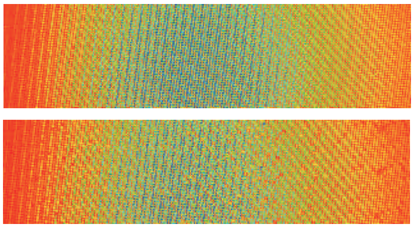
OPTICAL FREQUENCY COMBS

Frequency brush



Nature **445,** 627–629 (2007)

Extremely stable pulsed lasers can generate a long series of narrow spectral lines — a frequency comb — where the frequency of each line is known with a high degree of precision. For spectroscopic applications, normally only one or a few lines of the comb are used. In the approach now taken by Scott Diddams and his colleagues, more than 2,000 lines are used to create a distinct chemical fingerprint. Filtered emission from a Ti:sapphire laser, centred around a wavelength of 633 nm, is first passed through a so-called virtually imaged phased array. Light bounces around inside this component and interference causes the different frequencies to emerge at different angles in the vertical direction. This resulting beam is then directed towards a grating where diffraction separates the different frequencies in the horizontal direction. The result is the transformation of the spectral separation of the lines into spatial separation, resolving them in a two-dimensional grid, each point representing a different comb frequency. Diddams *et al.* demonstrate the potential for spectroscopy by inserting a chamber filled with iodine vapour into the path of the light, observing a change in intensity of certain pixels, a pattern that will probably be distinct for each chemical species.

METAMATERIALS

Into the red

Opt. Express **15,** 1076–1083 (2007)

If the losses associated with optical negative-refractive-index metamaterials are to be overcome, metal–dielectric composites with a negative effective permeability — a measure of how strongly a material responds to magnetic fields — could prove essential for further development. Researchers from Purdue University have now moved such metamaterials into the visible.

Although a negative refractive index can be achieved in a material with a positive permeability, such materials suffer from optical loss. Simulations have shown that pairs of thin silver strips separated by a dielectric spacer could offer an easy way of obtaining a negative magnetic response. With advances in the terahertz and infrared spectral ranges already demonstrated, Hsiao-Kuan Yuan and colleagues have experimentally implemented an approach that now moves this concept into the visible range, albeit at the red end. They fabricate an array of coupled silver nano-strips with a periodicity of about 300 nm. Two samples with slightly different geometries and different silver surface roughness are tested. The researchers observe negative permeability of −1 and −1.7 at the wavelengths of 770 nm and 725 nm respectively. The team expect to get a much stronger negative magnetic response once the imperfections in surface quality are minimized.

QUANTUM PHYSICS

All-knowing photon

Science **315,** 966–968 (2007)

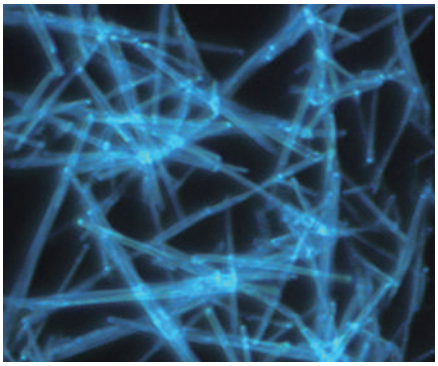
During the early development of quantum mechanics, the counter-intuitive nature of quantum mechanics was investigated through thought experiments. One such experiment has now been practically realized by a team of scientists in France. Wave-particle duality is an important aspect of quantum physics. Pass light into a beamsplitter and half leaves in one direction, half in another. These two beams can be recombined at a second beamsplitter where they interfere, a well-known property of waves. Repeat the experiment with a single photon, a particle of light, and the same result is observed — the photon travels along both paths at the same time and interferes with itself. However, if the two paths are not recombined, it makes sense that the photon must choose one. So what happens if the choice to use a recombining beamsplitter is only made after the photon has left the first splitter? In Vincent Jacques and colleagues' set-up, this choice is made by a quantum random-number generator and switching takes only 40 ns, much shorter than the 160 ns it takes the photon to travel along either of the two paths. The results bear out the current interpretation of quantum mechanics — the photon behaviour depends on the measurement, even if the photon doesn't 'know' what that measurement is going to be.

POLYMER PHOTONICS

A template for lasers

Nature Nano. **2,** 180–184 (2007)

For decades now, inorganic semiconductors, such as gallium arsenide, have been the first choice when it comes to compact, solid-state light sources. However, organic semiconductors are now rapidly catching up, and this progress is further highlighted by the first demonstration of lasing in single polymer nanowires. Fluoride-based conjugated polymers offer high-efficiency light sources at room temperature with the potential for chemical control of emission wavelength. Deirdre O'Carroll and co-workers at the Tyndall National Institute in Ireland and the Max Planck Institute for Polymer Research in Germany have created tiny cylinders of such a material. Using the pores in alumina films as a template, the wires are 150–400 nm in diameter and between 1 μm and 34 μm in length. The key for laser action are the ends of the nanowires, which are smooth enough to reflect light, confining the fluorescence within the cylinder and providing the optical feedback necessary for lasing. Exciting the nanowires with an external laser, the team observed many of the characteristics of a laser, most noticeably a narrowing of the emission spectrum, in this case between 450 nm and 460 nm. The results demonstrate that polymer nanostructures could emerge as a building block for future photonic devices.



MID-INFRARED SOURCES

Making a difference

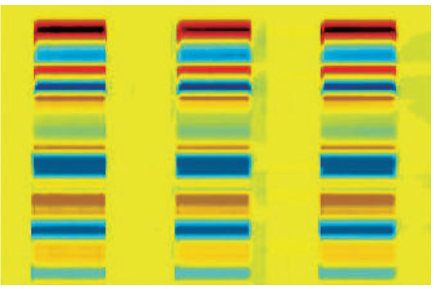
Opt. Lett. Doc. ID: 78938 (2007)

Despite the demand for ultrashort pulses of mid-infrared light (wavelengths between 2 μm and 10 μm) for various applications, a source that can directly obtain such emission is proving difficult to find. A team of researchers from Switzerland and Germany hold 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.