A Technique for Fingerprinting Multiple Trace Gases

An updated method for detecting trace amounts of gases could allow researchers to identify minuscule amounts of multiple gases in the same sample.

By **Samuel Jarman**

Researchers in Germany have demonstrated an upgrade of a technique called quartz-enhanced photoacoustic spectroscopy (QEPAS) for detecting the spectral fingerprints of gases at ultralow concentrations [**1**]. The upgraded QEPAS could help researchers to rapidly identify individual gases in mixtures containing many trace gases, an ability that could prove invaluable in areas ranging from medical diagnostics to environmental monitoring.

QEPAS is a rapidly growing technique for detecting gases at concentrations as low as a few parts per trillion. This extreme sensitivity is made possible by the photoacoustic effect, through which a gas absorbs a laser beam at a specific frequency and converts its energy into heat. If the laser's intensity is varied periodically at a certain modulation frequency, the varying energy absorbed by the gas will cause it to expand and contract periodically. This expansion and contraction, in turn, generates a sound wave with the same modulation frequency as the original laser.

Researchers have demonstrated a new way to detect trace amounts of gases using a tuning fork.
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In QEPAS, the laser modulation frequency is matched precisely to the resonant frequency of a quartz tuning fork. Because of the piezoelectric properties of quartz, vibrations induced by the gas-caused sound waves can generate an electrical signal through the fork that can then be amplified and processed to detect the gas.

Despite its advantages, the use of QEPAS has so far been mostly limited to single-wavelength laser sources. This limitation is a problem since the spectral fingerprints of many gases span a broad range of wavelengths. The fingerprints of different gases also often overlap each other, making it extremely difficult for researchers to pinpoint individual gases in cases where many are present. “For that, you need to scan through a range of wavelengths,” explains team member Simon Angstenberger of the University of Stuttgart, Germany.

But doing that can introduce a problem if the scanning is performed too quickly, as the tuning fork can ring for a long time. When you arrive at the next wavelength, this ringing can still be still present, Angstenberger says, and that smears out the absorption features. This problem has been encountered in several previous studies that scanned a range of spectral wavelengths using an optical parametric oscillator. This device uses an optical crystal to convert a pump laser beam into a tunable output beam.

In their research, Angstenberger and colleagues modified this approach to overcome the lingering tuning fork vibrations encountered in previous studies. Specifically, as soon as the tuning fork's vibrations were detected, they shifted the phase of the laser beam's modulation frequency by exactly half an oscillation cycle. This adjustment meant that when the prongs of the tuning fork were moving inward, the photoacoustic expansion of the gas acted to counteract the prongs' motion by pushing them outward. Conversely, when the prongs were moving outward, the gas's contraction pulled them inward. This change dampened the tuning fork's vibrations almost immediately, leaving it ready to pick up sound waves generated by an optical parametric oscillator with a different wavelength. "This mechanism is extremely simple, as you can still use the same setup," Angstenberger says.

Using the method, the team was able to acquire an absorption spectrum of methane at a concentration of 100 parts per million in 3 seconds. On the basis of this result, the researchers are now hopeful that their technique could be used to pinpoint unknown trace gases in practical environments. "Our findings bring QEPAS closer to real-world applications where multiple gases might be present," Angstenberger says. "One could quickly identify which trace gas at which concentration is present with just one setup." The researchers say that this ability could ultimately lead to better real-time measurement techniques across a wide array of fields, from medical diagnostics to environmental monitoring, where even trace amounts of certain gases can be important to capture.

Samuel Jarman is a science writer based in the UK.

REFERENCES

1. S. Angstenberger *et al.*, "Coherent control in quartz-enhanced photoacoustics: Fingerprinting a trace gas at ppm-level within seconds," **Optica 12, 1 (2025).**