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Laser Detection

Infrared Laser Light Technology May Be Used To Detect Explosives at a Distance

By WILLIAM MATTHEWS

Laser light invisible to the human eye might make it possible for soldiers to spot roadside bombs and suicide bombers from a safe distance. The same laser technology might also scan cargo containers and autos to detect explosives or drugs as they cross the border to enter the United States.

Scientists at Oak Ridge National Laboratory have used infrared laser light to detect minute amounts of TNT, RDX and PETN — three powerful explosives — from a distance of 20 meters. Their standoff distance was limited by the size of their laboratory, said Larry Senesac, a physics professor and visiting scientist at the U.S. Energy Department's Oak Ridge lab.

Senesac said he and two colleagues plan to build a detector that can spot bombs from a distance of 100 meters.

The technology works by shining an infrared laser on a suspected bomb and analyzing the light that reflects back.

"Every molecule has a unique spectral signature," Senesac said. "For any particular molecule, there are some colors of light that it absorbs, some that it does not." So by illuminating a substance and analyzing the reflection, it is possible to determine what it is.

The Oak Ridge scientists use a small but powerful quantum cascade laser to illuminate suspected substances and collect the reflection with a mirror that focuses the returning light on a quartz crystal detector.

The laser light is pulsed at a rate of 32,000 times per second to match the mechanical resonant frequency of the quartz crystal detector. When the reflected laser light is focused on the detector, the pulses create a sound wave on the detector's surface, causing it to vibrate. The vibration creates a small electrical current.

When more light is reflected, the electrical current is stronger, and when more light is absorbed, the current is weaker. These fluctuations create a pattern that is then compared by computer to a database of reflection patterns in order to identify the substance.

As a bomb detector, this laser system can detect explosive residue on bomb casings, on suicide bombers' clothing or hands, and as vapor in the air, Senesac said.

To spot a roadside bomb like those being used in Iraq, soldiers would aim the bomb detector at the suspected bomb, and it would detect any explosive residue or vapors, he said.

Detecting Parts Per Billion

The technology is extraordinarily sensitive.

A "first-generation fingerprint" contains hundreds of times more explosive residue than is necessary for detection, Senesac said.

The molecules that make up explosives tend to be very sticky, so even tiny amounts will readily cling to hands, metal and clothing, Senesac said. As little as a millionth of a gram per square inch — an amount far less than the residue of a fingerprint — can be easily detected.

"If there is any explosive residue in the air or on the bomb, the technology will detect it," said Kale Franz, a founder of Primis Technologies, a small company started by Princeton University graduate students to turn quantum cascade lasers into useful products.

The quantum cascade laser's ability to detect minuscule amounts of substances — as little as parts per billion, Franz said — has made the laser of great interest to the military for a variety of purposes.

The ability to detect trace amounts of chemicals in gases could enable monitoring for suspicious activity. Detecting uranium hexafluoride in the air at a suspicious industrial site, for example, could indicate that uranium enrichment is under way.

Quantum cascade lasers also show promise for missile defense systems. The lasers' mid infrared wavelength is the same one heat-seeking missiles lock onto, Franz said. "By training the laser on a heat-seeking missile, we can blind it or steer it away from its target."

Compared with lasers used for that purpose today, quantum cascade lasers are more powerful and emit light in a narrower band, he said.

The lasers may also be good for laser radar and laser range-finding, Franz said.

That's because even when it is rainy or cloudy, the atmosphere is clear in the three-to-five and eight-to-12 micron bands — the ones used by quantum cascade lasers.

There are also compelling medical uses. The lasers' ability to detect minute traces of chemicals means they can be built into breath analyzers.

The human body naturally emits trace amounts of about 500 chemicals. Doctors know what levels are healthy, and with a detector to measure the amounts, they will know when something is wrong.

Today, that's done with blood tests that take hours or days to produce results. Breath analysis could be done instantly, Franz said.

Bell Laboratories invented the quantum cascade laser in 1994. Laboratory data on the laser says it also offers "numerous applications in the remote sensing of environmental gases and pollutants."

Gases and vapors "have characteristic chemical absorption 'fingerprints' unique to their chemicals structures," Bell said. "If a quantum-cascade laser is aimed above a smokestack, for example, the laser's wavelength can be tuned to match a 'fingerprint' wavelength in the air above the smokestack. Based on the fingerprint, it can then be determined if a certain pollutant is being emitted."

Bell said the lasers may also be used in detectors that guide vehicles during conditions of poor visibility, and for aircraft collision avoidance systems.

Primis Technologies says the lasers can be used in detection systems for biological and chemical weapons. They operate "with up to parts per trillion sensitivity," the company says. And "these detection systems will be compact, cost-efficient and operable by people with zero or minimal training."

"We've come a long way in the couple of years we've been working on this particular invention," Senesac said of the Oak Ridge explosives detector. But it may be two or three years more before a detector is ready to be sent to Iraq to search for roadside bombs and suicide bombers, he said.

"We still need to do more basic research," including fine-tuning the system for the more complicated task of identifying mixtures of chemicals, to detect smaller concentrations of substances, and to detect on a variety of surfaces, he said. ■

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