Tap Chi Tia Sang (Vietnam)
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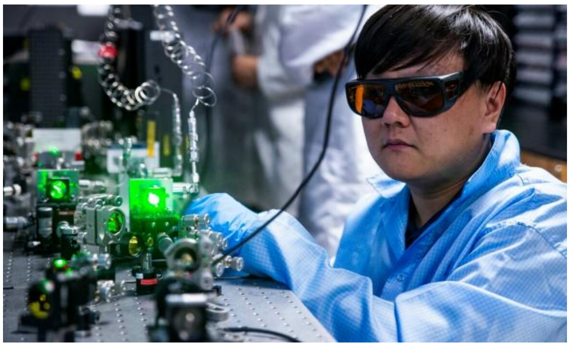
English translation

Detect harmful gases in a new way

A research team led by scientists at Nanyang Technological University, Singapore (NTU Singapore) has developed a new method of creating ultra-fast and high-intensity lasers that could promise integration in accurate instruments, increasing the level of detection of harmful gases.


Research fellow Deng Ang from NTU's School of Electrical and Electronics Engineering

Currently, lasers composed of invisible light in the mid-infrared range can determine within minutes what is in the air, whether it is greenhouse gas pollutants, toxic substances, or gases linked to diseases that are found in human breath.

Ultra-powerful versions of mid-infrared lasers produced by ultra-fast firing devices are important because they are the basis for ultra-sensitive devices capable of safely detecting magnetic fields. long distances, even when the compound is in very small amounts that many other devices cannot detect.

However, up to now, the ways to create lasers still have many disadvantages. A method that requires laboratory-like conditions to eliminate disturbances – such as vibrations and changes in temperature and humidity – that can lead to deviations that the instrument finely corrects for. international. That means the lasers cannot be used outside the laboratory.

Another method can generate laser beams while dealing with environmental influences such as vibrations, but their intensities are not strong enough to accurately detect minute amounts of compounds.

These challenges have been addressed by new research led by scientists at NTU Singapore.

The researchers used optical fibers made with hollow cores with adjustable thickness of the fiber architecture to create very bright lasers in the mid-infrared range of the electromagnetic spectrum. "Our method paves the way for developing portable, powerful and fast mid-infrared laser generators that don’t need well-controlled and vibration-free environments to work,” said Nanyang Assistant Professor Chang Wonkeun, from NTU’s School of Electrical and Electronic Engineering, who led the research.

“This means we can pair them with a detector and use them in the field to help test and identify a wide variety of unknown substances on the spot and at the same time, even in trace amounts, without spending extra time sending samples to labs for testing.”

This research has been published in the journal Laser & Photonics Reviews.

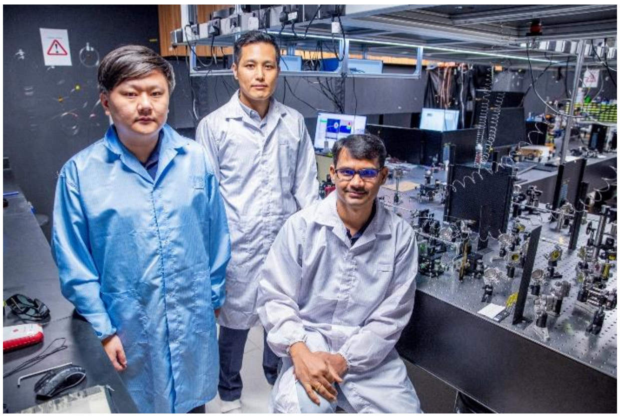
Hollow fibers

Mid-infrared lasers, with wavelengths of 2 to 20 micrometers, have outperformed other lasers in detecting compounds.

Many different types of molecules absorb lasers in the mid-infrared range in unique ways, more so than lasers at other wavelengths, and this characteristic can be used for identifying unknown compounds. Even if water is present in the compounds, the mid-infrared laser's accuracy in identifying the compounds is not affected by water molecules, unlike with other lasers.

A method of creating super-powerful mid-infrared lasers by shining super-fast and bright near-infrared radiation with shorter wavelengths through optical fibers.

Fibers with solid glass centers produce mid-infrared lasers that are often not very intense, making it difficult to accurately detect small amounts of compounds. To create high-intensity mid-infrared lasers, an interference-free environment is needed, which confines the use of the lasers. Assistant Professor Chang solved these problems by using hollow glass fibers. He discovered this while running computer simulations to determine the types of radiation that might be produced when near-infrared radiation passes through hollow fibers.



Unlike traditional optical fibers, a tube-shaped hollow fiber’s inner walls have a circle of small glass tubes arranged around the hollow center of the fiber. By changing the thickness of the fiber's mini tubes’ walls, Assistant Professor Chang's simulations showed that it was possible to convert a near-infrared laser into a high-intensity, ultra-fast mid-infrared laser.

His team then performed experiments with the centers of hollow fibers filled with argon gas, and the scientists were then able to confirm the simulations' predictions. They produced mid-infrared lasers with wavelengths of 3 to 4 micrometers with peak power in the megawatt range, a million times that of standard light bulbs.

This laser switching occurs because the near-infrared laser interacts with the fiber's shapes, energizing argon gas molecules and causing changes to the mid-infrared.

The thickness of the mini tubes closely corresponds to twice the wavelength of the mid-infrared laser being produced. So a mini tube with a wall thickness of 1.6 micrometers produces a laser with a peak wavelength of 3.7 micrometers.

Professor Sébastien Février from the University of Limoges, who studies mid-infrared lasers and was not involved in Chang's research, notes that the NTU group's laser generation method "is in striking contrast to the usual set-ups involving complicated non-linear arrangements".

"Furthermore, since fibers can be spliced to each together, these results pave the way towards generating mid-infrared lasers free from any moving mechanical parts."

Based on experimental data, the team's ultra-fast mid-infrared laser is 1,000 times more powerful than lasers produced by conventional methods using solid-core optical fibers.

These lasers could be many times more intense – potentially up to a million times – than the mid-infrared lasers currently used in handheld devices to detect toxic compounds. Due to the low intensity of their mid-infrared lasers, these handheld devices cannot detect compounds beyond a range of 100 meters.

"With a high-intensity laser, we can achieve high sensitivity and potentially use the laser in devices to safely detect even very small amounts of a substance that lasers or light produced from existing methods will have trouble with," Chang said.

The scientists' method of generating a mid-infrared laser with a wavelength of 3 to 4 micrometers has opened the way to developing more highly accurate sensors to detect pollutants in the environment and possibly for health monitoring.

Their lasers could be useful in identifying gases such as methane that absorb mid-infrared radiation in this range. And as methane found in patients' breath has been linked to colorectal cancer, this laser could open up a way to monitor patient health through breath analysis.

In the future, the scientists plan further research to create mid-infrared lasers with longer wavelengths that are even brighter.

Assistant Professor Chang believes that his method can, in theory, create a mid-infrared laser with a wavelength of up to 10 micrometers.

Such lasers can expand the range of compounds that can be detected, including chemicals such as formaldehyde that can leak in factory accidents, and toxic compounds such as TNT explosives which absorb mid-infrared radiation with wavelengths of about 6 to 8 micrometers respectively.

Professor Février said that if the wavelength spectrum of the generated laser could be extended to 10 micrometers, "among the various possibilities, it is clear that NTU team’s novel light source can be used to detect possibly hazardous compounds in the air”.

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