teristics of a random laser are similar to those of a normal laser: the emission spectrum can be extremely narrow, which means that the colour of the emission is well defined, and the output can be pulsed[7–9]. But unlike a regular laser, a random laser will emit randomly in all directions, just like the emission from a common light bulb.

The tiny random laser built by Cao *et al.*[1,2] consists of disordered clusters of zinc oxide (ZnO) nanocrystals. After excitation by an external light source, these ZnO nanocrystals provide both the amplification and the random scattering needed for random laser action. They are also easy to make and extremely cheap: one ZnO cluster costs much less than 1 cent. In addition, the laser characteristics can be easily tuned by varying the geometry of the clusters. Each cluster will operate at its own specific wavelength, depending on its shape and size.

One might question how laser action occurs in a disordered material, given that it lacks a real cavity (Fig. 2). The answer is simple. The condition for lasing comes from a careful balance between gain and loss. The gain depends on how much time the light spends inside the amplifying material; the loss depends on how easily the light can escape. Lasing simply occurs when the gain becomes larger than the loss. For example, within a sphere of disordered amplifying material of radius a, the gain is proportional to its volume ($4\pi a^3/3$) and the loss is proportional to its surface area ($4\pi a^2$). This means that, upon increasing the volume, it is possible to reach a situation where the gain becomes larger than loss and the system starts to lase. The threshold volume does not necessarily have to be very big: in the case of random ZnO clusters it is only a few cubic micrometres.

Although random laser action in ZnO clusters can be explained by multiple scattering, the details are still vague. Apart from the trapping of light by multiple scattering, other processes can play a role. If the scattering is very strong, light waves can start to bounce randomly in closed loops and get trapped. This is the mechanism behind localization of light in a disordered medium[3,4], a peculiar phenomenon in which light transport comes to a complete stop. But the conditions for obtaining localization are very strict, and not likely to exist in ZnO clusters. More common is additional feedback from the surface of the sample. The outer surface of a cluster will reflect light back inside, which enhances the entrapment. Especially for micro-size systems, such as small clusters or films, feedback from the boundaries is expected to be an important factor. More theoretical and experimental work is needed to understand these random microlasers in detail.

Reducing the size of a laser source to a few micrometres opens up many possibilities. It allows, for instance, the integration of a laser within tiny optical devices. There is a growing effort to develop materials, called photonic crystals, that can guide and switch light waves in the way that electronic devices control electric currents. A random microlaser would play the crucial role of the active element or miniature light source in such crystals. But this is just one of many possible applications. On a different note, random microlasers can be used to monitor the flow of liquids by adding a small amount of ZnO clusters to the liquid and detecting the laser emission over large flow distances. Furthermore, its specific wavelength of operation, depending on shape and size, makes the miniature random laser suitable for encoded marking of documents or materials. The presence of a specific ZnO cluster could be detected by monitoring its particular laser emission, but would be invisible to the human eye. ■

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1. Cao, H., Xu, J. Y., Seelig, E. W. & Chang, R. P. H. *Appl. Phys. Lett.* **76,** 2997–2999 (2000).

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Figure 2 **Model of an amplifying disordered material used to build a 'random laser'. Green light is multiply scattered by the spheres and charges the system, thereby enabling the amplification process. The red light is both multiply scattered and amplified. The combination of multiple scattering and amplification leads to random laser action. Miniature random lasers can be used as sources in optical devices, such as wave-guides or all-optical switches. Their tiny size also makes them suitable for marking documents or materials in a hidden way.**

NATURE

100 YEARS AGO

Mr. E. G. Green, Government entomologist at the Botanic Gardens at Peradeniya, Ceylon, has recently been able to confirm by personal observation the web-spinning habits of the red ant (*Œcophila smaragdina*). He has seen ants actually holding larvæ in their mouths and utilising them as spinning machines. To find what would be done, some leaves which had been newly fastened together by ants were purposely separated by Mr. Green. The edges of the leaves were quickly drawn together by the ants, and, about an hour later, small white grubs were seen being passed backwards and forwards across the gaps made in the walls of the shelter. Each grub… was held in the jaws of one of the worker ants, and its movements directed as required. A continuous thread of silk proceeded from the mouth of the larva, and was used to repair the damage. There were no larvæ amongst the occupants of the disturbed inclosures, and the grubs used for spinning were apparently obtained from a nest a short distance away, which probably accounts for the considerable time that elapsed before the rent was repaired.

From *Nature* 12 July 1900.

50 YEARS AGO

The Royal Canadian Air Force, Engineering Division, has carried out investigations upon aircraft de-icing for some time past, and now considers that thermal de-icing, or actually anti-icing, appears to hold more promise than either the heated surface, mechanical pulsation, or chemical treatment hitherto employed. It has equipped a large four-engined Rolls-Royce Merlin-powered 'North Star' aircraft with the necessary apparatus for flying tests and observation, and intends to collect meteorological data upon cloud conditions… as well as to experiment upon the dispersal or prevention of ice accretions. The principal feature of the 'Ice Wagon' is a large 'shark's fin' on the top of the body. This will be fitted with the electro-thermal de-icing devices, and has blister-type observation domes on either side from which an operator can study and control the ice-shedding process during flight. The propellers are also fitted with similar electric blade heating… The general principle of the new technique is one of intermittent flow of current along wires installed at places where the ice that is forming is most readily dislodged. This is considered to be more efficient than continuous heating of a surface.

From *Nature* 15 July 1950.