QEPAS: Quartz-Enhanced Photoacoustic Spectroscopy

THORLABS
APPLICATION NOTE

PRINCIPLE

Photoacoustic spectroscopy, based on the photoacoustic effect, can accurately detect trace gas concentrations for a wide variety of applications. Similar to laser absorption spectroscopy, a laser beam is sent through a gas-tight chamber to excite the target gas molecules. However, instead of detecting the absorption lines with an optical detector, the pressure wave generated by the relaxation of those molecules is detected by a transducer.

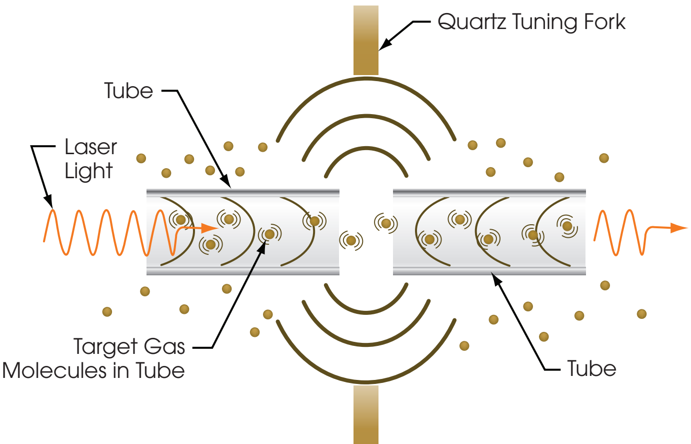


Illustration of QEPAS Principle

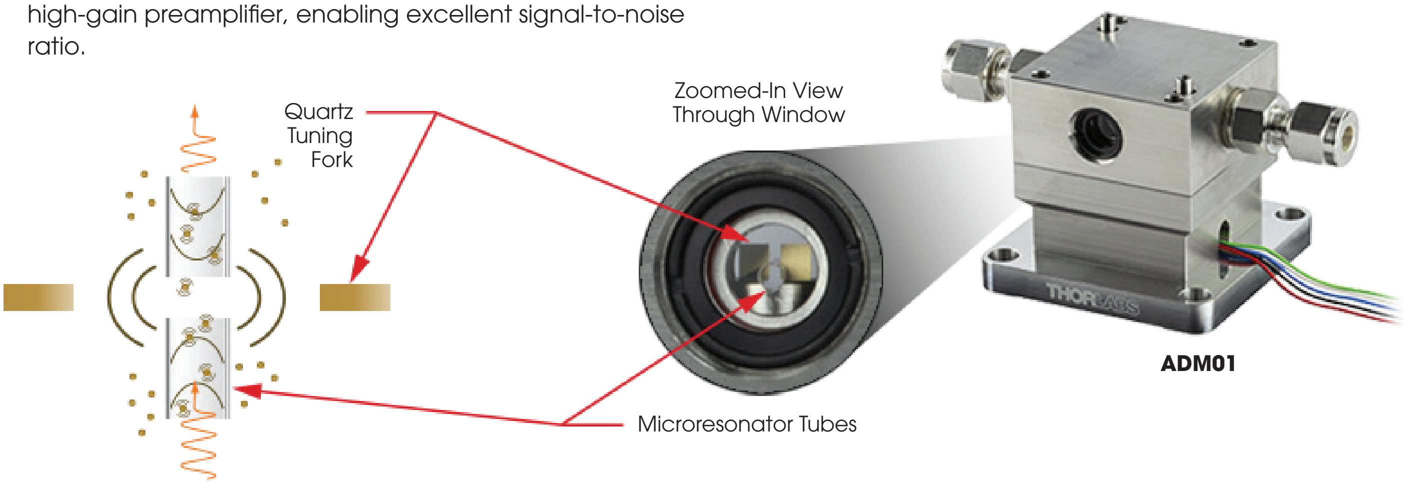
In the case of QEPAS, the transducer is a sharply resonant quartz tuning fork (QTF). The high-Q acoustic resonance enables the detection of weak excitation within small volumes, bypassing the acoustic resonance restrictions of conventional methods. When the laser source is modulated with a sine wave, the induced pressure (sound) wave will have double the frequency as that of the light modulation; therefore, the laser source modulation must be at half of the resonance frequency of the QTF. The resulting amplitude from the QTF is directly proportional to the concentration of trace gas in the sample.

The QTF also has good environmental noise immunity due to its being an acoustic quadrupole, since the primary vibrational modes require the prongs to move away from each other to be piezoelectrically active. Sound from external sources has a longer wavelength than the prong separation and will cause the prongs to move in the same direction, resulting in no piezoelectric response.

ADM01 ACOUSTIC DETECTION MODULE

The Acoustic Detection Module is a photoacoustic cell designed to be easily built into a complete quartz-enhanced photoacoustic spectroscopy (QEPAS) system. The module has an inlet and outlet allowing a gas sample to be pumped into the airtight chamber, which contains microresonator tubes and a custom quartz tuning fork (QTF). When an external laser source passes through the wedged windows, the tubes enhance the acoustic signal generated by the relaxation of the excited gas particles. This acoustic signal is transduced by the custom QTF and then amplified by the integrated high-gain preamplifier, enabling excellent signal-to-noise ratio.

The module is designed for on-axis QEPAS, which uses two tubes on either side of the QTF as an acoustic microresonator which the light must pass through, as shown in the diagram above. Each tube has a length of ~λ/2, where λ is the wavelength of sound in air at the resonance frequency of the tuning fork, and there is a small gap between them for the QTF. The acoustic resonator increases the effective interaction length between the generated sound and the QTF, allowing the QTF to have greater sensitivity to the near-field photoacoustic wave.



ADM01

FURTHER READING

For more information on the science of QEPAS, please see:

P. Patimisco, A. Sampaolo, L. Dong, F. K. Tittel, and V. Spagnolo, "Recent advances in quartz enhanced photoacoustic sensing," *Appl. Phys. Rev.* **5**, 011106 (2018). https://aip.scitation.org/doi/10.1063/1.5013612