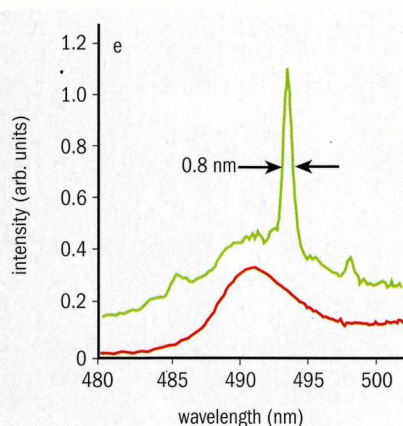
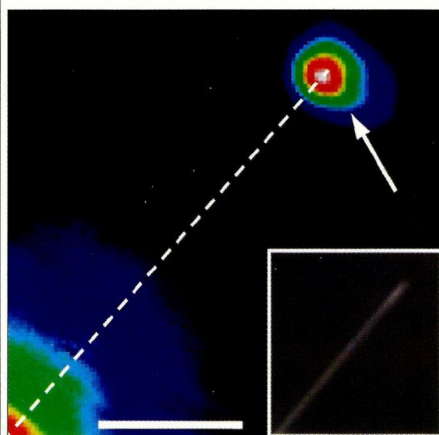


Edited by Archana Sharma

Nanolasers get compact

Qubits realize universal NOT logic



Left: a photoluminescence image of a cadmium sulphide nanowire excited by a laser (bottom left) shows its behaviour as an optical cavity, as light shines from its end (top right) 15 μm from the point of excitation. Inset: an image in white light illumination. Right: emission spectra (offset by 0.1 intensity units for clarity) recorded at 8 K for a cadmium sulphide nanowire laser at two different injection currents, 200 μA (red) and 280 μA (green).

Miniscule lasers that could be incorporated into silicon microchips have been created by researchers in the US. Charles Lieber and colleagues at Harvard University have fabricated single-wire lasers made of the semiconductor cadmium sulphide. These "nanowires", with a diameter of around only a hundred millionths of a millimetre, promise devices that could help make information technology faster and more compact.

Telecommunications and medicine already use semiconductor lasers routinely, but making the devices a thousand times smaller could give rise to a multitude of new applications. Such lasers are currently too big to fabricate on silicon microchips, but semiconductor nanowire lasers could solve this problem because of their small size. Various research groups have in the past made suitable nanowires – indeed, the first zinc oxide nanowire UV lasers were made in 2001. However, these require optical pumping to turn them on and off, using light from another laser; most applications require semiconduc-

tor lasers that can be driven electrically.

This critical electrical control has now been achieved by Lieber's group, using a cadmium sulphide nanowire assembled on a silicon surface, with a metal layer for an electrical contact on top. At a certain voltage, a current flows and blue-green light around 490 nm light emerges from the ends of the nanowire.

At a large enough injected current, the light is almost monochromatic – an essential characteristic of laser action. Other semiconductor materials, such as gallium nitride and indium phosphide, offer the possibility of providing laser light of different colours, in fact, spanning the optical spectrum from UV to IR wavelengths. There are still problems to solve, but the Harvard group believes that new applications, for example chemical or biological sensors, and microscopy and laser surgery, could be on the horizon.

Further reading

X Duang *et al.* 2003 Single-nanowire electrically driven lasers *Nature* **421** 241–245.

The electronic NOT gate changed the face of information processing. Though its direct quantum equivalent is impossible, the best possible approximation to the universal NOT transformation has now been demonstrated using photons. Quantum mechanics is radically different from classical physics, and quantum information processing differs from classical information processing. Two of the most elementary processes on a classical bit, b (equal to 0 or 1), are copying or cloning, and negation – in other words transforming b into $1 - b$. But these operations are impossible using quantum bits (qubits) that are a superposition of the basic quantum states $|0\rangle$ and $|1\rangle$.

Now, however, Francesco De Martini in Rome and colleagues have reported the first near-realization of the universal NOT transformation. The science of quantum information exploits quantum effects at the level of individual particles. Photon polarization was used for the qubits. For any input polarization, the NOT gate (as in conventional electronics) should transmit the opposite – in this case it should produce a photon in the orthogonal polarization state, for example going from vertical to horizontal polarization, or right circular to left circular. When the photon state is known, quantum NOT gates and cloning are possible, because the result of the transformation can be computed and the corresponding state engineered. But if nothing is known about the input state, this strategy is clearly impossible.

The universal NOT gate is an effort to develop quantum logic circuits and with the ambitious goal of building a quantum computer. However, quantum repeaters for quantum cryptography – the means to transmit decoding keys over large distances – will definitely use photons, and the necessary technology will involve these techniques.

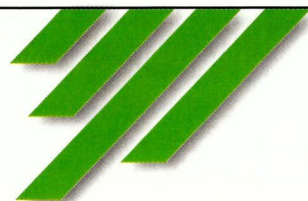
Further reading

F De Martini *et al.* 2002 *Nature* **419** 797–798.

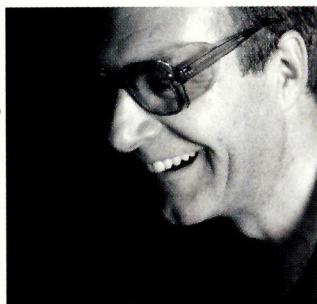


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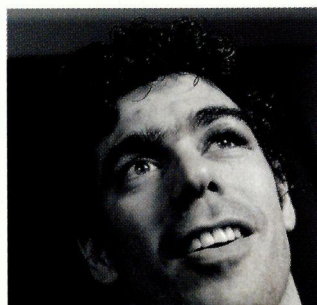
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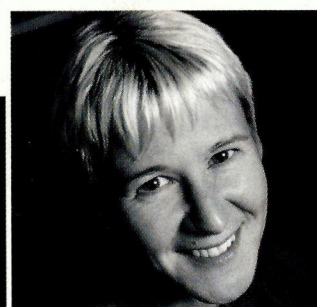
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