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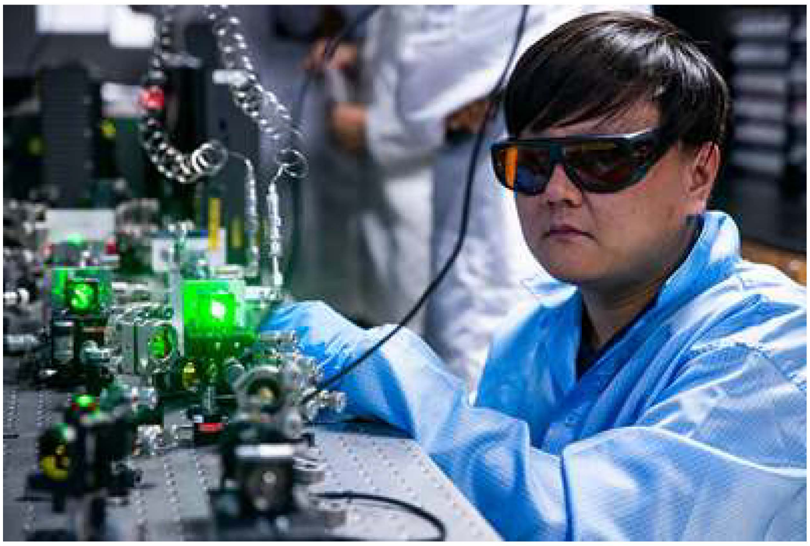
NTU Singapore develops new way to produce intense, ultrafast lasers

06 Nov 2023

Source is promising route to precise detectors of trace pollutants, hazardous gases.



Dr Deng Ang from NTU Singapore's School of Electrical & Electronic Engineering.

Scientists led by **Nanyang Technological University**, Singapore (NTU Singapore) have developed a novel method to produce intense and ultra-fast lasers, which they say "holds promise for making precise devices that can speed up how quickly trace amounts of pollutants and hazardous gases can be sniffed out".

Currently, lasers emitting in the mid-infrared range can be used to determine in minutes what is in the air, whether it be greenhouse gas pollutants, toxic substances, explosives, or gases linked to diseases found in a person's breath.

High-powered versions of the mid-infrared laser produced in ultra-fast spurts are in demand because they underpin highly sensitive devices that can safely detect, from a distance, even tiny amounts of a substance that would otherwise go unnoticed or prove tricky to identify.

However, the usual ways to generate such lasers have drawbacks, for now. One method requires laboratory conditions free from disturbances – like vibrations and even changes in temperature and humidity – that can misalign delicately calibrated equipment. This means the lasers cannot be used outside the lab.

Another method can produce the lasers while coping with environmental interferences such as vibrations, but their intensities are not strong enough to detect minute amounts of substances accurately. These challenges have been addressed with new research by NTUS.

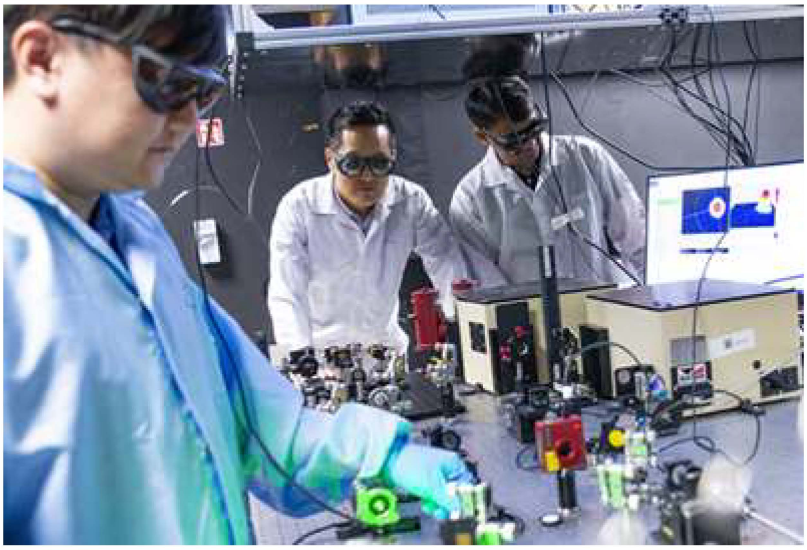
The achievement is described in **Laser & Photonics Reviews**.

The researchers used specially created optical fibers with hollow cores, tweaking the thickness of sub-structures in the fibers to produce very bright lasers in the mid-infrared range.

“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 & Electronic Engineering, who led the latest 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.”

Detection advantages

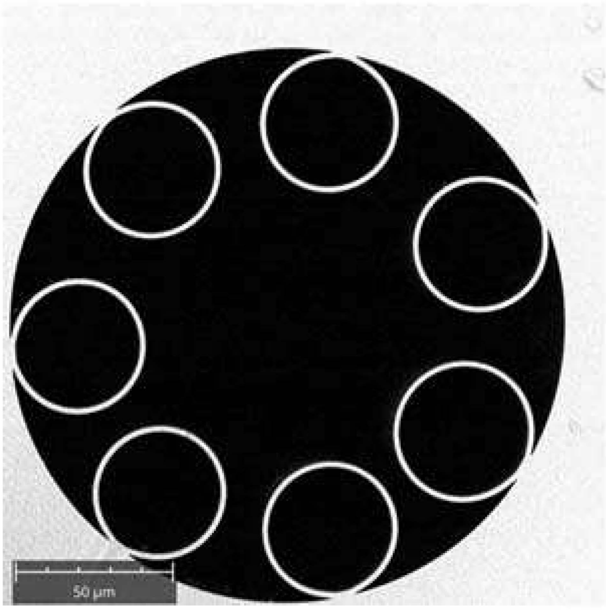


Dr. Deng Ang, Prof. Chang Wonkeun, and Dr. Trivikramarao Gavara.

Mid-infrared lasers, which have wavelengths of 2 µm – 20 µm, have advantages over other lasers in detecting substances. Many different types of molecules absorb lasers in the mid-infrared range in unique ways, more so than lasers in other wavelengths, and this feature can be used to identify unknown substances. Also, even if water is present in these substances, the accuracy of using mid-infrared lasers to identify the substances is not affected by the water molecules, unlike with other lasers.

One method to produce high-power mid-infrared lasers in rapid bursts is to shine bright and ultra-fast, near-infrared radiation, which has a shorter wavelength, through optical fibers. Fibers with solid glass centres produce mid-infrared lasers that are usually not powerful, which makes it difficult for small amounts of substances to be detected accurately.

To produce high intensity mid-infrared lasers, an environment free of interference is typically needed, which confines the use of the lasers to the lab. Asst. Prof. Chang resolved these issues using glass fibers with hollow cores. He discovered this when he ran computer simulations to determine the types of radiation that could be produced when near-infrared radiation was passed through hollow-core fibers.



Wavelength conversion

Unlike a traditional optical fiber, the tube-like hollow-core fiber’s inner wall has a ring of smaller glass tubes around the fiber’s empty center. By changing the wall thickness of the fiber’s mini tubes, Asst Prof Chang’s simulations showed that converting the near-infrared laser into a powerful, ultra-fast mid-infrared laser was possible.

His team later conducted experiments which filled the hollow-core fibers’ centres with argon gas, and the scientists were able to confirm the simulations’ predictions. They produced mid-infrared lasers with wavelengths of

SEM photo of cross-section of hollow-core fiber.

3 μm – 4 μm at peak power in the megawatt range, which is about a million times more powerful than a standard light bulb.

This laser conversion happens because the near-infrared laser interacts with the fiber's shape, energising the argon gas molecules and causing the laser to change to mid-infrared. The thickness of the mini tubes correlates to slightly more than two times the wavelength of the mid-infrared laser generated. So, a mini tube with a wall thickness of 1.6 μm results in a laser with a wavelength that peaks around 3.7 μm.

Professor Sébastien Février from the University of Limoges, who researches mid-infrared lasers and was not involved in Asst Prof Chang's study, said that the NTU team'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 other, these results pave the way towards generating mid-infrared lasers free from any moving mechanical parts," said Prof Février.