

VIEW FROM... IEEE PHOTONICS SOCIETY ANNUAL MEETING

# Smaller is better

Miniature lasers with dimensions approaching the nanoscale could provide the ultimate integrated source of bright and coherent light if losses can be overcome and electrical pumping made efficient.

David Pile

Lasers are shrinking towards the wavelength of light and beyond. Several groups working in the field of small lasers showcased their latest progress at the 23rd Annual Meeting of the IEEE Photonics Society, which took place in Denver, Colorado, USA, on 7–11 November 2010. Topics at the meeting spanned from hybrid optical wireless systems to extreme high-power photonics, but it was the topic of small lasers that really packed the seminar rooms. The variety of approaches and goals is truly staggering; there are numerous resonator and waveguide types supporting bulk or surface-guided modes, endless material considerations and various modes of operation, including low or high temperature, optical or electrical injection, and pulsed or continuous wave.

Rupert Oulton from Imperial College in the UK works on the lasing of highly confined surface plasmon waves (light coupled to free-electron oscillations on the surface of a metal). He told *Nature Photonics* that plasmonic lasers can generate and focus light to dimensions much smaller than conventional lasers. In his talk, Oulton explained that small lasers may enable new, compact and low-energy laser devices capable of generating extremely high-intensity light by spatial compression of the optical mode. He also explained that another attraction of such systems is the ability of nanoscale light to interact strongly with matter.

“However, it’s the combination of these two features — the localization of light and strong interaction with matter — that points to potentially new capabilities in optics and photonics,” Oulton told *Nature Photonics*. “Achieving strong nonlinear optical effects within compact and ultimately scalable devices is something we haven’t been able to do yet. This would be essential for realizing large-scale schemes that switch light using light, and compact sensors based on Raman scattering, for example.”

In Oulton’s research, waveguide modes propagate down a cylindrical cadmium sulphide semiconductor nanowire situated



Hotly contested student awards being presented at the 23rd Annual Meeting of the IEEE Photonics Society in Denver, Colorado, USA.

5 nm from a flat metal substrate. Although the device must be at least 10  $\mu\text{m}$  long, the cross-sectional area of the propagating mode can be up to 100 times smaller than the area of a diffraction-limited spot in vacuum. According to Oulton, semiconductor materials are important for providing sufficient gain to compensate for the strong losses present in metals at optical frequencies. His team has managed to achieve room-temperature operation of plasmonic semiconductor lasers, and is now able to completely eliminate ‘bulk’ waves in a different laser structure using a slab instead of a cylinder.

“On the device side, it is important to strive for the smallest electrically injected lasers with the smallest possible mode sizes. This is where Martin Hill’s group is making significant progress,” Oulton explained.

Martin Hill from Eindhoven University of Technology in The Netherlands is developing metal–insulator–metal waveguide structures made by encapsulating a thin ridge etched in a heterostructure of InP/InGaAs. These devices, comprising a 90-nm-thick slab of InGaAs with  $\sim 15$  nm of SiN on either side and surrounded entirely by metal, are electrically pumped and designed for  $\sim 1,400$  nm light. The mode is not as tightly confined in the other dimensions, however, with a pillar height of  $\sim 1.2$   $\mu\text{m}$  (the optical field being confined to  $\sim 300$ – $400$  nm

in pillar centre) and a cavity length of 3  $\mu\text{m}$ . The team is aiming to increase the operating temperature of these electrically injected devices, as most proposals today rely on low temperatures.

“Smaller size means faster speed and lower power, perhaps providing new applications requiring arrays of subwavelength pitch emitters or high field intensity in a small region,” explained Hill. “Metallic and plasmonic devices have an advantage over photonic crystal structures owing to their smaller mode size (perhaps less than the diffraction limit) and overall small size resulting from tighter confinement. Forming part of the cavity from metal provides good heatsinking, while also offering good electrical connection for electrical pumping.”

Cun-Zheng Ning from Arizona State University in the USA is pushing for efficient electrical injection and high operating temperatures. “Nanoscale lasers may eventually allow many applications, such as computing and communications, sensing and detection, to be integrated onto a chip,” explained Ning. “This is why electrical injection is the ultimate goal — no one wants an integrated chip to be pumped by a giant external laser. The same goes for room-temperature operation.”

It seems clear that dielectric microcavities supporting the lasing of conventional bulk-guided modes will always have their place when factors such as high efficiency are concerned. However, incorporating metals to achieve highly confined modes seems to be one of the best options towards truly nanoscale lasers, despite the associated losses.  $\square$

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## Correction

In the Correspondence ‘Avoiding the blinding attack in QKD’ (*Nature Photon.* **4**, 800–801; 2010), the  $10^{-6}$  and  $10^{-3}$  units on the horizontal axis were incorrectly placed. The HTML and PDF versions are correct.