Devices for Gas Measurement
Supporting Gas Analysis with Optical Devices
There are two major approaches to detect gases by optical absorption: the one using infrared light and the other using ultraviolet light. Gas molecules have unique absorption wavelengths. Gas density is measured by measuring their absorbances. Particularly in the infrared region, there are many absorption wavelengths specific to a gas due to the vibration of gas molecules, so the infrared region is used for measuring various gases. By selecting the optimal device with consideration for the light absorption characteristics of the target gas and its surrounding environment, an optical method can realize even better high-speed response, higher accuracy, and longer life gas measurement than other systems. Hamamatsu Photonics meets the needs of customers with a variety of light sources and detectors used for optical gas measurement.

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### Advantages of optical gas measurement against other sensing technologies

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<tr>
<td>MOS type detection</td>
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<td>Catalytic type detection</td>
<td>Contactless detection with optical measurement contributes to make it robust system and less degradation of sensor itself. Moreover, the frequency of the maintenance can be done less often.</td>
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<td>DOAS</td>
<td>Simple structure, wide selection of wavelengths</td>
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### Technologies of optical gas measurement

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<td>Lamp</td>
<td>Quantum type detector</td>
<td>P07</td>
</tr>
</tbody>
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### Features of optical based measurement

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

- Less affected by heat
- Less affected by background light
- Does not overlap with absorption wavelengths of water
**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. It offers superior reliability and maintainability due to the simple detection principle, which uses no moving parts. Few expensive optical parts are used, and it is non-dispersive and does not use image sensors. For these reasons, it offers high cost performance, and is used in many gas measuring devices, including portable measurement devices and environmental measurement devices installed in various places.

**Applications**

- CO₂ measurement in plant factory
  - Measuring CO₂ concentration required for photosynthesis.
- Portable gas sensor
  - Gas leak detection at factories and other worksites.

**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
  - P13243 series
  - Equipped with a band-pass filter supporting CO₂ and CH₄
  - Two-element types are available
  - Surface mounted types are also available
- Type II superlattice infrared detector
  - P15409-901
  - Supports 14 µm band
  - Liquid nitrogen cooled type
  - Excellent linearity

**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**

- Automobile exhaust gas test
  - Concentration analysis of complex gas in automobile exhaust gas.
- Flue emission gas monitor
  - Analysis of complex gases emitted from factories and the like.

**Recommended products**

- InAsSb photovoltaic detectors
  - P13894 series
  - Supports 10 µm band
  - Non-cooled types and TE-cooled types are available
  - Excellent linearity
  - Large photosensitive area products are available
- InAsSb photovoltaic detectors
  - P13894 series
  - Supports 5 µm band
  - Non-cooled types and TE-cooled types are available
  - Excellent linearity
  - Large photosensitive area products are available
- 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 high speed and high accuracy measurement by combining with wavelength modulation spectroscopy, represented by the 2f method. Because DFB semiconductor lasers have extremely narrow emission linewidth, they can selectively measure absorption of gases derived from different isotopes of the same molecule, and so they are applicable in the field of isotope measurement.

**Applications**

- **Industrial process control**
- **Flue emission gas monitor**

**Recommended products**

- **CW Quantum cascade lasers (QCL)**
  - L1200x series
- **InAsSb photovoltaic detectors**
  - P13894 series
- **Infrared detection modules with preamp**
  - C12494 series

**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 light. 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**

- **Automobile exhaust gas measurement**
- **Air quality monitoring**

**Recommended products**

- **Xenon flash lamps**
  - L13651 series and others
- **Xenon lamps**
  - L2273 and others
- **Deuterium lamps**
  - L2D2 series, S2D2 series

- **Infrared detection modules with preamp**
  - C12494 series
- **Xenon flash lamps**
  - L13651 series and others
- **Xenon lamps**
  - L2273 and others
- **Deuterium lamps**
  - L2D2 series, S2D2 series
### Product Lineup

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>UV</th>
<th>VIS</th>
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<th>MIR</th>
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### 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
  - Achieves about 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

#### Detectors
- Si photodiodes
- InAs photovoltaic detectors
- InAsSb photovoltaic detectors
- Thermopile detectors
- Type II superlattice infrared detector

#### Gas absorption wavelength
- N₂ (232 nm), N₂O (230 nm), SO₂ (280 nm), O₂ (376 nm), HF (631 nm), HC₃ (710 nm), HCl (845 nm), H₂O, SO₂, NO, O₃

### Optical Gas Measurement

#### Devices for Gas Measurement
- Light sources
- Detectors
- Measurement Method

#### Product Lineup
- LEDs
- Lasers
- Lamps

#### Measurement Method
- Narrow
- Line spectrum
- Wide

#### Output
- High
- Medium
- Low

#### Time response characteristics
- High
- Medium
- Low

#### Power consumption
- High
- Medium
- Low

#### Lifetime
- High
- Medium
- Low

#### Cost benefit
- High
- Medium
- Low
**LEDs / Lasers**

**Mid infrared LEDs**
L15893 series, L15894 series, L15895 series

These mid-infrared LEDs have peak emission wavelengths of 3.3 µm, 3.9 µm, and 4.3 µm respectively, which have been achieved using Hamamatsu unique crystal growth technology and process technology. Output is significantly increased compared to the 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 oscillation in the mid-infrared region, and has attracted attention as a new light source for mid-infrared spectroscopy. Our cutting edge proprietary and the superior experience of semiconductor manufacturing contribute to offer high reliable devices for the spectroscopic application.

**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 output current to laser.

**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 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 various types of analysis. Using high-performance cathodes, both higher stability and longer life are achieved compared to conventional lamps.

**Wavelength** ... UV to IR

**Method** ...... DOAS

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**Comparison of noise spectral density**

Company A

Company B

Company C
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

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

Quantum type detectors

- Excellent output stability
- High-speed response
- Wide operating temperature

Thermal type detectors

- Excellent linearity

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

- High-speed response: It has a high-speed response of about 10 to 100 times speed, making it suitable for use 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.
- 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 Lineup

- Light Sources
- Detectors

Optical Gas Measurement

Measurement Method

- Product & Chips
- Light Sources
- Detectors

Devices for Gas Measurement
### Quantum Type Detectors

**InAsSb photovoltaic detectors (with band-pass filter)**  
P13243 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).

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Method</td>
<td>NDIR</td>
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</table>

### 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.

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### Type II superlattice infrared detector

P15409-001, C15780-401

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

<table>
<thead>
<tr>
<th>Wavelength →</th>
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<tbody>
<tr>
<td>Method</td>
<td>FTIR</td>
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</table>

### Infrared detection modules with preamp

C12494 series

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. The non-cooled type supports 50 MHz, while the cooled type supports 1 MHz, and can be used in combination with a QCL.

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### Thermal Type Detectors

**Thermopile detectors**  
T11272-01, T11361-01

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.

<table>
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### 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.

<table>
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<tbody>
<tr>
<td>Method</td>
<td>DOAS</td>
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**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.

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**Si photodiodes**  
S12698 series

These are Si photodiodes that 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.

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</table>

**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 and is incorporated in many analysis devices.

<table>
<thead>
<tr>
<th>Wavelength →</th>
<th>UV</th>
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</table>