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English translation

Nanyang Technological University has developed a new method for producing ultra-powerful, ultra-fast lasers

Currently, lasers emitted in the mid-infrared range can determine what is in the air – whether it is a greenhouse gas pollutant, a toxic substance, an explosive substance, or a gas associated with diseases found in human breath – in a matter of minutes.

High-power mid-infrared lasers are in high demand in ultrafast pulses because they support highly sensitive devices that can safely detect even trace amounts of substances from a distance that would otherwise go unnoticed or are difficult to identify.

Recently, scientists led by Nanyang Technological University (NTU Singapore) in Singapore have developed a new method to produce high-intensity and ultrafast lasers. This approach, they said, "holds promise for making precise devices that can speed up how quickly trace amounts of pollutants and hazardous gases can be sniffed out."

However, the current conventional methods for generating such lasers have their own drawbacks: one of them requires laboratory conditions free of interferences (e.g., vibrations, temperature/humidity changes) that can misalign the finely calibrated equipment – meaning that the laser cannot be used outside of the lab.

Another method can generate a laser while responding to environmental disturbances such as vibrations, but it is not strong enough to accurately detect trace substances. New research from Nanyang Technological University has addressed these challenges.

The results were published in Laser & Photonics Reviews.

The researchers used a specially fabricated hollow fiber to produce a very bright laser light in the mid-infrared range by adjusting the thickness of the fiber's core structures.

Chang Wonkeun, an Assistant Professor at Nanyang Technological University's School of Electrical and Electronic Engineering, who led the latest study, said: "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."

"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."

Detection advantages

Mid-infrared lasers have a wavelength of 2um-20um, which has an advantage over other lasers in detecting substances. Many different types of molecules absorb laser light in the mid-infrared range in a unique way, more so than lasers at other wavelengths, a feature that can be used to identify unknown substances. In addition, even though water is present in these substances, unlike other lasers, the accuracy of identifying substances using mid-infrared lasers is not affected by water molecules.

One way to generate high-power mid-infrared lasers in a fast burst is to emit bright and ultrafast near-infrared radiation through optical fibers, which has a shorter wavelength. Fibers with solid glass centers typically produce less powerful mid-infrared lasers, which makes it difficult to accurately detect small amounts of substance.

In order to produce high-intensity mid-infrared lasers, a interference-free environment is often required, which limits the use of lasers to the laboratory and makes it difficult to achieve specific applications. Professor Chang of Nanyang Technological University solved these problems with hollow glass fiber. He discovered this when he used computer simulations to determine the type of radiation that near-infrared radiation might produce when it passed through hollow fibers.

Wavelength conversion

Unlike conventional fibers, this tubular hollow fiber has a ring of smaller glass tubes around the empty center of the fiber. Simulations show that by varying the wall thickness of the fiber minitubes, it is possible to convert near-infrared lasers into powerful, ultrafast mid-infrared lasers.

His team then conducted experiments in which argon gas was used to fill the center of the hollow core fibers, and the scientists were able to confirm the simulation's predictions. They have created mid-infrared lasers with peak power in the megawatt range and wavelengths of 3um-4um, which is a million times more powerful than standard light bulbs.

This laser conversion occurs because the near-infrared laser interacts with the shape of the optical fiber, which converts the laser into mid-infrared light by the excitation of argon molecules. The thickness of the minitubes is correlated to a slightly more than twice the wavelength of the mid-infrared laser produced – so, a minitube with a wall thickness of 1.6um produces a laser peak wavelength of about 3.7um.

Professor Sébastien Février (from the University of Limoges), who has been working on mid-infrared lasers for a long time, said the Nanyang Technological University team's approach to laser generation was "in striking contrast to the usual set-ups involving complicated non-linear arrangements".

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

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