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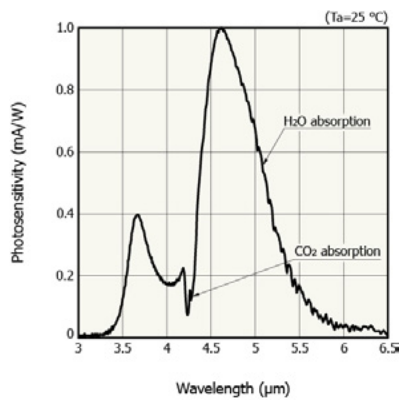
Quantum Cascade Detectors – a hidden champion in mid-infrared sensing

Quantum cascade detectors (QCDs) are atypical mid-infrared (MIR) detectors that challenge the long-held perceptions of the photonics world about MIR detectors. A room-temperature detector with high specific detectivity, extremely low noise, a speed well within the optical communication domain, and a small package is generally not associated with an MIR detector QCDs however, have achieved this feat. Hamamatsu Photonics is the first company to launch room-temperature operating QCDs to the market [1].

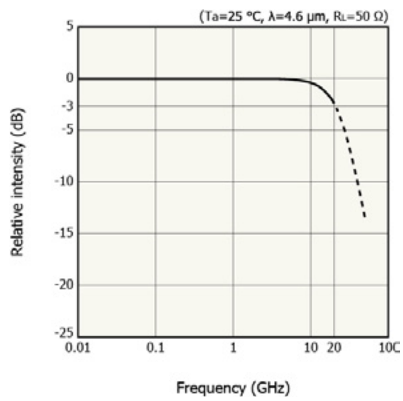
Principle of Quantum Cascade Detectors

Quantum cascade detectors (QCDs) share design similarities with quantum cascade lasers (QCLs) in the sense that both use intraband transitions in semiconductor superlattice structures [2]. In QCDs, absorption of MIR photons leads to intraband transitions, and the resultant photoelectrons cascade down the quantum levels created by the superlattice structure. This design does not require external voltage bias. **In other words, QCDs do not need a power source for operation.** However, the more significant advantages of this feature are room temperature operation and low noise characteristics. This low noise characteristic boosts the **specific detectivity of QCDs to greater than 1 × 10⁹ cm √ Hz /W.** The design of QCDs also allows them to operate at **high speeds, reaching 20 GHz (3 dB cut-off)** [3]. The wavelength sensitivity of QCDs can be tuned by the design of the superlattice structure, as with the output wavelength tuning of QCLs.

Quantum Cascade Photodetector P16309-01



Fiigure 1: Spectral response (example)



Fiigure 2: Response frequency (example)

Range of applications for QCDs

QCDs exactly meet the needs of high-speed photonic applications in the MIR region.

Free Space optical communications

In free-space optical (FSO) communications, MIR wavelengths are being considered instead of the standard communications wavelengths because of relatively lower scattering of MIR wavelengths in the atmosphere. For achieving high data transfer rates, fast and energy efficient MIR detectors are required and QCDs are one of the most promising candidates [4].

High speed MIR spectroscopy

QCDs sensitivity to MIR wavelengths is useful in the direct detection of small molecules and gases. What makes QCDs different from other MIR detectors is their high speed and sensitivity at room temperature. These properties are well suited for studying kinetics of fast chemical processes like combustion, pyrolysis, cracking, etc. When combined with ultrafast spectral sources, QCDs have been shown to acquire ~1 M spectra per second [5].

Optical Heterodyne detection

Another interesting application for QCDs is in heterodyne detection, which is used in high-precision dual-comb spectroscopy. Recently, **a research group demonstrated the sub-Poissonian noise characteristics of Hamamatsu's QCD, the P16309-01** [6], proving that it is an ideal detector for small signals over a large background, like in heterodyne detection.

World's first quantum cascade photodetector

The world's first quantum cascade photodetector was developed by Hamamatsu and launched in October 2021. The P16309-01 boasts a cut-off frequency of 20 GHz with no cooling. It is an ultrafast mid-infrared photodetector with a peak sensitive wavelength of 4.65 μm, ideal for high-frequency and fast time-resolved measurements like heterodyne detection in the mid-infrared region. Visit the P16309-01 quantum cascade photodetector product pages [3] for further details.

Hamamatsu's P16309-01 mid-infrared quantum cascade photodetector.

QCDs can facilitate demanding mid-infrared sensing applications previously discounted due to the prolonged absence of such detectors, giving researchers and engineers a greater choice for their projects.

For more details about Hamamatsu's QCDs, please visit our website us at info@hamamatsu.eu.

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