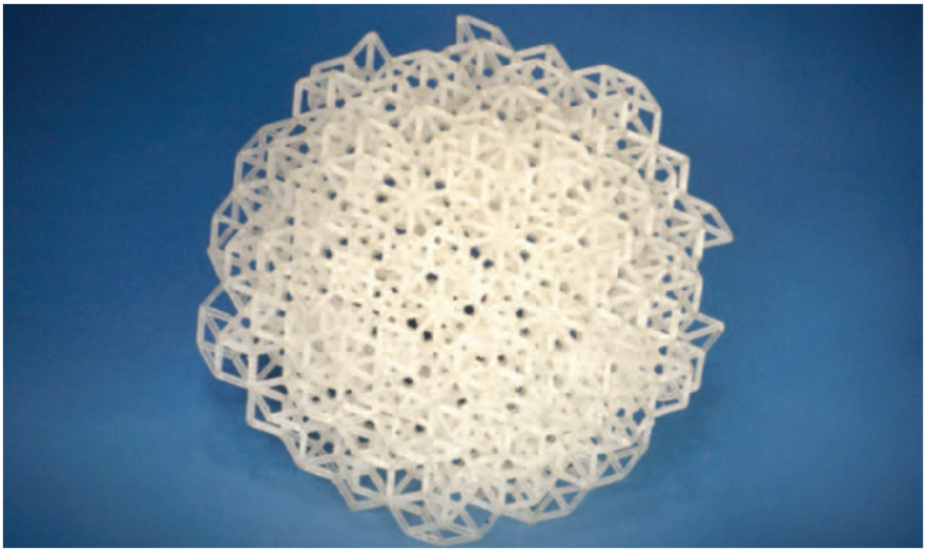
Disordered times

Two Nobel Prizes, as well as a growing number of papers and potential applications, suggest that research into disorder and aperiodicity is an increasingly popular undertaking that could offer a wealth of important applications.



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Spatial order and periodicity are often considered to be essential attributes in photonics, as many optical phenomena are attributable to these traits. Indeed, researchers strive to optimize regularity and eliminate disorder in many applications — just think of the careful arrangement of atoms in a crystal lattice, or the pitch of a photonic crystal or distributed Bragg reflector. In such cases, a higher achieved level of order (in principle) improves the performance of the device. Good control over order and periodicity therefore makes it possible to manipulate the phase and flow of coherent light in a powerful and reproducible fashion. As a result, it's probably no surprise that for many years disorder and scattering were considered annoying and detrimental features that were best avoided or minimized.

However, in recent years the study of disorder and aperiodicity has become an increasingly active topic of research, with scientists learning how to harness optical media that are not intrinsically regular and can be strong random scatterers of light. In this issue, *Nature Photonics* celebrates this fact by bringing together a collection of commissioned articles that discuss some of the most intriguing, useful and latest findings in the field and provide opinions on what the future has in store.

On page 188, Diederik Wiersma from the Laboratory for Nonlinear Optics and Spectroscopy in Florence, Italy, provides a general overview of disordered photonics, explains why research in this field is exciting, and highlights some of the potential benefits it may bring. Perhaps the most obvious example here is the desire to image and focus light through scattering media, such as biological tissue. Achieving this immensely difficult task will have enormous consequences for medical imaging, optogenetics and the delivery of light for therapeutic purposes such as photodynamic therapy.

In an Interview on page 164, Hui Cao from Yale University in the USA discusses the field of random lasers — light sources that do away with the usual discrete mirrors of a precisely defined cavity and instead rely on gain and scatter in a disordered material to achieve the necessary feedback and amplification for lasing. Over the years, a wide variety of different techniques have been used to create random lasers, ranging from grinding up a laser crystal to mixing a laser dye with colloidal particles, or fabricating an array of semiconductor nanostructures.

Unsurprisingly, random lasers have quite different characteristics from conventional lasers in well-defined resonators. For example, unlike a conventional monochromatic, single-mode laser in a carefully defined resonator, random lasers often have low spatial and temporal coherence owing to the existence of many modes. Although this trait is considered highly detrimental in many cases, it is useful for reducing coherent effects such as laser speckle or achieving broader spectral bandwidth.

On page 197, Mordechai Segev and co-authors discuss the more fundamental aspects of disorder, including the curious phenomenon of Anderson localization in a disordered medium under sufficiently strong scattering. This effect was discovered by the physicist Philip Anderson, for which he shared part of the 1977 Nobel Prize for Physics. While studying electron transport in semiconductors, Anderson predicted that if the level of scattering through defects and impurities was sufficiently high, the electrons would become localized at a single position within the semiconductor. This was later found to be a wave phenomenon that is equally applicable to light, and many researchers are now trying to confirm and investigate this effect in strongly scattering disordered optical materials.

Thirty-four years later, Israeli scientist Dan Schechtman received the 2011 Nobel Prize for Chemistry for his contribution to the characterization of quasicrystals. Quasicrystals are quite different from regular crystals, which can be visualized as being created by 'stamping' a single unit cell across space and thus have translational symmetry and periodicity. Although quasicrystals do exhibit order, as Schechtman's surprising observations of beautiful symmetric electron diffraction patterns suggested, they are in fact aperiodic. On page 177, Valy Vardeny and co-workers from the University of Utah in the USA explain the optical characteristics and potential applications of such structures.

Disorder is a rich and fertile subject area whose wealth of surprisingly physical effects are only now being discovered. There is still much work to be done in terms of both fundamental physics and potential applications, and no doubt yet more surprises lie in store. ❐