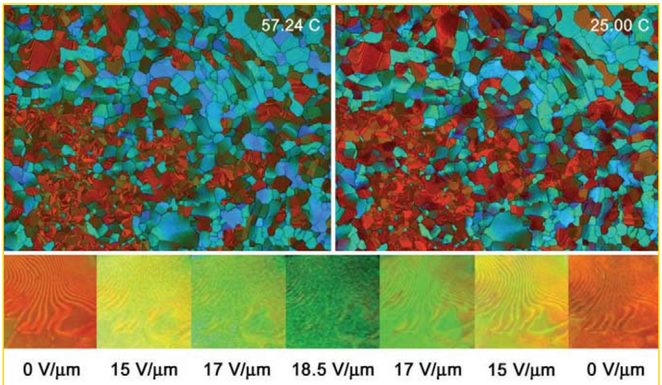
Blue phases stabilized over wide temperature range

OPTICAL MATERIALS



Liquid crystal blue phase on forming at 57.24°C (left) then at 25°C (right). Apart from a change in reflection color, platelet texture is identical. (bottom) Color switching of a display pixel with varying applied field at 25°C. (Courtesy of Mikhail N. Pivnenko.)

Typically, liquid crystals consist of rod-like molecules that line up in at least one direction but remain mobile and disorderly in others. In 'blue phases', the molecules self-assemble into cylindrically shaped arrays in which the direction of alignment twists in a helix, while the helices criss-cross in three dimensions.

The complex structure repeats with a period of several hundred nanometres. This is of the order of the wavelength of visible light, causing vivid specular reflection of a particular color. Blue phases can be considered as tunable photonic crystals since an applied electric field can induce deformation of the lattice, switching the color. The disadvantage is that blue phases have very limited thermal stability. They only exist over a narrow temperature range of 0.5-2°C on cooling from isotropic to chiral nematic thermotropic phases.

Now, University of Cambridge researchers have discovered a new class of blue-phase liquid crystal that is stable from 60°C down to 16°C [Coles and Pivnenko, *Nature* (2005) 436, 997]. Also, the reflected color is switchable linearly and reversibly in an applied electric field over a wide color range in just 10-40 ms, with relaxation times of 1-10 ms.

The blue phases are made from molecules in which two stiff, rod-like segments are linked by a flexible alkyl chain incorporating methylene spacers. This unusual structure is what makes the blue phase so stable, believes Mikhail N. Pivnenko. The behavior is a result of the high flexoelectric coefficients of the molecular structure in the chiral nematic phase.

Potential applications of the photonic crystals include electrically switchable three-color pixels for full-color displays, tunable optical filters, and, because of the materials' photonic band gap nature, tunable three-dimensional organic lasers with a wide temperature range of stability.

Mark Telford

Model photonic quasicrystals

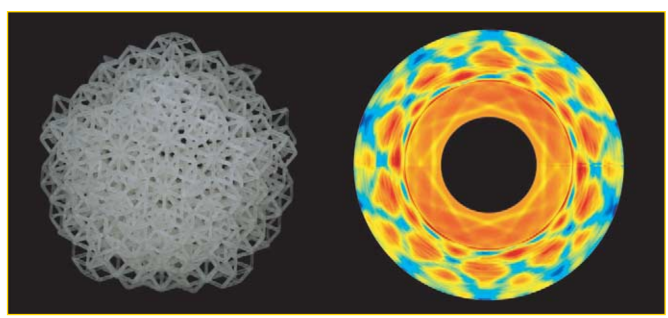
OPTICAL MATERIALS

The varying dielectric constant in photonic crystals results in a range of photon energies and directions – characterized by a photonic band gap and Brillouin zone, respectively – for which the propagation of light is forbidden. The closer the band gap is to being spherically symmetric, the better light can be stopped in all directions, redirected, switched, or processed in photonics applications such as optical computing and communications.

A photonic quasicrystal consists of two or more types of dielectric building blocks (groups of atoms) arranged in a quasiperiodically repeating pattern. The arrangement allows more spherical symmetry than in ordinary periodic crystals, which consist of a single building block repeated with uniform spacing. This should make quasicrystals excellent candidates for photonic band gap materials.

Quasiperiodicity and unconventional symmetry limit the ability to calculate the band gap structure in three dimensions. So, a team led by Paul J. Steinhardt of Princeton University, Paul M. Chaikin of New York University, and Mischa Megens of Philips Research Laboratories in The Netherlands has instead made a model of a three-dimensional photonic quasicrystal and measured its band gap structure and effective Brillouin zone [Man *et al.*, *Nature* (2005) **436**, 993].

An icosahedral quasicrystal was built from 4000 pieces of centimeter-long polymer rods and its microwave transmission measured as a function of wavelength and orientation. Visualizing the Brillouin zone confirms that it is almost spherical. The researchers conclude that, despite the quasiperiodicity, much of the intuition built up from conventional crystals can be applied to quasicrystals.



Polymer model of icosahedral quasicrystal (left) and visualization of the Brillouin zone from microwave transmission (right). (Courtesy of Weining Man, Mischa Megens, Paul J. Steinhardt, and Paul M. Chaikin.)

The team is now exploring three developments: techniques for building a micron-scale model (using either laser tweezers for particle trapping or two-photon polymerization) with band gaps at visible wavelengths; developing a computer algorithm to find the optimal structural configuration combining rods, spheres, and surfaces (a sample with 250 spheres has already been assembled); and investigating different types of photonic, electronic, and even acoustic applications.

Mark Telford