaic detectors
P16112/P16612/P16849 series

- Supports 5 μm band
- Excellent linearity
- TE-cooled types and large photosensitive area products are available



InAsSb photovoltaic detectors
P16114-011MN / P16614-011CN

- Supports a wide range of gas absorption wavelengths (8μm band, 10μm band)
- TE-cooled types are available
- Excellent linearity



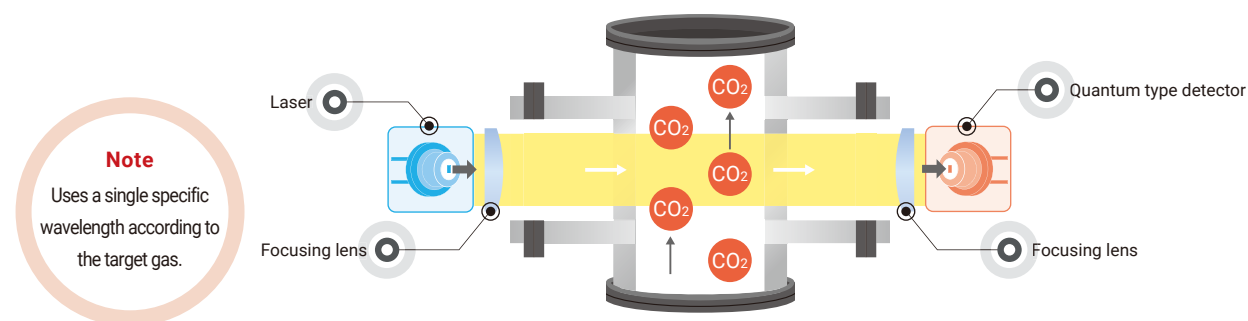
Type II superlattice infrared detector
P15409-901

- Supports 14 μm band
- Liquid nitrogen cooled type
- Excellent linearity

TDLAS (Tunable Diode Laser Absorption Spectroscopy)

Realizes high-speed, high-accuracy gas measurement

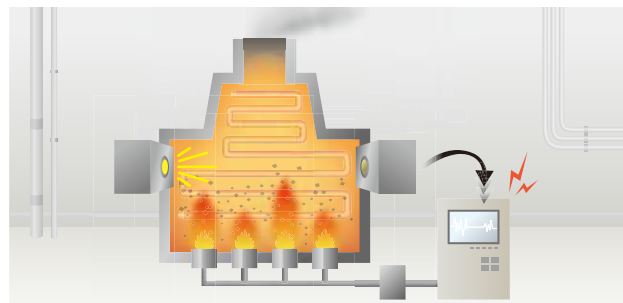
TDLAS (Tunable Diode Laser Absorption Spectroscopy) is a measurement method in which a DFB (distributed feedback) type semiconductor laser is wavelength swept at high speed by modulating an applied current. This method enables a high-speed and high-accuracy measurement combination using wavelength modulation spectroscopy, represented by the 2f method. DFB semiconductor lasers are applicable in the field of isotope measurement due to their extremely narrow emission linewidth, which selectively measures the absorption of gases derived from different isotopes of the same molecule.



Applications

Industrial process control

Process control with real-time measurement of industrial gas.



Flue gas monitor

Analysis of SOx and NOx in gases emitted from factories and the like.



Recommended products



CW Quantum cascade lasers (QCL)
L1200x series

- MIR semiconductor laser
- Distributed Feedback structure
- Fast wavelength tuning by current modulation



InAsSb photovoltaic detectors with preamp
P16702-011MN

- Supports a wide range of gas absorption wavelengths (8 μm band, 10 μm band)
- High-speed response (100MHz)
- Built-in preamplifier



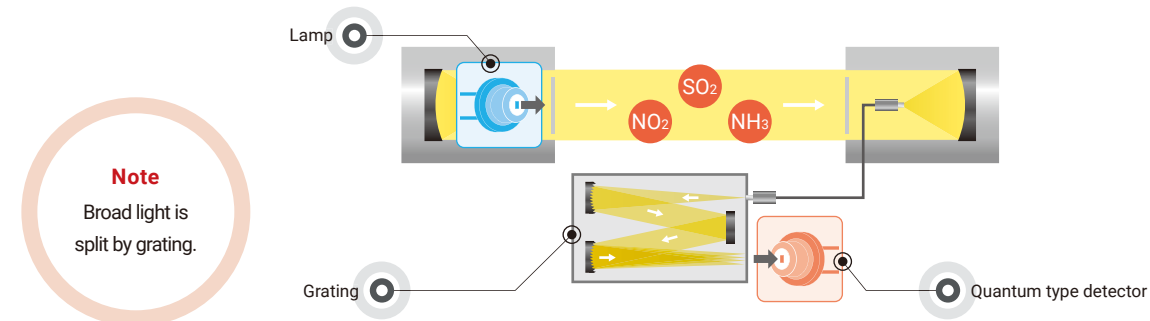
Infrared detection modules with preamp
C12494-211L/-222S

- High-speed response
- TE-cooled type, high sensitivity

DOAS (Differential Optical Absorption Spectroscopy)

Simple structure, wide selection of wavelengths

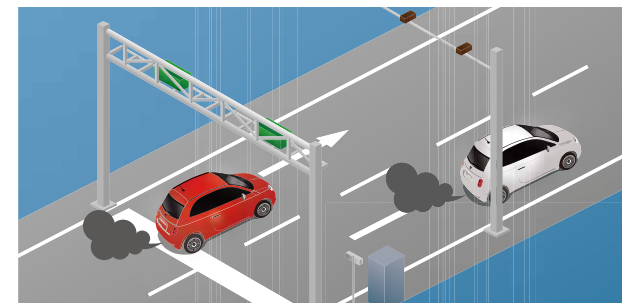
DOAS (Differential Optical Absorption Spectroscopy) is a method that outputs the concentration of the target gas by calculating the difference in the absorption spectrum and is optimal for measuring NOx and SOx. While gas-measuring instruments generally use infrared light, DOAS often uses visible and ultraviolet lights. The absorption spectrum of water is out of ultraviolet region, therefore, this method is effective for measurement in environments that are easily affected by absorption of water such as in the atmosphere.



Applications

Vehicle exhaust gas measurement

Real-time monitoring of vehicle exhaust gas



Air quality monitoring

Analysis of pollutant gases in the atmosphere



Recommended products



Xenon flash lamps
L13651 series and others

- Instantaneously high-peak output
- Low-heat generation
- Continuous spectrum: UV to MIR



Xenon lamps
L2273 and others

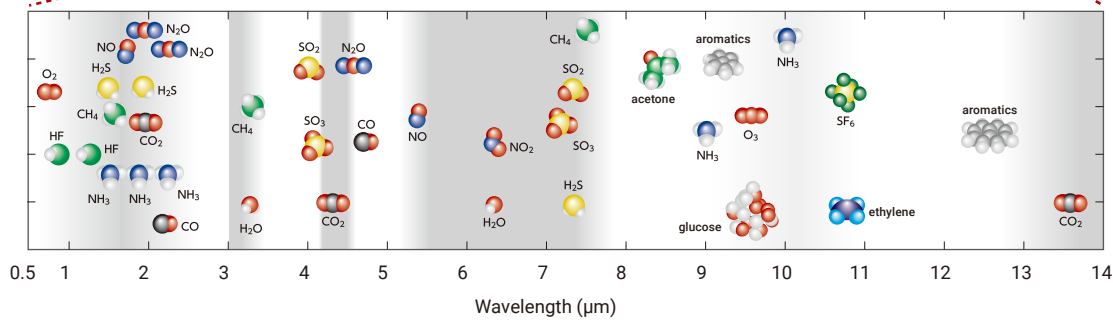
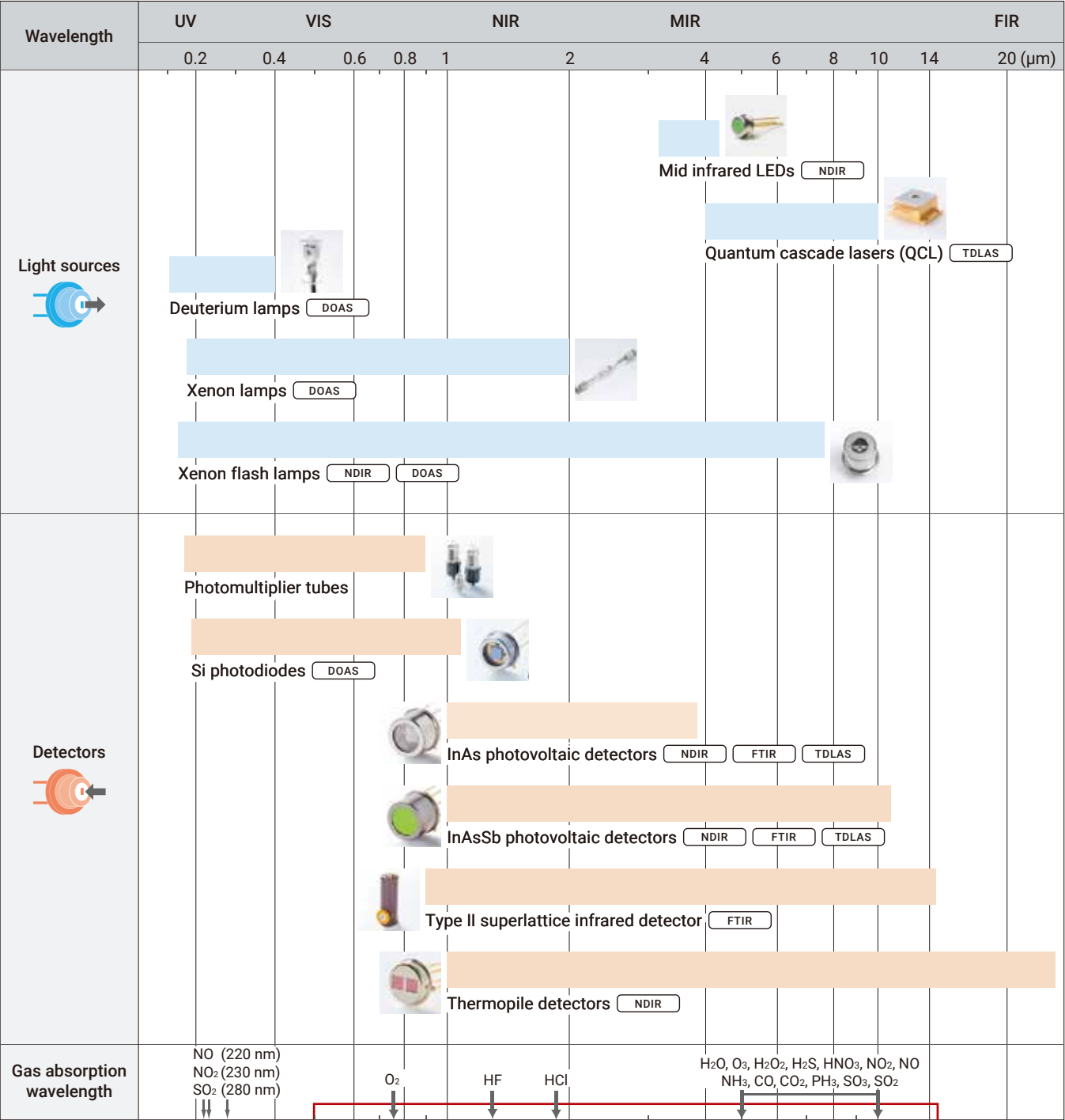
- High stability
- Continuous spectrum: UV to NIR



Deuterium lamps
L2D2 series, S2D2 series

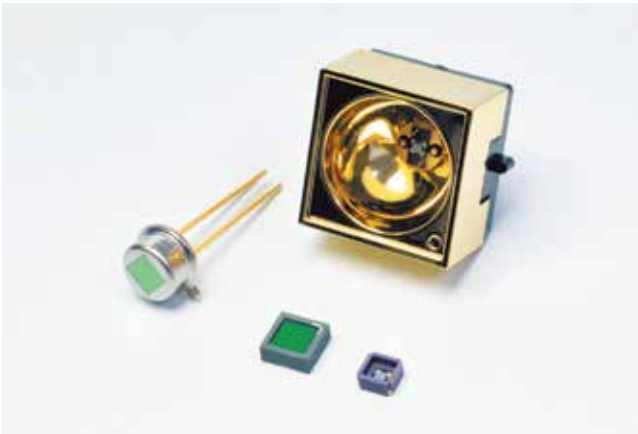
- High stability
- Long life
- Continuous spectrum in UV range

Product Lineup



Light Source Comparison

LEDs



For gas measurement in compact and portable devices

- Wavelength: 3.3 μm (CH₄) / 3.9 μm (reference light) / 4.3 μm (CO₂)
- Lower power consumption, higher reliability, and higher-speed response than lamps
- 10 times the radiant flux of previous products

Lasers



For trace gas measurement

- Wavelength: 4 μm to 10 μm
- High directivity, high output, high reliability, high-speed response
- Adaptable into in-situ measurement
- High-resolution measurement by narrow line width

Lamps



For multiple gas measurement

- Continuous spectrum: UV to MIR
- Instantaneously high-peak output
- Low-heat generation

Light source	Wavelength range	Output	Time response characteristics	Power consumption	Lifetime	Cost benefit
LEDs	Narrow	☆☆	☆☆☆	☆☆☆	☆☆☆	☆☆☆
Lasers	Line spectrum	☆☆☆☆	☆☆☆	☆☆	☆☆	☆
Lamps	Wide	☆☆☆☆	☆☆	☆	☆☆	☆☆

LEDs / Lasers

Mid infrared LEDs

L15893 series, L15894 series, L15895 series

Our Mid infrared LEDs' peak emission wavelengths of 3.3 μm , 3.9 μm and 4.3 μm respectively are achieved using our unique crystal growth and process technology. Their output has significantly increased compared to previous products (approx. 10 times the radiant flux).

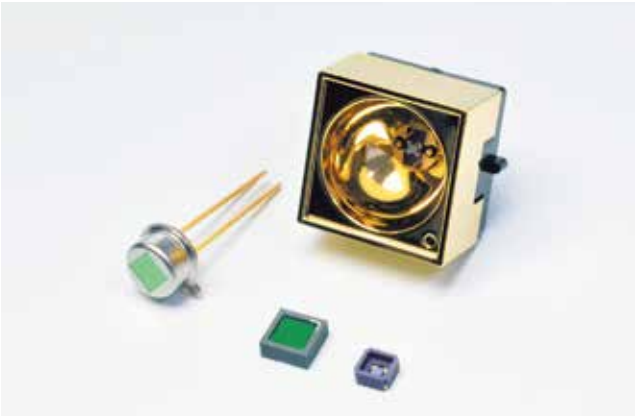
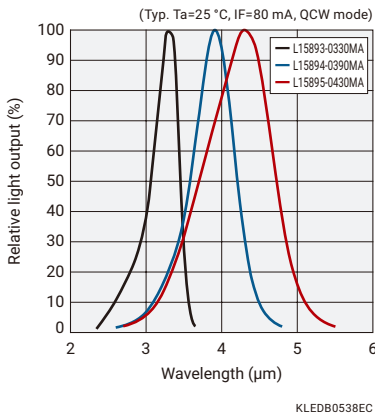
Wavelength ...

IR

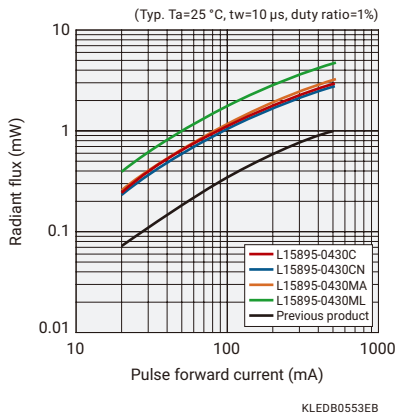
Method

NDIR

Emission spectrum



Radiant flux



CW Quantum Cascade Lasers (QCL)

L1200X series

QCL is a semiconductor laser with an emission in the mid-infrared region that has attracted attention as a new light source for mid-infrared spectroscopy. Our cutting-edge, proprietary manufacturing processes and extensive experience enable us to offer high reliability devices for spectroscopic applications.

Wavelength ...

IR

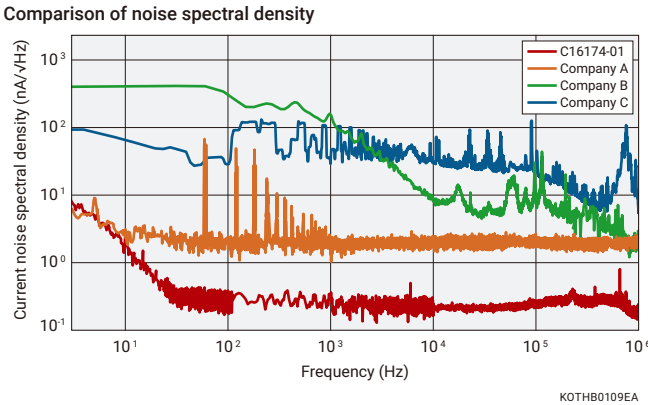
Method

TDLAS



Accessory: CW controller C16174-01

Ultra-low noise controller unit assigned to work with CW QCL. It easily controls QCL's temperature and QCL itself via PC. This is a suitable controller for TDLAS as it is capable to modulate the output current to the laser. Using advanced signal processing, the current noise of this device is significantly lower than similar systems.



Lamps

Xenon flash lamps

L13651 series and others

This is a pulsed light source with a high momentary peak output. This multi-wavelength light source has a continuous spectrum, spanning from the ultraviolet region to the infrared region, making it suitable for a wide range of measurement and analysis.

Wavelength ...

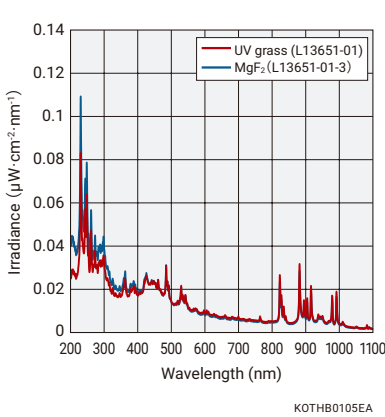
UV to IR

Method

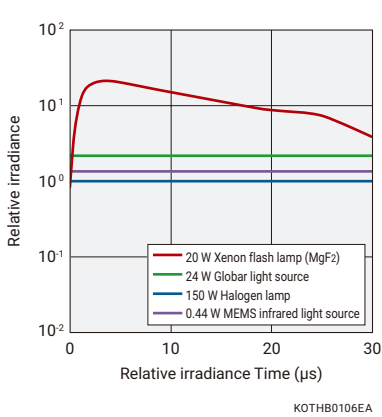
NDIR

DOAS

Spectral irradiance (typ.)



Emission pulse waveform at 7.5 μm (typ.)



Deuterium lamps

L2D2 series, S2D2 series

It is a highly stable lamp with a strong emission spectrum in the ultraviolet. This light source has good characteristics of life, stability, and output required for an analytical lamp.

Wavelength ...

UV

Method

DOAS



Xenon lamps

L2273 and others

It has both high luminance and high-color temperature, and it emits a continuous spectrum from ultraviolet to infrared, so it is the optimal light source for a variety of analyses. Using high-performance cathodes, both higher stability and longer life are achieved compared to conventional lamps.

Wavelength ...

UV to IR

Method

DOAS



Detector Comparison

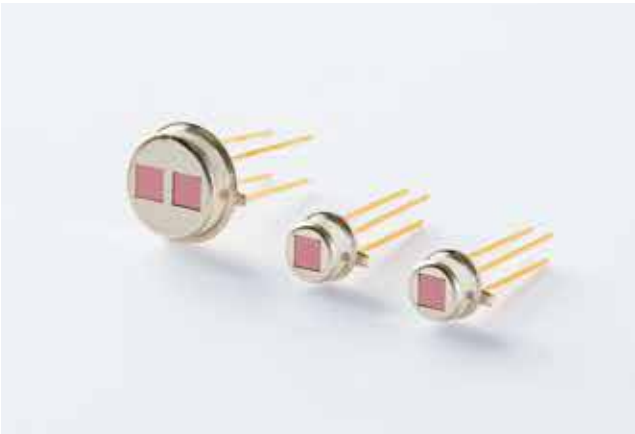
Quantum type detectors



Used in pair with LED: for relatively simple applications
Used in pair with QCL: for applications requiring comparative precision

- High sensitivity
- High-speed response

Thermal type detectors

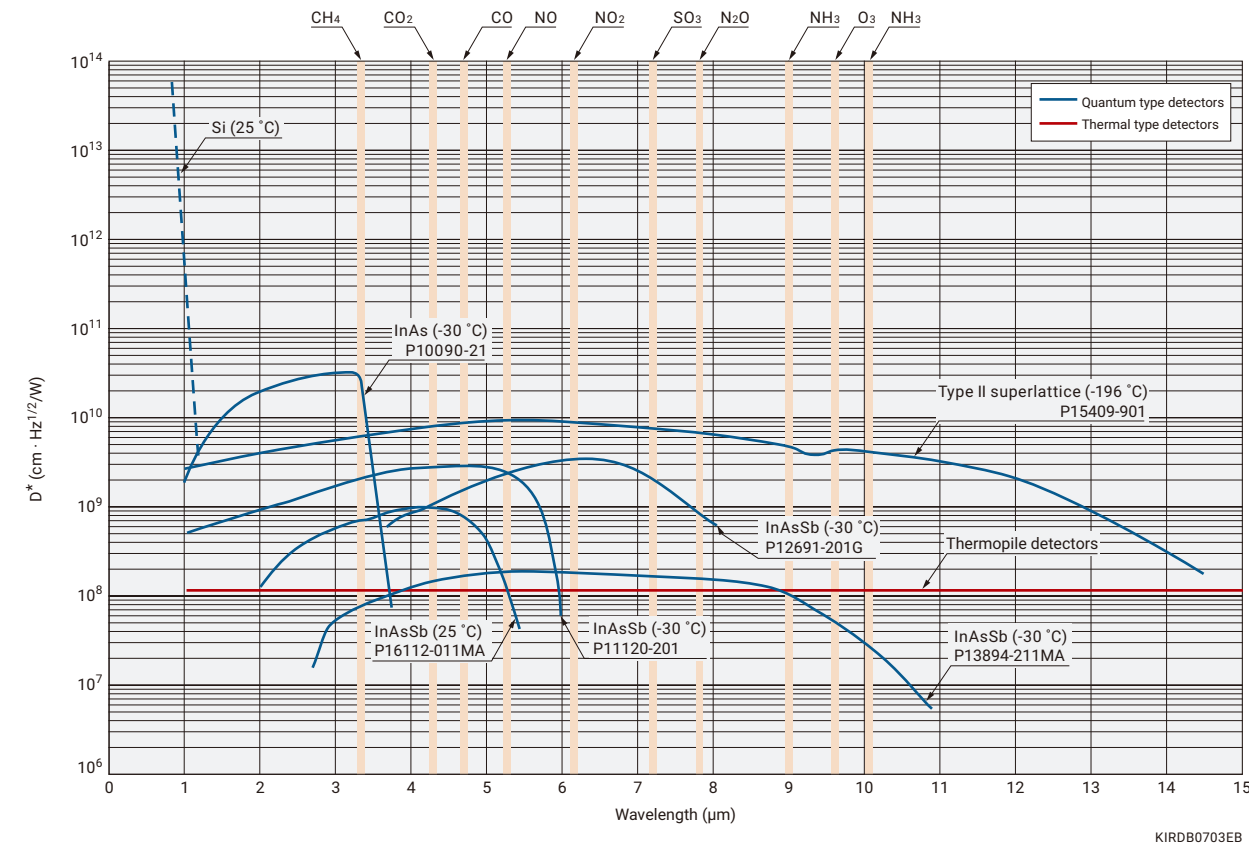


For relatively low-end applications

- Spectral response is not wavelength-dependent
- Less affected by ambient temperature

Detector	Sensitivity	Wavelength dependence	Time response characteristics	Cooling	Cost benefit
Quantum type detectors	☆☆☆	Yes	☆☆☆☆	Cooled (partially not required)	☆☆
Thermal type detectors	☆☆	None	☆	Non-cooled	☆☆☆

■ Absorption wavelengths of major gases and spectral response of a detector (typ.)



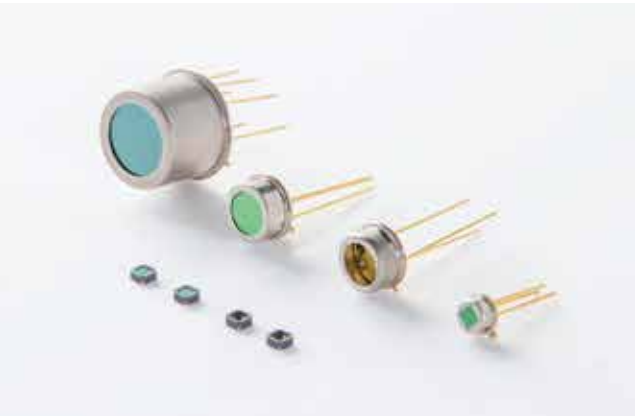
Quantum Type Detectors

InAsSb photovoltaic detectors
P16112/P16612 series etc.

These sensors have achieved high sensitivity in the mid-infrared region using Hamamatsu unique crystal growth technology and process technology. These products do not use lead, mercury or cadmium, which are RoHS Directive restricted substances. Hamamatsu offers a lineup of products that support the 5 μm band, 8 μm band, and 10 μm band.

Wavelength ... **IR**

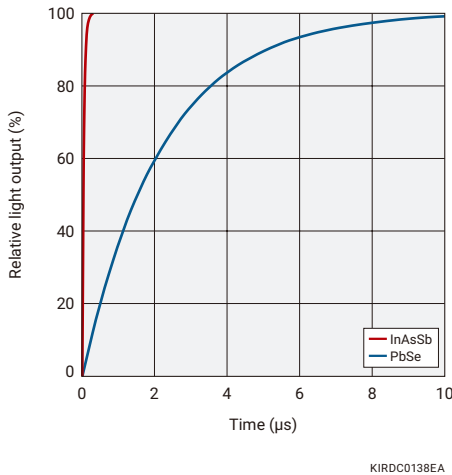
Method **NDIR** **FTIR** **TDLAS**



Superiority of the InAsSb photovoltaic detector (compared with our conventional product: PbSe)

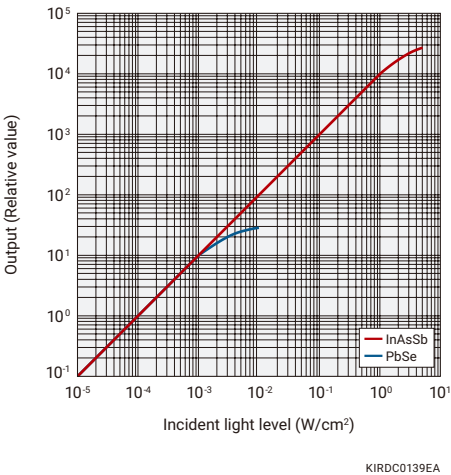
● High-speed response

Because it is capable of high-speed response of about 10 to 100 times speed, it can be used in combination with a high-speed pulse drive light source, such as QCL.



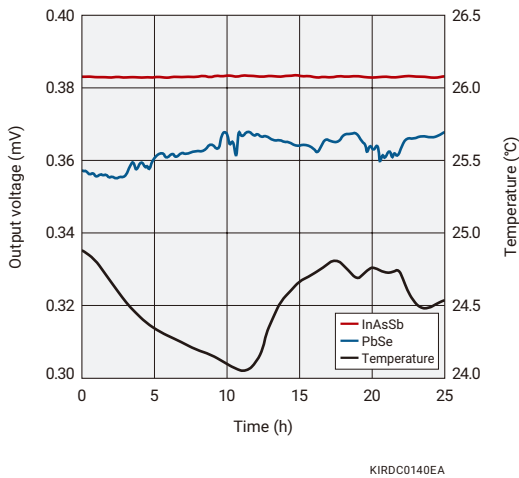
● Excellent linearity

It has nearly 1000 times better linearity, so no dimming is required for high-power light sources. Also, its wide dynamic range contributes to improved S/N.



● Excellent output stability

It has superior short-term and long-term output stability, making correction of analysis devices easier and improving maintainability.



● Wide operating temperature

Unlike PbSe, it offers high reliability, as its characteristics are not subject to degradation even when used for a long time in a high-temperature environment.

Product	Operating temperature
InAsSb photovoltaic detectors	-40 to +85 °C
PbSe photoconductive detectors	-30 to +50 °C

Quantum Type Detectors

InAsSb photovoltaic detectors (with band-pass filter)

P16112/P16612/P16849 series

These InAsSb photovoltaic detectors use a band-pass filter suitable for CH₄ (3.3 μm), reference light (3.9 μm), and CO₂ (4.26 μm). Two-element types are available (reference light is also detected).

Wavelength ... **IR**
Method **NDIR**



InAs photovoltaic detectors

P10090 series

The features of these sensors include low noise, high-speed response, and high reliability. These do not contain lead, which is a RoHS Directive restricted substance, and have sensitivity up to the 3 μm band, which is similar to conventional PbS photoconductive detectors.

Wavelength ... **IR**
Method **NDIR** **FTIR** **TDLAS**



Type II superlattice infrared detector

P15409-901, C15780-401

This infrared detector has a superlattice structure in which InAs and GaSb are layered alternately, with an extended spectral response range to the 14 μm band. It does not contain mercury or cadmium, which is part of the RoHS Directive of restricted substances, and it is a replacement for the conventional MCT photovoltaic detector. Modules with preamps are also available.

Wavelength ... **IR**
Method **FTIR**



Infrared detection modules with preamp

C12494-222S, C12494-211L

These are amplifier-integrated modules that can detect infrared light simply by connecting a DC power supply. Since their spectral response range is wide, these are suitable for detecting numerous gases. These support 1 MHz. We also provide an ultra-compact InAsSb photovoltaic device with a preamplifier built into the CAN package. and can be used in combination with a QCL.

Wavelength ... **IR**
Method **NDIR** **FTIR** **TDLAS**



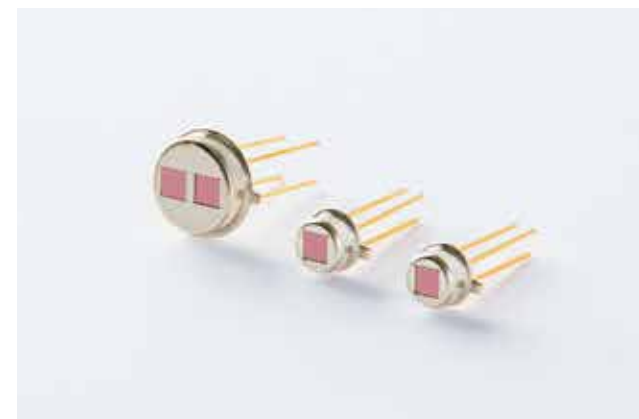
Thermal Type Detectors

Thermopile detectors

T11361-01, T11722-11, T11722-12

These sensors generate thermoelectromotive force in proportion to the incident infrared light energy. Since they have no wavelength dependence, their spectral response is determined by the transmittance characteristics of window material. By attaching an external band-pass filter, customers can apply them to various types of gas density measurements.

Wavelength ... **IR**
Method **NDIR**



Other detectors

Mini-spectrometers

C10082CA, C13053MA, C13555MA

This is a palm-sized spectrometer (polychromator) consisting of an optical system, image sensor, and circuit. Optical spectra can be easily collected by connecting to a PC via USB.

Wavelength ... **UV to IR** Method ... **DOAS**



MPPC modules

C13365 series, C13366 series

MPPC is a photon-counting device using multiple APD pixels operating in Geiger mode. This module equipped with an amplifier, temperature-compensation circuit, and high-voltage power supply circuit required for MPPC operation, can measure very low-level light simply by providing a power supply.

Wavelength ... **UV to IR** Method ... **DOAS**



Si photodiodes

S12698 series

These Si photodiodes have achieved high reliability for monitoring ultraviolet light. They exhibit low-sensitivity deterioration under ultraviolet light irradiation and are suitable for applications such as monitoring intense ultraviolet light sources.

Wavelength ... **UV** Method ... **DOAS**



Side-on type photomultiplier tubes

The side-on photomultiplier tube is a photodetector with the characteristics of extremely high sensitivity and high-speed response. Hamamatsu has a wide lineup which are integrated in many analytical devices.

Wavelength ... **UV**



Main Products

Opto-semiconductors

- Si photodiodes
- APD
- MPPC®
- Photo IC
- Image sensors
- PSD
- Infrared detectors
- LED
- Optical communication devices
- Automotive devices
- X-ray flat panel sensors
- MEMS devices
- Mini-spectrometers
- Opto-semiconductor modules

Electron Tubes

- Photomultiplier tubes
- Photomultiplier tube modules
- Microchannel plates
- Image intensifiers
- Xenon lamps / Mercury-xenon lamps
- Deuterium lamps
- Light source applied products
- Laser applied products
- Microfocus X-ray sources
- X-ray imaging devices

Imaging and Processing Systems

- Scientific cameras
- Spectroscopic and optical measurement systems
- Ultrafast photometry systems
- Life science systems
- Medical systems
- Non-destructive inspection products
- Semiconductor manufacturing support systems
- Material research systems

Laser Products

- Single chip laser diodes
- Laser diode bar modules
- Quantum cascade lasers
- Applied products of semiconductor lasers
- Solid state lasers
- Laser related products

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* Please thoroughly read the precautions and the prohibited uses included in the user manual before installation and use.