S. M. AWRAMIK

Figure 2 | Cutting through the complexities of stromatolites. Modern stromatolites — such as those shown here at Lee Stocking Island, Bahamas, as well as from places such as Shark Bay, Western Australia — provide essential comparisons for interpreting analogues from earlier in Earth's history.

of interspace areas: sediment in the interspace area has a vertical gradation in grain size, indicating the operation of mechanical processes, whereas grains in the laminae are not graded. Rather, these grains evidently accumulated on the steep slopes of the cones[8], suggesting that there was some mechanism for trapping and binding them, like that found in microbially influenced sediment accretion. Allwood *et al.*[2] also point out that there are no known abiotic processes that could produce the facies-related stromatolites persistently and sometimes simultaneously on the carbonate platform.

No mechanical processes have been identified that form coniform stromatolites[11]. But we do know of modern coniform stromatolites that are built by microorganisms. Growth experiments[12] on the microbes that build the modern cones indicate that the cone shape results from gliding by a photosynthetic filamentous microorganism (a cyanobacterium). Horizontally gliding filaments interfere with one another, form a clump, and other gliding filaments encounter the clump. These are deflected upwards towards the light and a cone results. Such structures could become fossilized by trapping and binding of sediment and/or by precipitation of mineral matter while the cones are growing. Coniform stromatolites make up about 44% of ten types of stromatolite recognized from 35 geological units ranging from 3.5 billion to 2.5 billion years in age[13].

Hydrothermal environments have been favoured as the most likely places where life existed on the early Earth[14]. But the setting for the stromatolites of the Strelley Pool Chert indicates that microorganisms were adapted to and thriving in shallow marine environments, and that it is not necessary to invoke the presence of hydrothermal activity. The same conclusion applies to the microbial mats from the 3,416-million-year-old Buck Reef Chert in South Africa[15].

So, microbial ecosystems evidently developed in environments that we know (carbonate platforms) and produced structures that we recognize (stromatolites; Fig. 2). Why do we have to demand evidence that is more absolute? The prudent use of well-understood ancient analogues and modern examples to interpret stromatolites is a powerful scientific tool[5]. Actualism has served palaeontology well.

The late American comedian Rodney Dangerfield[16] had a perpetual complaint: "I don't get no respect." The status of stromatolites as indicators of early life on Earth has suffered from a similar attitude. The work of Allwood *et al.*[2] will surely help to change that. ■

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PHOTONICS

Transparency on an optical chip

Robert W. Boyd and Daniel J. Gauthier

A two-laser trick that renders opaque media transparent can be achieved in systems of tiny optical resonators — with potentially profound consequences for optical communication and information processing.

The discovery of electromagnetically induced transparency (EIT) — an unusual effect that occurs when two laser beams interact within an optical material — and the use of novel techniques to fabricate ever smaller structures to control light have been recent exciting developments in optical physics. Writing in *Physical Review Letters*, Xu *et al.*[1] neatly combine the two, demonstrating an on-chip, all-optical analogue of EIT based on the response of coupled optical microresonators. The result may open up untrodden pathways in photonics, offering prospects of smaller, more efficient devices for the manipulation and transmission of light.

As originally implemented[2], EIT involves the interaction of laser light with a collection of atoms. It relies on the fact that when an incident photon has a 'resonant' energy equal to the difference in the energies of two levels of an atom, the photon can be absorbed by that atom and its energy used to excite the atom into the higher energy state. When two separate laser fields drive two such atomic transitions that share the same upper level (Fig. 1a, overleaf), destructive interference between the pathways connecting the upper level with the lower levels allows the quantum-mechanical probability that the atom is in the upper level to vanish. As there are no atoms in the upper level, there has been no absorption of the applied fields. The atom is thereby rendered 'transparent' to the applied laser fields in an extremely narrow frequency range (Fig. 1b). This interference process has analogies in classical physics, where the coupling between two oscillators results in a reduction in the amplitude of their oscillation[3].

The EIT phenomenon can be used to greatly strengthen nonlinear optical effects — such as the dependence of a material's refractive index on the intensity of the incident light — on which the operation of many photonic devices depend. In general, such nonlinear effects can be achieved by using as the source of the applied field a frequency-tunable laser tuned close to the resonance frequency of an atomic transition. Unfortunately, absorption of the laser light also increases at exactly these frequencies, and this effect undoes much of the benefit of working close to resonance. With two laser sources, however, quantum interference can be used to ensure that atomic absorption is eliminated, while retaining a large nonlinear response.

A downside of the 'traditional', atomic EIT effect — and more generally of nonlinear optics based on atomic resonance — is that it can be implemented only for light in a very small range of frequencies near fixed atomic transitions. An alternative way of achieving the transmission characteristics of EIT, as investigated by Xu and colleagues[1], uses small devices called optical microresonators[4] (Fig. 1c), whose resonance frequency depends on their physical size. In such devices, resonance frequencies occur

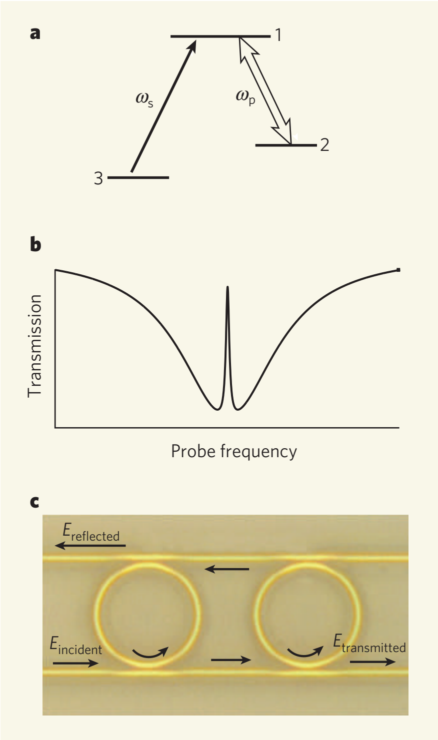

Figure 1 | Electromagnetically induced transparency. a, In conventional EIT in an atomic system, a strong pump field ω_p is tuned to an atomic energy transition (1–2) and creates a 'transparency window' for the signal field ω_s, which is tuned to a second transition (1–3). **b**, Destructive interference between the two absorption pathways results in a narrow spike of increased transmission within a wider absorption line. The refractive index of the material thus varies rapidly over a narrow frequency range, and the resulting increased dispersion can lead to ultraslow propagation of light. The narrow spike also provides a well-defined frequency marker for precision measurements. **c**, In a system of microresonators, studied by Xu *et al.*[1], EIT occurs because of destructive interference between two fields, leaving two appropriately spaced rings in the direction of the reflection port. The width of the absorption feature is determined by the overall loss of the ring resonator system (often dominated by coupling to the straight waveguide), whereas that of the transparency window is set by the internal loss of the ring resonators. (Part **c** adapted from ref. 1.)

whenever a whole number of wavelengths of the incident light fits into the resonator. Moreover, destructive interference occurs between light emerging from two coupled resonators.

Early microresonators were simply aerosols containing particles of varying sizes, but modern fabrication procedures produce individual resonators with highly controllable resonance frequencies[4]. These resonators come in various forms: ring shapes; disks or spheres, in which the light skims across the outer surface as sound does in a 'whispering gallery'; or less obvious forms, such as defects in an otherwise perfect photonic crystal. Their small size makes them ideally suited to perform operations on light analogous to those performed by components of silicon chips on electrons, and numerous applications have been proposed for them[5–7].

Several methods[5,8,9] for combining EIT and optical microresonators to obtain EIT-like resonances in integrated optical systems were proposed in 2004, and a laboratory demonstration of such an effect was published last year[10]. In that experiment, EIT-like transmission spectra were observed in two interacting microresonators in the form of glass spheres approximately 400 micrometres in diameter that supported resonances of the whispering-gallery type.

Xu *et al.*[1] take this advance a stage further. Using modern nanofabrication procedures, they manufactured a pair of micro-ring resonators coupled to parallel waveguides on a silicon-on-insulator substrate typical of an electronic chip. The refractive index of the silicon that made up the waveguides and the rings (3.45) was significantly greater than that of the silicon oxide that surrounded them on all sides (1.46). This meant that light could be confined in rings of a very small diameter through the process known as total internal reflection. EIT-like behaviour was demonstrated by measuring the transmission at different frequencies of a laser beam injected into the system. The authors constructed several such devices, where the distance between the micro-rings was varied from device to device, and thus the spectral location of the EIT-like transmission peak could be adjusted.

So what good is all this? As the name indicates, EIT is primarily a way of rendering transparent an otherwise highly absorbing material, and so lends itself to applications such as the construction of long-distance optical transmission lines. The dispersion characteristic that results from EIT has already allowed 'slow light' propagation to be achieved[11–13] at speeds just a small fraction of the normal speed of light. Optical 'buffers' to temporarily store light are an obvious application of such slow-light technology.

Perhaps most importantly, EIT resonances can be much narrower than those of individual resonators, whether these are atoms or microresonators. As a resonance frequency can typically be measured only to an accuracy given by some fixed fraction of the resonance linewidth, narrowed linewidths could be useful for performing precise optical measurements of quantities such as magnetic field strength[14]. The ability to synthesize such components on an optical chip suggested by Xu and colleagues' innovation[1] is a crucial step towards the development of such integrated optical devices. ■

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NEUROBIOLOGY

Extending influence

Eve Marder

Rather than merely firing in a digital on–off fashion, vertebrate neurons may have an analogue aspect to their signalling too — a finding that will not surprise many who have worked on invertebrate neurons.

Much of what we know about electrical signalling in the brain comes from extracellular recordings that detect when a neuron is firing action potentials. These recordings do not, however, provide continuous monitoring of the fluctuations of membrane potential, and do not capture sub-threshold changes in membrane potential such as those caused by individual synaptic events. The prevalence of extracellular recordings in the literature has contributed to a collective consciousness in which the action potential or 'spike' is viewed as an invariant, all-or-nothing stereotyped event that occurs once a threshold membrane potential is reached. This 'digital' signal carries information from the neuronal cell body, the soma, down the axon to presynaptic terminals, where it evokes the release of neurotransmitter