Bending the rules

The abstract mathematics of topology is generating excitement in photonics.

A new way of thinking about photonics driven by topology — the 'rubber sheet' mathematics that describes the equivalence and conservation laws of spaces as they are stretched, squashed and deformed — is rewriting the rules of photonic circuit design. It's also generating great excitement in the process.

Research is being inspired by the discovery of topological insulators — materials that are electrically insulating in their interior but conductive at the surface. These curious materials were first discovered in the 1980s, in the form of the quantum Hall effect, but their topological origins have only been generalized to investigate new topological materials in the past few years. Indeed, so profound are the effects that many tipped the discovery of such topological phenomena as a probable candidate for this year's Nobel Prize in Physics (see Editorial below).

Since their discovery, researchers have realized that analogous 'edge states' for transporting light can also be formed in carefully designed periodic media like photonic crystals, metamaterials and coupled resonators. The behaviour of such states is dictated by the rules of topology and concepts of topological invariance and topological phase transitions. When applied to the frequency bands of periodic optical structures, these rules can yield a host of enticing and unique properties that are 'topologically protected'. For instance, such edge states are predicted to be intrinsically unidirectional and immune to backscatter. They also naturally circumnavigate and flow around imperfections that lie in their path.

Ultimately this may lead to more robust photonic waveguides that are lower-loss, more tolerant of fabrication defects, self-routing and free from troublesome reflections. It would also lead to a new way of realizing optical isolators. Now the challenge is to realize suitable materials that have the correct characteristics for practical operation at optical wavelengths.

According to Ling Lu and Marin Soljačić at the Massachusetts Institute of Technology, in the USA, who have a Review Article on topological photonics on page 821 of this issue, "the field has exploded in the past two years" and is growing exponentially. "Every month there are new papers in photonics related to topology appearing on arXiv," remarks Lu. "We're just at the tip of an iceberg in terms of new physics."

Soljačić also makes the point that as topological effects apply to many types of classical or quantum waves, many of the concepts are being transferred to surface plasmons, excitons, exciton-polaritons, phonons and magnons, inspiring many opportunities for further research. Exciting times indeed. ❐

Photonics dominates Nobel Prizes

Awards for blue LEDs and super-resolution microscopy announced.

Optical scientists around the world are celebrating the news that this year's Nobel Prizes for both physics and chemistry have been awarded to important developments in photonics. On 7 October it was announced that the 2014 Nobel Prize in Physics had been awarded to three Japanese scientists — Isamu Akasaki, Hiroshi Amano and Shuji Nakamura — for the invention of efficient blue LEDs based on gallium nitride (GaN), which underpin bright and energy-saving white light sources. Then, just a day later, the news broke that Eric Betzig, Stefan Hell and William Moerner were to share the 2014 Nobel Prize in Chemistry for the development of super-resolved fluorescence microscopy and single-molecule microscopy — techniques that successfully overcome the Abbe diffraction limit.

The physics award celebrates the pioneering work on GaN blue LED fabrication that was conducted independently in the late 1980s and early 1990s by Akasaki and Amano at Nagoya University and by Nakamura at the Japanese chemical company Nichia. Both groups were trying to find ways of fabricating a high-quality doped GaN material suitable for the formation of a light-emitting p–n junction. Their achievements in this area ultimately led to the successful commercialization of high-performance blue LEDs, which, when combined with suitable phosphors, yield the white LEDs that are now leading a revolution in energy efficient lighting. The work also paved the way for the development of the blue semiconductor laser, commonly used in Blu-ray high-capacity optical disk data storage, and ultraviolet LEDs and lasers that are useful as light sources for sterilization, adhesive curing and biomedical applications.

The chemistry award recognizes the transition of microscopy to nanoscopy (microscopy with nanometre-scale spatial resolution). This makes it possible to use visible light to observe chemical and biological processes on an unprecedented scale and perform single-molecule microscopy. The key to the advance was learning how to control fluorescence so that its origin can be determined in a more precise manner. Betzig and Moerner both contributed to the development of temporal schemes that switch fluorescence on and off in different locations to make this possible. In contrast, Hell developed a scheme that uses a special ring-shaped laser beam to quench or extinguish fluorescence everywhere except for a very small inner region.

We wish to heartily congratulate the prize winners. In-depth coverage of both awards will be appearing in our next issue. ❐