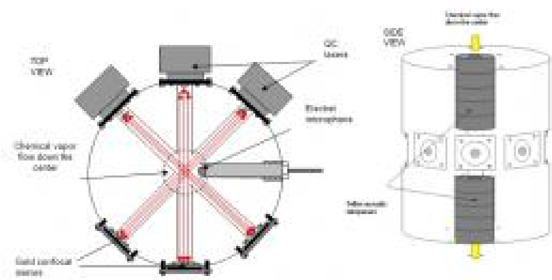
PHYS.ORG

Hearing the telltale sounds of dangerous chemicals

August 14 2012



A device based on selective real-time detection of gaseous nerve agent stimulants using multi-wavelength photoacoustics could look like this, in which now "multiple" lasers are used. Credit: U.S. Army Research Laboratory

To warn of chemical attacks and help save lives, it's vital to quickly determine if even trace levels of potentially deadly chemicals—such as the nerve gas sarin and other odorless, colorless agents—are present. U.S. Army researchers have developed a new chemical sensor that can simultaneously identify a potentially limitless numbers of agents, in real time. A paper describing the system has been published today in the Optical Society's journal, *Optics Letters*.

The new system is based on a phenomenon known as the photoacoustic effect, which was discovered by Alexander Graham Bell, in which the absorption of light by materials generates characteristic acoustic waves. By using a laser and very sensitive microphones -- in a technique called laser photoacoustic spectroscopy (LPAS) -- vanishingly low concentrations of gases, at parts per billion or even parts per trillion levels, can be detected. The drawback of traditional LPAS systems, however, is that they can identify only one chemical at a time.

"Photoacoustics is an excellent analytic tool, but is somewhat limited in the sense that one traditionally only measures one absorption parameter at a time," says Kristan Gurton, an experimental physicist at the U.S. Army Research Laboratory (ARL) in Adelphi, Md. "As I started looking into the chemical/biological detection problem, it became apparent that multiple LPAS absorption measurements -- representing an 'absorption spectrum' -- might provide the added information required in any detection and identification scheme."

To create such a multi-wavelength LPAS system, Gurton, along with co-authors Melvin Felton and Richard Tober of the ARL, designed a sensor known as a photoacoustic cell. This hollow, cylindrical device holds the gas being sampled and contains microphones that can listen for the characteristic signal when light is applied to the sample.

In this experiment, the researchers used a specialized cell that allows different gases to flow through the device for testing. As the vapor of five nerve agent mimics was flowed in, three laser beams, each modulated at a different frequency in the acoustic range, were propagated through the cell.

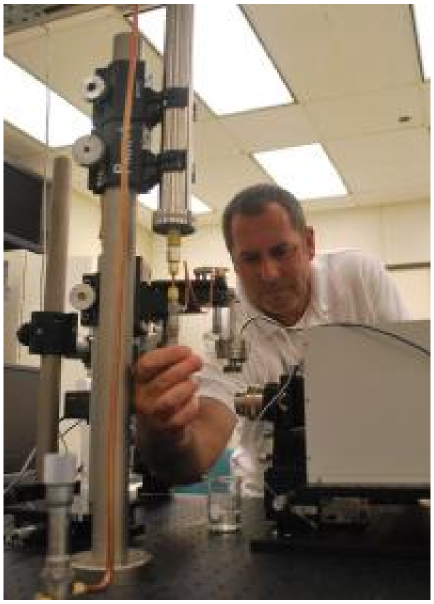
This laser is used to optically "heat" very small particles. Credit: U.S. Army Research Laboratory

"A portion of the laser power is absorbed, usually via molecular transitions, and this absorption results in localized heating of the gas," Gurton explains. Molecular transitions occur when the electrons in a molecule are excited from one energy level to a higher energy level. "Since gas dissipates thermal energy fairly quickly, the modulated laser results in a rapid heat/cooling cycle that produces a faint acoustic wave," which is picked up by the microphone. Each laser in the system will produce a single tone, so, for example, six laser sources have six possible tones. "Different agents will affect the relative 'loudness' of each tone," he says, "so for one gas, some tones will be louder than others, and it is these differences that allow for species identification."

The signals produced by each laser were separated using multiple "lock-in" amplifiers -- which can extract signals from noisy environments -- each tuned for a specific laser frequency. Then, by comparing the results to a database of absorption information for a range of chemical species, the system identified each of the five gases.

Because it is optically based, the method allows for instant identification of agents, as long as the signal-to-noise ratio, which depends on both laser power and the concentration of the compound being measured, is sufficiently high, and the material in question is in the database.

Before a device based on the technique could be used in the field, Gurton says, a quantum cascade (QC) laser array with at least six "well-chosen" mid-infrared (MidIR) laser wavelengths would need to be available.



Dr. Kristan Gurton, an experimental physicist in the Battlefield Environmental Division, Computational and Information Sciences Directorate, US Army Research Laboratory, conducts experiments. Credit: U.S. Army Research Laboratory.

"There are groups of researchers producing QC laser arrays that will operate with sufficient power, and will house as many as 10 -- or more -- lasers at different frequencies in the spectroscopically rich region of the MidIR," he says.

Once such laser arrays are available, the method ultimately "could be tailored for a variety of detection scenarios ranging from the obvious need to protect our soldiers during conflict to civilian applications like detecting the presence of harmful chemical gases that are difficult to detect with conventional techniques," Gurton says. A sufficiently rugged device for in-the-field use, he envisions, could be about the size of a milk carton. "A photoacoustic cell is surprisingly simple and inexpensive to produce, with all of the cost and size driven primarily by the packaging of the quantum cascade laser array," he adds.

In theory, the method could be used to identify an unlimited number of chemical agents.

"In our paper we demonstrated the ability to measure as many identifying absorption features as you want," Gurton says. "You're only limited by the number of laser sources available." However, he notes, "at some point, as the number of species spectra increase in the database, a degree of spectral overlap would occur, which might result in erroneous identification. It just depends on how similar the spectra are to each other. You could have just two that have very similar spectra and that could cause problems, or you could have 20 to 30 species spectra that all have distinguishable features that can be identified easily."

More information: "Selective real-time detection of gaseous nerve agent simulants using multi-wavelength photoacoustics (www.opticsinfobase.org/ol/abst … fm?uri=ol-37-16-3474)," *Optics Letters*, Vol. 37, Issue 16, pp. 3474-3476 (2012).

Provided by Optical Society of America