New maser in a 'shoebox' promises portable precision

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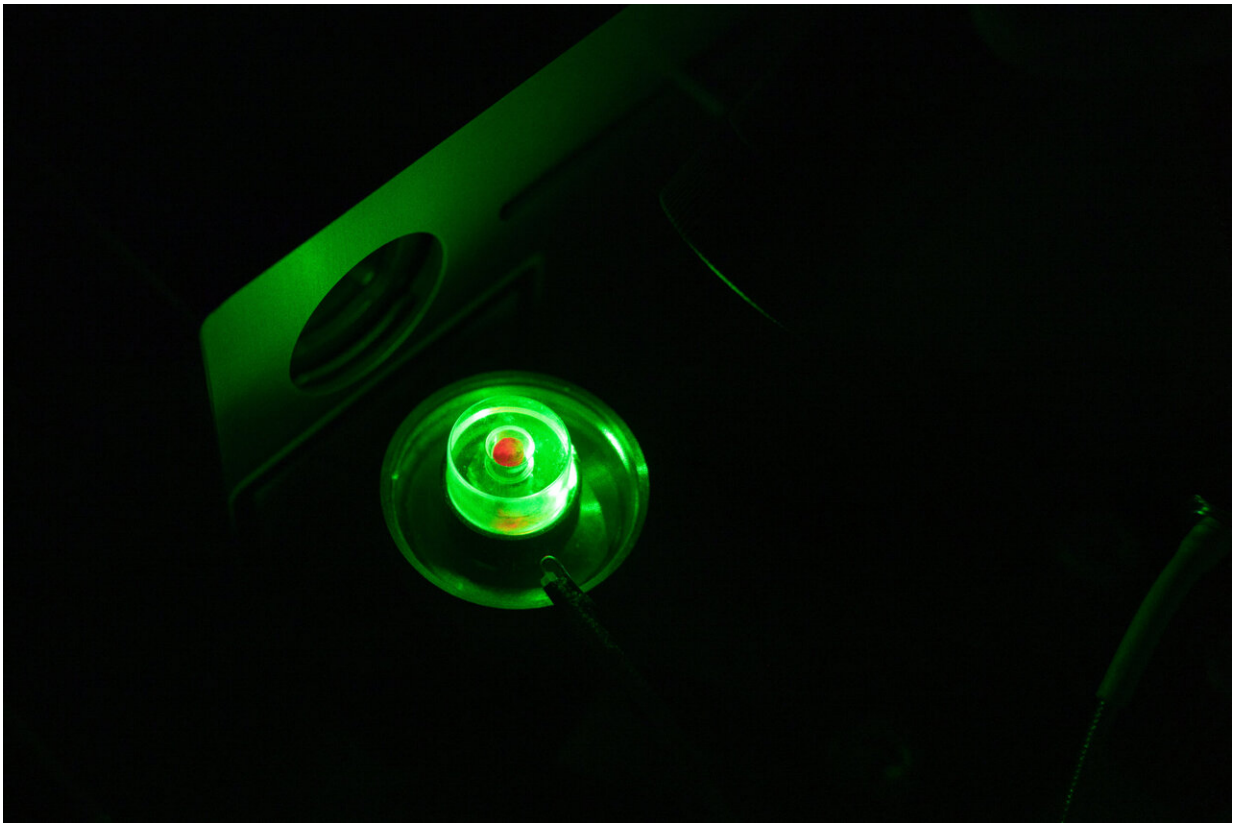

The new 'showbox' maser in operation. Credit: Thomas Angus

Researchers in Imperial College London's Department of Materials have developed a new portable maser that can fit the size of a shoebox.

Imperial College London pioneered the discovery of room-temperature solid-state masers in 2012, highlighting their ability to amplify extremely faint electrical signals and demonstrate high-frequency stability. This was a significant discovery because microwave signals can pass through the Earth's atmosphere more easily than other wavelengths of light. Additionally, microwaves have the capability to penetrate through the human body, a feat not achievable by lasers.

Masers have extensive applications in telecommunications systems—everything from mobile phone networks to satellite navigation systems. They also have a key role in advancing quantum computing and improving medical imaging techniques, like MRI machines. They are typically large, bulky, stationary equipment found only in research laboratories.

A new study has found a way to make masers significantly more compact and portable. The new device, weighing just a few kilograms and the size of a shoebox, can boost microwave signals at an affordable cost. It relies on a pentacene gain material, a chain of five benzene rings that can "mase" at room temperature.

Dr. Wern Ng, author of the paper published in *Applied Physics Letters*, stated, "Masers always needed very cold temperatures, and they usually needed vacuums, which made them very heavy.

"We have managed to shrink the maser to only 5 kilograms, with no cooling needed, no need for vacuum, and it is all solid state.

"What sets the portable maser apart from previous designs is that the shoebox maser is the first portable room-temperature maser, operating close to the quantum limit but small and light enough to be portable.

"Portability is key to encouraging more people to use this device. It

makes all the difference when someone can hold a device and easily flick a switch."

Developing the design

One of the team's biggest challenges was miniaturizing the pump source. While a room-temperature gain material eliminated the need for cooling, existing masers still had to use a large, high-energy pump.

Dr. Daan Arroo, another author on the paper, explains, "You have to think about what is absolutely essential when making a maser the size of a shoebox!

"To amplify microwaves, the pentacene molecules must be "pumped" using pulses of visible light that place them in an excited state. The energy of these pulses depends on the material properties of the organic crystal in which the pentacene molecules are found.

"Our biggest challenge was reducing the required pulse energy to a level low enough that a compact pulsed laser could pump the maser."

Masers of the future

While the shoebox maser is much smaller than the previous generation of pentacene masers, researchers aim to miniaturize the design further.

Dr. Arroo suggests, "It may be possible to replace the laser with a smaller LED-based light source if we can reduce the energy required for pumping the molecules.

"We are also considering how a diamond maser, which can also operate at room temperature, can be miniaturized to a portable form."

Diamond masers can operate continuously, as opposed to the pulsed operation of pentacene masers, which could lead to more applications if we can develop this type of maser.

Dr. Ng adds, "We have shown that we can successfully miniaturize the pentacene maser. The pentacene maser is extremely useful; however, it cannot offer a continuous beam—unlike diamond masers.

"Our next task is miniaturizing room temperature masers with different gain media such as diamond."

More information: Wern Ng et al, "Maser-in-a-shoebox": A portable plug-and-play maser device at room temperature and zero magnetic field, *Applied Physics Letters* (2024). DOI: 10.1063/5.0181318

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