Argonaute proteins in plants and animals. It will be interesting to know whether plant and animal Argonaute proteins promote nucleation of all of the guide strand's nucleotides with the RNA target to increase binding and silencing specificity, or whether they nucleate only up to position 16, like bacterial Argonaute. Another question is whether interaction between animal microRNA (a type of small RNA encoded in the genome that is used as a guide strand) and target mRNA can be accommodated by the Argonaute protein, because microRNA typically binds imprecisely to target mRNA and forms an imperfectly paired RNA double helix. Comparing the structural features of Argonaute proteins from different organisms will help us to further understand their functions within the RNA silencing pathways and might even uncover new roles for this versatile protein family. ■

Samir Bouasker and Martin J. Simard are at the Laval University Cancer Research Centre, Hôtel-Dieu de Québec, Quebec City, Quebec G1R 2J6, Canada.
e-mail: martin.simard@crhdq.ulaval.ca

1. Hutvagner, G. & Simard, M. J. *Nature Rev. Mol. Cell Biol.* **9,** 22–32 (2008).
2. Wang, Y. *et al. Nature* **461,** 754–761 (2009).
3. Song, J.-J., Smith, S. K., Hannon, G. J. & Joshua-Tor, L. *Science* **305,** 1434–1437 (2004).
4. Yuan, Y.-R. *et al. Mol. Cell* **19,** 405–419 (2005).
5. Ma, J.-B. *et al. Nature* **434,** 666–670 (2005).
6. Wang, Y. *et al. Nature* **456,** 209–213 (2008).
7. Wang, Y. *et al. Nature* **456,** 921–926 (2008).

PHOTONICS

One-way road for light

Eli Yablonovitch

The transmission of information from one place to another by light waves sent through waveguides is hampered by light attenuation and scattering loss. Magnetic photonic crystals could provide a solution to such problems.

The concept of photonic crystals — periodically arranged structures specifically engineered to trap and guide light — grew from an initial analogy[1–3] with the electronic band structure of semiconductors. In these materials, no electrons can be found that have energies within a range known as the 'band gap'. Similarly, in photonic crystals, photons whose frequencies fall within the 'photonic band gap' are prevented from flowing inside the material.

Haldane and Raghu[4] have recently extended the equivalence between the behaviour of photons in photonic crystals and that of electrons in electronic systems. They have predicted the photonic analogue of the 'edge' states that characterize the quantum Hall effect[5] that is experienced by the electrons of a two-dimensional (2D) electron gas when it is subjected to a strong magnetic field. Under certain conditions, photons can be confined to the edges of a 2D photonic crystal — one whose lattice structure has 2D periodicity — and be restricted to unidirectional propagation. On page 772 of this issue, Wang *et al.*[6] report observing such photonic edge states in a magneto-optical 2D photonic crystal, verifying Haldane and Raghu's theoretical prediction[4].

To achieve unidirectional photonic edge states requires a system that lacks time-reversal symmetry — that is, one with physical properties that are not preserved by a time-reversal transformation. To realize such a 'non-reciprocal' system, Wang and colleagues[6] used a photonic crystal consisting of a 2D-periodic arrangement of magneto-optical ferrite rods; the magneto-optical nature of the rods confers the desired time-reversal asymmetry on the system. After characterizing the system's band gap, the authors demonstrated the unidirectional character of the system's edge states: forward-propagating transmission outweighed backward-propagating transmission by almost 50 decibels.

Wang and colleagues' experimental demonstration[6] of the correspondence between the optics of a photonic crystal and the elegant physics of the quantum Hall effect is not only a delight for fundamental science, it also opens the door to practical applications based on non-reciprocal photonic crystals. These crystals may provide the means to develop a new type of optical-fibre waveguide that would be utterly immune to energy loss caused by scattering from material defects or obstacles.

Photonic-crystal fibres[7], a form of optical fibre based on 2D photonic crystals, have been very successful in providing unique functions[8] in fibre-optic communications. The most interesting type of photonic-crystal fibre has a hollow core in which light is confined by a surrounding cladding that consists of either a 2D-periodic photonic crystal or concentric 'Bragg rings'[9]. Because their cores are hollow rather than being filled with a material substance, light channelling through them suffers less absorption loss, enabling low-loss propagation over long distances. Indeed, it has been shown[10] that photonic-crystal fibres can achieve very low loss. But they are not quite as lossless as one would hope owing to scattering caused by the intrinsic roughness of their internal (glass) cladding surfaces[10]: the lowest reported loss is still about a factor of ten larger than that of their best conventional counterparts. In transoceanic optical-fibre systems, underwater amplifiers must be placed approximately every 100 kilometres to compensate for loss.

One of the distinctive properties of 3D-periodic photonic crystals is that light is confined in all directions. As a consequence, and unlike in ordinary fibres or 2D-periodic photonic-crystal fibres, light travelling through hollow waveguides carved out of 3D-periodic photonic crystals is not subject to scattering loss. This increases the possibility of attaining ultra-low-loss light propagation, with both absorption and scattering losses suppressed. However, it does not prevent back scattering. Light can propagate both forwards and backwards within the same hollow waveguide, and back scattering off an obstacle within the waveguide can reduce forward transmission, and so be a source of loss even in a 3D-periodic photonic crystal.

Haldane and Raghu's theoretical ideas[4], together with the experiments of Wang *et al.*[6], now offer a solution to the back-scattering problem. By using a magneto-optical, photonic-crystal system that breaks time-reversal symmetry, Wang and colleagues show that it is possible to design the material's dispersion relationship, which describes the way in which wave propagation varies with frequency, such that, for a given frequency band, only forward-propagating waves exist. The ferrites the authors[6] used operate at microwave, rather than optical, frequencies. Nonetheless, there are several other magneto-optical materials that are used in the optical regime.

To sum up, the ideal optical waveguide would be made of a low-loss hollow core, with a layer of non-reciprocal material, surrounded by a 3D-periodic photonic crystal, providing immunity to both back scattering and surface-roughness scattering. With such a low-loss waveguide, the possibility would then exist for one-hop transoceanic communication across 10,000 kilometres — about the distance from San Francisco to Tokyo — without the current requirement for electronic repeaters or amplifiers. ■

Eli Yablonovitch is in the Electrical Engineering and Computer Sciences Department, University of California, Berkeley, California 94720-1770, USA.
e-mail: eliy@eecs.berkeley.edu

1. Yablonovitch, E. *J. Opt. Soc. Am. B* **10,** 283–295 (1993).
2. John, S. *Phys. Rev. Lett.* **58,** 2486–2489 (1987).
3. Yablonovitch, E. *Phys. Rev. Lett.* **58,** 2059–2062 (1987).
4. Haldane, F. D. M. & Raghu, S. *Phys. Rev. Lett.* **100,** 013904 (2008).
5. von Klitzing, K., Dorda, G. & Pepper, M. *Phys. Rev. Lett.* **45,** 494–497 (1980).
6. Wang, Z., Chong, Y., Joannopoulos, J. D. & Soljačić, M. *Nature* **461,** 772–775 (2009).
7. Russell, P. St J. *J. Lightwave Tech.* **24,** 4729–4749 (2006).
8. www.nktphotonics.com
9. Yeh, P., Yariv, A. & Marom, E. *J. Opt. Soc. Am.* **68,** 1196–1201 (1978).
10. Roberts, P. *et al. Opt. Express* **13,** 236–244 (2005).