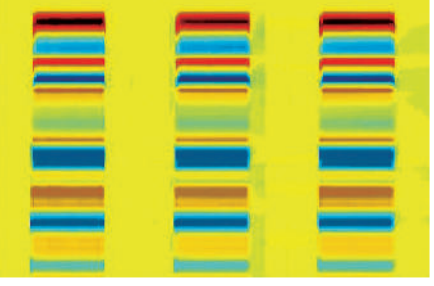
the opinion that nonlinear optics provides a solution.

In difference-frequency generation, light is created at a frequency equal to the difference in frequency of two rays meeting in a nonlinear optical medium. In the approach taken by Christian Erny and colleagues, an erbium-doped fibre laser and amplifiers create two beams of near-infrared laser light in a 2-mm thick slab of $MgO:LiNbO_3$. Their set-up is able to provide mid-infrared femtosecond pulses tunable from 3.2 μm to 4.8 μm, with an average power level of up to 1.07 mW at 3.6 μm; this corresponds to a maximum quantum-conversion efficiency of more than 30%. Owing to the use of the compact fibre laser, the generated ultrashort pulses are ideal for various applications, including infrared spectrometry. The researchers are confident that the tuning range could be extended to wavelengths of up to 12 μm, just by using a different nonlinear crystal.

PLASMONIC SENSORS

Plasmon litmus test



Nano Lett. **2,** 180–184 (2007)

Plasmonic technology has found a real home in chemical sensing. The interplay between light and electrons near the surface of a metal is strongly dependent on the refractive index at the interface — very small changes in the index cause changes in light transmission through the metal. But what if an analyte property other than refractive index — acidity for example — needs to be monitored? This is just what Nathan Mack and co-workers at the University of Illinois at Urbana-Champaign are studying. Their plasmonic detector is made by placing a layer of gold on a dimpled membrane. The key to detecting changes in pH level is a hydrogel thin film attached to the gold. The hydrogel expands and contracts depending on the pH level, in effect converting changes in acidity to changes in refractive index, which influence the plasmons. Mack *et al.* test a number of solutions with a pH between 1.44 and 7.86, and observe a substantial change in the optical transmission through the device. The technique is sensitive enough to detect changes as small as 0.1 pH units, with real potential for improvement. What's more, the transmission changes take place in the visible part of the spectrum, allowing direct imaging of the changes in the chemical properties.

SILICON MODULATORS

Powering down

Appl. Phys. Lett. **90,** 071105 (2007)

Researchers are fervently pushing to make silicon more light-friendly. A group of researchers based at the University of Texas have taken silicon modulators to new heights. Lanlan Gu and colleagues present a high-speed silicon modulator that can operate at low voltages — a factor that is crucial if modulators are to be successfully integrated onto single chips. Carrier injection is the only practical way of achieving optical modulation in silicon, and in order to reach useful gigahertz modulation speeds, a current density of at least 10^4 A cm^{-2} is required. The trick is to scale down the device dimensions so that this minimum current density can be obtained with a relatively small current. Gu *et al.* use a photonic-crystal waveguide: the slow group velocity of light along the guide means that the light interaction length within the device can be shrunk to 80 μm (two orders of magnitude smaller than that of conventional CMOS capacitors) and the device height to hundreds of nanometres. This compactness significantly reduces the voltage needed to achieve the desired current density to just 2 V. The result: a fast, low-powered modulator that could get even better with further miniaturization.

PHOTONIC CRYSTALS

Cavity tuning

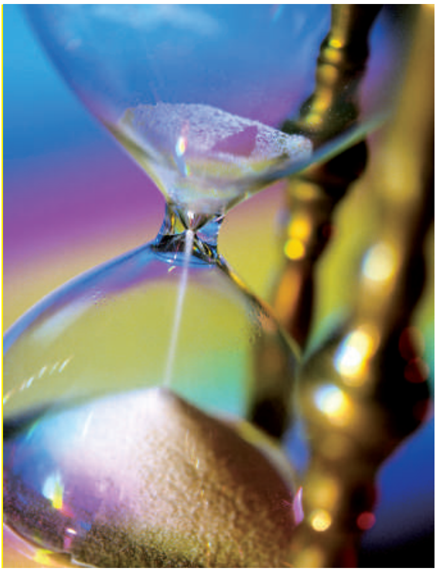
Appl. Phys. Lett. **90,** 091118 (2007)

In order to implement photonic-crystal devices as nonlinear switches in an optical network, it is important to be able to modify their cavity properties both rapidly and conveniently. Ilya Fushman and his co-workers have now shown that it is possible to optically tune the resonant wavelength of GaAs photonic-crystal cavities containing InAs quantum dots at speeds of up to 20 GHz using low-energy (60 fJ, 3 ps) optical pulses. The incident pulses blue shift the cavity resonance by means of free-carrier injection, which alters the refractive index of the cavity. Shifts of nearly one linewidth were observed.

The team's structure was fabricated by molecular beam epitaxy and consisted of a ten-period distributed Bragg reflector mirror made of alternating thin layers of AlAs and GaAs. Above this lies an active GaAs region containing an InGaAs–GaAs quantum-dot layer, which is capped with GaAs. As for applications for the tuning technique, the researchers say that in the future it could be used to control the elements of an optical or quantum on-chip network. Their ultimate goal is the demonstration of chip-based all-optical logic based on photon packets.

OPTICAL CLOCKS

Defining time



Phys. Rev. Lett. **98,** 083002 (2007)

Atomic clocks have transformed the way we measure time. Researchers from the National Institute of Standards and Technology in Colorado are helping to make our definition of the second increasingly accurate.

Atomic clocks operate by carefully probing atoms with electromagnetic waves of a certain frequency. When this frequency matches the spacing between two energy levels within a ground-state atom, we can obtain an accurate definition of the second, related to the frequency of the atomic transition. Optical-lattice clocks are particularly promising, because they involve large numbers of atoms and therefore offer increased clock stability. Martin Boyd and colleagues study in unprecedented detail the systematic uncertainties associated with a strontium-87 lattice clock. They cool 20,000 strontium atoms to 1.5 μK, load them into a lattice and use lasers to induce the atomic transition. They measure the overall systematic uncertainty on the transition frequency to be 9×10^{-16}, the first experimental demonstration of an inaccuracy below 10^{-15} — indicating that the technique can compete with the benchmark caesium-fountain clocks. Optical-lattice clocks could help to redefine the second. This work is a step along that path.