particles. Other methods, such as electroplating and chemical vapour deposition, are also prone to such drawbacks when the layers are only a few nanometres thick.

On the other hand, such nanogranularity might actually turn out to be advantageous for sensing applications that use metallic gratings and nanostructures. Techniques such as surface-enhanced Raman scattering, in particular, benefit from hot spots of large field enhancement that can form at locations where two nanoshells are brought close together[7,8].

Plasmonics has the potential to touch many different fields as diverse as physics, nano-optics, spectroscopy, sensing and biology. New technologies, such as the one presented by Eurenius and co-workers, which facilitate fabrication of subwavelength grating structures, could be key to future nanotechnological success.

References

1. Eurenius, L., Hägglund, C., Olsson, E., Kasemo, B. & Chakarov, D. *Nature Photon.* **2,** 360–364 (2008).
2. Barnes,W. L., Dereux, A. & Ebbesen, T. W. *Nature* **424,** 824–830 (2003).
3. Soukoulis, C. M., Linden, S. & Wegener, M. *Science* **315,** 47–49 (2007).
4. Shalaev, V. M. *Nature Photon.* **1,** 41–48 (2006).
5. Christ, A., Tikhodev, S. G., Gippius, N. A., Kuhl, J. & Giessen, H. *Phys. Rev. Lett.* **91,** 183901 (2003).
6. Willets, K. A. & van Duyne, R. P. *Ann. Rev. Phys. Chem.* **58,** 267–297 (2007).
7. Lal, S., Link, S. & Halas, N. J. *Nature Photon.* **1,** 641–648 (2007).
8. Lassiter, J. B. *et al. Nano Lett.* **8,** 1212–1218 (2008).

OPTICAL QUANTUM CIRCUITS

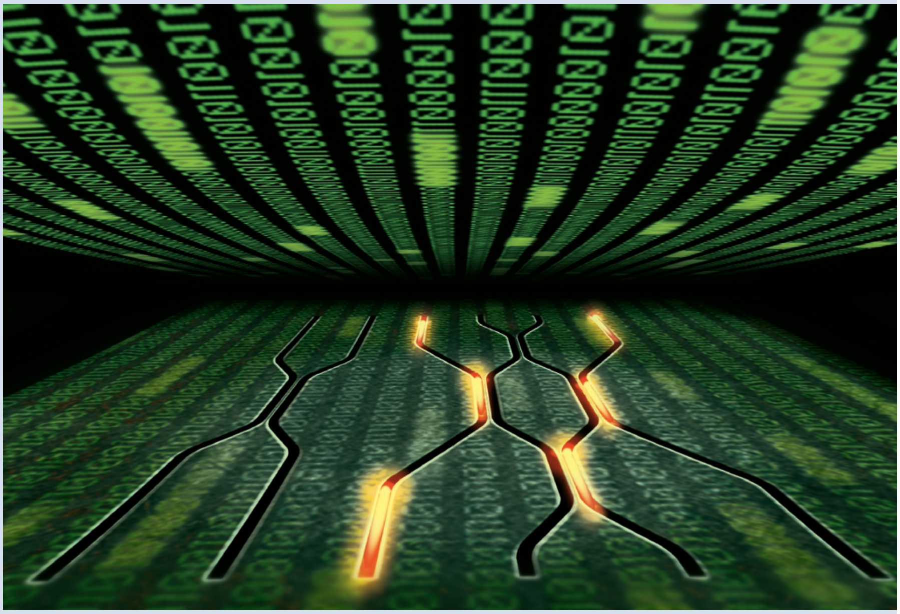
To the quantum level

Integrated optical circuits are seen as a long-term solution to the speed, size and heat bottlenecks that will probably limit the future development of electronic chips. What's more, the inherently quantum nature of photons presents the exciting possibility of on-chip technology that takes advantage of the strange and powerful phenomena of the quantum world. Alberto Politi and his co-workers at the University of Bristol have now shown that it is possible to create tiny optical quantum logic circuits using silicon-compatible materials (*Science* **320,** 646–649; 2008).

The beauty of silicon is not only its low cost, but also its compatibility with mass production. After 50 years of developing techniques for the production, processing and characterization of silicon electronics, it is now possible to fabricate almost any type of structure or device, cost effectively on a massive scale. As a result, it is unsurprising that optics researchers are keen to exploit the material.

Quantum information processing, where quantum bits of data (qubits) are stored in the polarization of individual photons, is a promising approach for making very small but powerful computers of the future. However, the development of the necessary chip-scale quantum logic circuits presents a great challenge for photonics.

To be feasible, the material used must be low loss at wavelengths where devices exist that can efficiently generate and detect single photons. Efficient single-photon detectors such as avalanche photodiodes, for example, work best at wavelengths around 800 nm. Silicon dioxide can meet both of these needs. By adding impurities — for example, phosphorous, boron or germanium — the optical properties of the silicon dioxide, such as its refractive index, can be adjusted.



The scientists from Bristol use silicon dioxide to fabricate a waveguide with a cross-sectional area of only 12 μm^2. This is small enough to ensure that only a single optical mode is supported and allows hundreds of devices to be fabricated on a single silicon '4″ wafer' (10-cm diameter).

An important element of a photonic quantum circuit is the beam splitter: separating and recombining optical modes to create the interference needed to observe quantum effects. Two waveguides can be used to make a beam splitter simply by arranging them so that they run close to one another; their separation determines how much light couples from one waveguide to the other. Being able to reproducibly construct such a beam splitter with known properties is of course vital to their successful implementation. Politi *et al.* were able to construct beam splitters where the fractional light coupling was within 3.4% of the desired value. To further demonstrate that these waveguides can really be used for quantum information applications, the scientists constructed and tested an important type of quantum logic gate known as a controlled-NOT (or CNOT) gate.

The realization of a complete quantum computer is still a long way off. However, the demonstration of quantum logic gates, which have previously required large optics tables and bulk optical components, on a single chip is another important step forward.

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