accessible by mains-operated cryocoolers and at which silicon electronics perform splendidly — and the authors expect to push this temperature even higher. The successful epitaxial growth on silicon suggests that the interface chemistry problems have been largely eliminated, and bodes well for integration with conventional electronics. That the material's conductivity is so readily controlled is even more enticing. It offers the possibility of impedance-matched diffusive spin-injection. However, Schmehl and colleagues' beautiful reflection high-energy electron diffraction data (published as supplementary information) that show layer-by-layer growth control suggest also the flexibility to grow a spin polarizer and associated tunnel barrier in a single operation, thereby greatly simplifying fabrication and eliminating interface incompatibility.

The work by Schmehl *et al.* has still wider implications. Developments in spintronics have so far concentrated on low-frequency devices. Despite the appearance of techniques that are capable of manipulating magnetism coherently on a femtosecond timescale, the advancement of high-speed spintronics — that is, in the microwave regime and above — has been neglected. The advent of new spin-asymmetric materials such as EuO could change all that. One possible new avenue is the application of spin control to transferred-electron phenomena to generate a 'spin-Gunn' effect by which spin-dependent negative resistance might be realizable. Such developments could open the way to microwave spintronic capability and hence to a new range of commercial opportunity. The material's huge Faraday rotation suggests it might also have future uses in high-speed spin-optics.

The limits to the merit of this new material will become more apparent as sample characterization proceeds: but it already seems certain that it will bring spintronics closer to the silicon world.

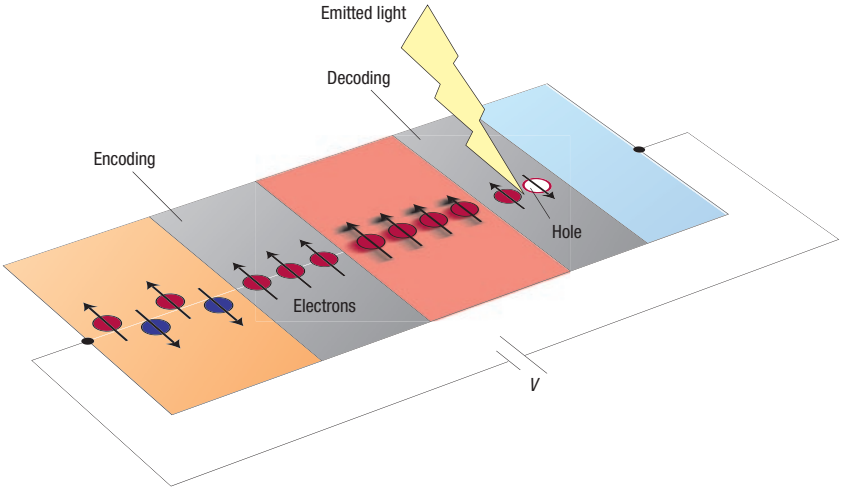

Figure 2 A typical spintronic device. The electrons injected into the electrode on the left are randomly spin-oriented. Their spin orientation is subsequently defined in the encoding region. These spin-polarized electrons then move towards the other electrode where the decoding takes place. In this particular case, decoding occurs through recombination with a positive carrier (hole) with consequent emission of light of either right- or left-handed circular polarization depending on the encoder orientation. A similar scheme is used, for example, in the spin LEDs[5]. The spin-coded information partially decays in transit between encoder and decoder on a mesoscopic lengthscale called the spin-diffusion length, whose magnitude is determined by the rate of spin-memory loss due to spin-flip processes.

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PHOTONICS

Photonic crystals go dynamic

Photonic crystal resonators present unique properties for confining light in volumes much smaller than the wavelength. The ultrafast dynamic change of these properties is an important step towards the complete control of light.

Jorge Bravo-Abad and Marin Soljačić

are in the Physics Department and the Research Laboratory of Electronics, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139, USA.

e-mail: jbravo@mit.edu; soljacic@mit.edu

Playing a guitar can illustrate a variety of different phenomena of wave physics. Imagine, for instance, plucking at one of the strings of the guitar, and while it is vibrating, sliding a finger along that string. By doing this, the frequency of the sound changes with the movement of the finger. Such a dynamic change in properties is a general phenomenon that can be observed in many different resonators. However, if the wave in question is light, the resonator is of micrometre scale and the time available is of the order of picoseconds, the task to induce significant changes in the resonator properties is quite a bit more challenging than plucking a guitar string. An important step in this direction has now been taken by Yoshinori Tanaka and colleagues, who report on page 862 of this issue the capability to dynamically change the lifetime of a photonic crystal resonator[1].

It can be said that such strong and ultrafast dynamic control of light is one of the main challenges of modern photonics. Its resolution could open new venues in some of the most exciting topics currently under investigation, such as optical quantum information processing or integrated optical devices. In terms of optical microresonators,

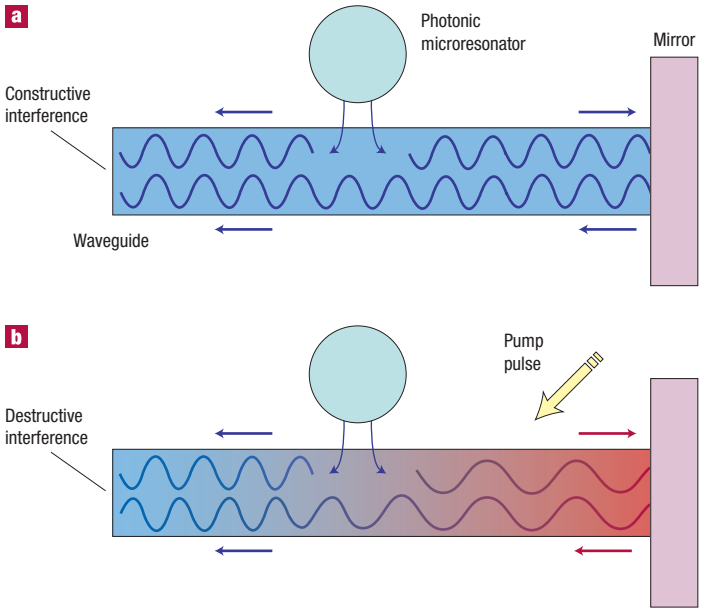

Figure 1 Working principle of the system. The structure consists of a photonic microresonator, a waveguide and a mirror. **a**, When the waveguide is not illuminated, the lightwaves reflect directly from the microresonator in the backward direction (to the left in the figure) and those reflected from the mirror interfere constructively, yielding a large coupling of the system to the external light. **b**, When another optical pulse irradiates the waveguide, it changes the properties of the waveguide in such a way that the two lightwaves interfere destructively, dramatically reducing the coupling to the external light and therefore trapping the light inside the system, for a significantly longer time than in the previous case.

the desired feature would be to change their properties at timescales shorter than the resonant lifetime. This would enable remarkable and novel phenomena including the stopping of light in all-dielectric structures[2], large frequency shifts in linear media[3], and so on.

One of the most illustrative descriptions of photonic crystals is that they are to light what semiconductors are to electrons. In particular, photonic crystals represent an environment where light is scattered periodically as it propagates inside them[4,5]. This results in unique properties, including negative refraction of light[6] and topics as diverse as the inhibition of light emission from a molecule located inside a photonic crystal[4]. But that is not the whole story. Photonic crystals with defects inside them are ideal systems to act as microscopic resonators for light, due to the photonic crystals' unique properties for light confinement[7]. Currently, these microresonators enable storage of light 2,000,000 times longer than the period of light, in volumes substantially smaller than the wavelength[8].

On a separate front, the rapid development of various experimental techniques has provided the possibility to dramatically slow and eventually stop the propagation of light. The first successful demonstrations of stopping light were based on the interaction of light with atomic resonances of gases[9,10]. However, such gaseous approaches are not suitable for on-chip implementation.

In contrast, dynamically controlled optical microresonators seem quite promising[2], and the work by Tanaka and co-workers represents a method of ultrafast control of the properties of a photonic crystal resonator. In essence, their resonator is a system that consists of three elements, namely, a photonic microresonator coupled to a waveguide whose properties can be externally controlled, and a mirror located at one of the ends of the waveguide (Fig. 1). To understand the behaviour of this system, it should be realized that the relevant timescale characterizing this structure is given by the typical time that a photon spends trapped inside the system. This is defined by the so-called quality factor of the structure — the *Q*-factor. This dimensionless quantity measures the number of time-periods of light after which most of the light energy has left the system. The higher the *Q*-factor, the stronger the confinement of light in the structure.

Now, if we could substantially increase the *Q*-factor of the system at a timescale comparable to the duration of the pulse we could first couple the light pulse into the structure, and then, through a fast increase of *Q*, trap the pulse inside the system. This is precisely what Tanaka *et al.* have achieved. To perform the ultrafast variation of the *Q*-factor, they use an additional optical pulse to irradiate the structure (the pump pulse) and to reduce, through its nonlinear optical response, the refractive index of the waveguide. In turn, this variation of the refractive index modifies the interference properties between the waves that are reflected directly from the microresonator, and those reflected from the mirror (Fig. 1). This interference can be constructive (Fig. 1a) or destructive (Fig. 1b), and thereby controls whether the system couples to the external light strongly or weakly, respectively. This makes it possible to induce a rapid change of the *Q*-factor.

Importantly, to implement this idea on the microscale, Tanaka and co-workers make good use of the unique properties of photonic crystals. The researchers' optical microresonator consists of a high-*Q* point defect in a two-dimensional periodic photonic crystal slab formed by a triangular array of air holes in silicon. The waveguide is built inside the photonic crystal just by removing one row of air holes. Finally, as a mirror, the authors use an interface between two photonic crystals with slightly different lattice constants. They demonstrate changes of *Q* by a factor of 4 (from 3,000 to 12,000) within picoseconds.

In future work, if the fabrication process could be well controlled, it might be possible to couple many consecutive nearly identical resonators with the same properties to form a waveguide[11] in which the speed of light could be controlled or even stopped[2]. Either way, it should be expected that, even as it stands now, this work, together with other related approaches[12], will represent an important contribution for adding optical microresonators as one of the main elements of the basic toolbox for the emerging field of strong and ultrafast dynamic control of light.

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