a wet etch and calcination, respectively, to create the so-called inverse opals[2,7] with arbitrary air-core defects (Fig. 2d).

This technique ensures that the crystal lattice around the defects is retained during the TPP and the subsequent removal of the template. Most importantly, *in situ* confocal monitoring is possible during direct defect 'writing' by adding a fluorescent dye to the monomer solution, which enables submicrometre-scale registration accuracy of the defects with the surrounding crystal lattice. The team use their technique to create various high-quality structural defects with sub-100-nm edge resolution. These include vertical and multi-bend waveguides, Y-shaped splitters, and planar cavities, all of which are incorporated into 3D silicon inverse opals with a complete photonic bandgap. Rinne *et al.*[3] also show light localization in planar cavities and waveguiding of telecommunication-wavelength light along a line defect with two 90° bends.

The significance of this work is that both passive and active optical components, which are crucial for all-optical integrated circuits, could be easily and cheaply created using this mainly self-assembly-based approach. Optically active materials, such as quantum dots, nonlinear materials or even liquid crystals, could be incorporated into 3D photonic crystals to provide on-demand light manipulation. To achieve practical photonic-crystal devices for next-generation optical telecommunication and high-speed optical computing, the geometry of the embedded defects needs to be well-defined by both experiment and theoretical modelling, and the optical performance of the components (for example, insertion and propagation losses and the polarization and dispersion of the coupled light) need to be quantitatively characterized. Fortunately, both optical modelling and characterization techniques for microphotonics are already available and relatively mature. Although many challenges remain before the ultimate realization of all-optical integrated circuits, Rinne and colleagues' work represents a major advance towards this goal.

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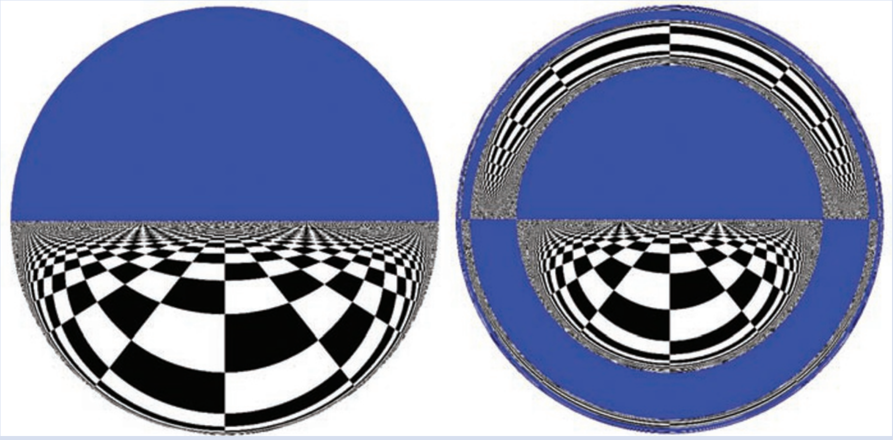
METAMATERIALS

Lost in space

When you think of metamaterials, wormholes might not be the first things that spring to mind. But scientists working in the USA and the UK are suggesting that these materials could actually be used to make devices that act as invisible tunnels for electromagnetic waves (*Phys. Rev. Lett.* **99,** 183901; 2007).

The concept of a wormhole is familiar in cosmology. Now Allan Greenleaf and colleagues describe how to build a device that affects the propagation of electromagnetic waves in such a way that the topology of space seems to change. They consider a wormhole manifold made from two components 'glued' together: a space containing two holes located some distance apart, and a curved handle-shaped tunnel or wormhole that connects those two holes.



With special combinations of the electric permittivity and magnetic permeability in this system, the researchers describe how electromagnetic waves can be made to behave as if they travel through the curved handle from one hole to the other. In practice, metamaterials could be used to specify the electromagnetic parameters as needed. Of course, there is no tearing apart and gluing together of space; rather the researchers are meeting certain mathematical electromagnetic field conditions (using metamaterials as their basis) to make waves behave as if they pop from one hole to the other through the tunnel without being seen by an external radiation probe or observer.

The paper outlines a number of applications that could result from wormhole devices. A wormhole device, for example, could function as an invisible optical tunnel or cable. Such a cable could be used to measure electromagnetic fields without disturbing them, as the tunnel does not radiate energy to the outside world except from its ends.

Alternatively, electromagnetic wormholes could be used in light-based computers, where active components could be placed inside the tunnels with only visible exits for the input and output of signals. The research might also have implications for magnetic resonance imaging (MRI). Scientists could use a wormhole to build a tunnel or 'scope' that does not disturb the uniform magnetic field needed for imaging. Instead, the scope would make it possible to have metals, magnetic materials or other components in the area being imaged without disturbing the MRI process, perhaps even as part of a medical procedure.

Finally, these wormholes could give rise to virtual magnetic monopoles. By enabling a magnetic field to enter one end of the wormhole and disappear inside, the other end of the tunnel would behave as a magnetic monopole. Intriguing work.

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