control such entanglement phenomenon from first principles, which surely is no easy task. Mathematically, it is a very hard problem that Lucignano *et al.* have elegantly addressed by combining a very well-known and successful theory of unentangled electrons known as density functional theory (DFT)[4] with a more sophisticated technique dubbed numerical renormalization group (NRG)[5], which allows for a correct treatment of many-particle correlations. Their procedure can be summarized in three steps: first, identify the various possible scattering channels, and compute the corresponding phase shifts using DFT; second, for each channel, build an effective Anderson impurity many-particle Hamiltonian, with parameters adjusted to fit the DFT results, and third, apply NRG techniques to the many-particle Hamiltonians to compute transport properties, such as conductance.

Understanding transport phenomena in nanoscale systems is technically far more challenging than in mesoscopic and macroscopic systems. New physical properties may emerge at different length and timescales as a result of the competition between particle interactions and their variation in time. Undoubtedly, reliable mathematical tools for understanding and predict out-of-equilibrium many-particle phenomena are always welcome. This is of the upmost importance not only for basic research, but also for the design of nanodevices with well-engineered functionalities. As the size of physical nanodevices becomes smaller, the spooky action at a distance that once perturbed Einstein should become manifest and the fundamental concept of quantum measurement gets a practical meaning. The detection and tomography of a single spin and the manipulation of its entanglement by means of dynamical probes will be essential for quantum information processing purposes[6]. Therefore, new experimental and accurate theoretical ways of controlling the nanoscale with its mosaic of entanglements are desperately needed. The contribution from Lucignano and co-workers[2] is very welcome in this sense. Paraphrasing Jack (Ernest) Worthing from Wilde's play: it is time to appreciate the 'vital importance of being entangled', to extend the frontiers of nanoscience. ❒

Gerardo Ortiz is in the Department of Physics, Indiana University, Bloomington, Indiana 47405, USA.
e-mail: ortizg@indiana.edu

References

1. Einstein, A., Podolsky, B. & Rosen, N. *Phys. Rev.* **47,** 777–780 (1935).
2. Lucignano, P., Mazzarello, R., Smogunov, A., Fabrizio, M. & Tosatti, E. *Nature Mater.* **8,** 563–567 (2009).
3. Kondo, J. *Prog. Theor. Phys.* **32,** 37–49 (1964).
4. Kohn, W. *Nobel Lectures in Chemistry: 1996–2000* (ed. Grethe, I.) 213–237 (World Scientific, 2003).
5. Wilson, K. G. *Nobel Lectures in Physics: 1981–1990* (ed. Ekspong, G.) 102–132 (World Scientific, 1993).
6. Bulaevskii, L. N. & Ortiz, G. *Phys. Rev. Lett.* **90,** 040401 (2003).

MATERIAL WITNESS

DREAM ON

PHILIP BALL

One of the notable but seldom noted features of late-twentieth century science is its willingness to extrapolate beyond the lab bench. The work of Maxwell, Rayleigh, Kelvin and the Braggs, say, was firmly focused on problems of the here-and-now, characterizing and explaining the world as we find it. Even in the synthetic sciences such as chemistry and metallurgy, the rudimentary understanding of basic principles meant that new materials were either minor variations of existing ones or discovered by serendipity. And the thought experiments of early quantum theory were envisaged not as blueprints for real experiments (although some became that) but as heuristic devices used to explore and challenge interpretations of the quantum-mechanical formalism.

Now, in contrast, it is routine for molecules and materials with dramatic new properties to be designed and tested purely in the virtual realm, with barely a thought for whether they could actually be made. The ultimate examples of these leaps of imagination are found in fundamental physics, with its explorations of ultrasmall or higher-dimensional spaces that lie far beyond current empiricism. Sceptics dismiss some of those speculations as mere metaphysics.

The purely theoretical imagining of new substances has also been criticized as unproductive. At its best, however, these sojourns into fantasy might challenge preconceptions about what is and isn't permitted by physical law, as well as casting an existing field in a new light. The trick is to balance boldness of vision against sheer unattainability — a tightrope that physicist Michio Kaku tries to walk in his recent book *Physics of the Impossible* (Allen Lane, 2008).

A preprint by Che Ting Chan and colleagues at the Hong Kong University of Science and Technology arguably falls more towards the stimulating than the far-fetched end of this scale (http://www.arxiv.org/abs/0905.1484). It suggests that the invisibility cloaks that have captured much of the general interest in the field of optical metamaterials are just one manifestation of a more general topic, which the researchers call illusion optics. The paper demonstrates how, in principle, metamaterial 'cloaks' might be devised that allow any given object to take on the appearance of any other arbitrary object.

Invisibility shields are not exactly the same sort of illusion: they involve the bending and reshaping of light-ray trajectories, whereas the proposed illusion devices first cancel out the 'optical space' of the first object and then build up that of the disguise from scratch. This generalizes earlier work by Chan and colleagues on 'anti-cloak' shields (Y. Lai *et al. Phys. Rev. Lett.* **102**, 093901 (2009)).

In some ways the demands on the metamaterial are not so great — much of the cancelling medium is a homogeneous negative-refractive-index material, for instance. Needless to say, full implementation of the idea is still well beyond current means, although relatively simpler examples such as virtual tips for near-field optical microscopy could perhaps be entertained. And like all good what-if proposals, this one offers at least one mind-boggling possibility: using a slab of material to open up a virtual hole in a wall and allow us to look through it. ❒