of the polar systems $LaVO_3/SrTiO_3$ and $LaVO_3/LaAlO_3$, as well as by the observation of the fractional quantum Hall effect in MgZnO/ZnO heterostructures (Masashi Kawasaki, Tohoku University and RIKEN), which is a first for an oxide material. These investigations naturally led to another important theme underlying the conference, namely that theoretical work is strongly stimulated by the rapid development of materials and measurement tools. Indeed, many experimentalists presented their latest findings at the meeting, including Yoshinori Tokura, who showed remarkable Lorentz transmission electron microscope images of skyrmions (Fig. 1) and their twisted magnetic textures with unusual topology in thin-film helimagnets.

Some of the most exciting developments were showcased on the final day of the forum, when the local participants in the FIRST programme presented their latest achievements. The diversity of new materials, structures, characterization studies and theory presented left no doubt as to the vigour of this new effort. Among the most thought-provoking presentations was that of Naoto Nagaosa, who showed that a remarkable hidden 'twisted spin' can be long lived even in a strongly disordered, spin–orbit-coupled material in which spin rapidly relaxes. Following the theme of interplay of theory and experiment, he proposed a concrete memory effect by which to retrieve the twisted spin in the laboratory.

This conference provided a snapshot of an important aspect of the quantum theory of materials, where the pursuit of electron correlation physics, spin–orbit coupling and their interesting manifestations in confined structures have led to new methodology, new problems and new concepts. ❐

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MATERIAL WITNESS

FRACTAL STANDSTILL

PHILIP BALL

If Benoît Mandelbrot, who died in October, was sometimes pugnacious and fiercely protective of his priority claims, that's often how it is with scientists whose ideas genuinely alter science. Although some of the concepts underpinning fractal geometry did not originate with Mandelbrot, he saw their significance (and gave fractals their name), and his strong advocacy established the notion of self-similarity in topics ranging from economics to geomorphology and developmental biology.

At its most reductive level, Mandelbrot's message was that shape can matter: although a metal behaves the same way if it is a sphere or a cube, it may not do so when it has a fractal geometry. This notion is underscored in a report by Rémi Carminati and co-workers in Paris of localization of electromagnetic waves in a fractal gold film[1].

This sort of localization, in which a wave cannot propagate through a disordered medium because of strong scattering, was predicted by Philip Anderson, who showed that if a semiconductor contains a high proportion of randomly distributed defects such as impurities, interference between multiply scattered electron waves can prevent their diffusion, leading to insulating behaviour[2].

This is a general phenomenon of waves, applying equally to the propagation of sound and light. And indeed, the localization of light was reported in 1997 in powdered gallium arsenide[3]. In general, the degree of localization of the light field ought to be governed by the diffraction limit, so that the bright or 'hot' spots cannot be smaller than half a wavelength. However, that restriction for electromagnetic waves is relaxed in the system studied by Carminati *et al.*, because the optical energy is carried in surface plasmons: coherent excitations of electrons on (in this case) metal surfaces. It is for this reason that plasmonic excitations can convey light through holes in metal films smaller than the half-wavelength limit[4].

When such metal films are strongly inhomogeneous — if, for example, they are composed of fractal aggregates of nanoparticles — it was predicted that the plasmonic field should exhibit strong Anderson localization[5]. What's more, the fractal geometry of such a system imposes a unique signature on the localization, which is (like the fractal clusters themselves) scale-free: the hot spots exist on all size scales ranging from those of the nanoscale components of the system to that of the entire cluster. And the size of the hot spots should fluctuate widely from one cluster to another.

This is what Carminati *et al.* have observed[1,6]. They use fluorescent polystyrene beads to probe the optical states in thin films made from gold nanoparticles aggregated into reticulated, fractal networks. The fluorescence decay rates of the probe particles reveal large, scale-free fluctuations in the local density of optical states, as predicted theoretically.

This curious system is of more than academic interest. Random thin films such as this enhance Raman scattering from objects on their surface, a characteristic used for the sensitive detection of chemical and biological substances. That enhancement is related to the film's optical properties, which can now be understood as a product of their fractal geometry. ❐

References

1. Krachmalnicoff, V., Castanié, E., De Wilde, Y. & Carminati, R. *Phys. Rev. Lett.* **105,** 183901 (2010).
2. Nagaoka, Y. & Fukuyama, H. (eds) *Anderson Localization* (Springer, 1982).
3. Wiersma, D. S., Bartolini, P., Lagendijk, A. & Righini, R. *Nature* **390,** 671–673 (1997).
4. Ebbesen, T. W., Lezec, H. J., Ghaemi, H. F., Thio, T. & Wolff, P. A. *Nature* **391,** 667–669 (1998).
5. Stockman, M. I., Pandey, L. N., Muratov, L. S. & George, T. F. *Phys. Rev. B* **51,** 185–195 (1995).
6. Stockman, M. I. *Physics* **3,** 90 (2010).