# Not so random

Random lasers, as their name implies, are difficult to predict. *Nature Photonics* spoke to Diederik Wiersma at the European Laboratory for Nonlinear Spectroscopy in Florence, Italy, about taming their random nature.

**What is a random laser?**
That is not an easy question to answer because there has been a lot of confusion in the literature on the actual definition of a random laser. The two ingredients that are crucial are optical gain amplification and a disordered material that provides multiple scattering of light. As with most lasers, there is a threshold in the pumping power at which gain becomes larger than loss. For a laser to be random, it is essential that this threshold should be reached due to the multiple scattering process: if scattering does not play a key role then I would not call it a random laser. This definition is pretty broad and covers nearly everything that researchers have been working on in the past decade on random lasing.

**What types of materials can achieve this?**
The scattering can come from a powder or a suspension of particles. The particle diameter must be larger than, approximately, the wavelength of light; so from approximately 100 nm onwards the particles start to scatter light. In principle you can basically grind anything into a powder and it will suffice. In addition to suspensions, porous materials will also work: you can use a porous glass or porous semiconductor. The second element is the gain. For this you can take the same materials used in normal lasers: dyes, semiconductors such as gallium arsenide, or crystals such as those used in Ti:sapphire or Nd:YAG lasers. Crystals can be ground into a powder so that they provide both gain and scattering.

**What determines the lasing wavelength of a random laser?**
A normal powder scatters light at roughly the same efficiency over a very broad wavelength range; it scatters blue light with the same efficiency as red light, for example. The lasing wavelength is therefore determined not by the scattering but by the gain medium. A medium has a certain gain bandwidth, let's say going from 620 nm to 650 nm. The gain is most efficient at the centre of this band and hence this is where the random laser will lase: the emission simply follows the gain curve.

DIEDERIK WIERSMA

Diederik Wiersma's random lasers can be tuned to a desired wavelength simply by using small spheres of an appropriate size.

**You have now managed to control the emission wavelength. How did you achieve this?**
The multiple scattering process is a complex issue and has been a topic of research for years now even without the introduction of gain. If you have spheres that are monodisperse — that is, they all have the same diameter — you start to see some intriguing phenomena. One example is that the velocity of the light in the material can become extremely slow at certain resonant wavelengths — this is what is called the transport velocity of light. These resonances also present an interesting opportunity for random lasers. If you hit the right frequency, that is, when you achieve a resonance with the spheres, the efficiency of the random laser process becomes much higher, and it is much easier to bring the laser above threshold. In this way, the threshold becomes heavily dependent on the wavelength. So by selecting particles with a specific diameter, anywhere between 100 nm to several micrometres for example, it is possible to determine where the system will lase. The emission wavelength is then limited by the gain medium bandwidth, just as in a conventional laser.

**What applications do you foresee for random lasers?**
Random lasers emit light in many directions. This makes them useful in any situation where you want a light source with many of the properties of conventional lasers, such as a threshold, well defined colour and coherent emission, but without the monodirectionality. The most obvious application for this is display technology. Another one is remote sensing in hostile environments: a laser is used to excite the random laser, and binoculars are used to collect some of the fluorescence. The emission spectrum gives information about, for example, the temperature. A less obvious use is in the paper industry. By doping the paper with a gain material, the properties of the random laser can act as a form of encoding.

**What is the next step for random-laser technology?**
For many applications you really need to have electrical pumping. In 99% of cases at present, energy is supplied to a random laser optically using another laser or flash lamps. Of course, it undermines the point of having a random laser that is cheap and simple if you have to excite it with a laser that costs €100,000 ($150,000). We need a way of injecting an electrical current to bring the laser above threshold. Very recently, there have been some results on approaches to this, one in the terahertz and one in the near-infrared regime. You also have to deal with the fact that the material is random, which makes the transport of the electricity more complicated. This must be addressed if you really want to make a practical device, but the first steps have been taken and these show that it is not impossible.

*Interview by David Gevaux.*

*Diederik Wiersma and co-workers have a Letter on tunable random lasers on page 429 of this issue.*



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