More topological insulators

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Not since the isolation of graphene has a new material generated as much excitement among physicists as the discovery of topological insulators. Topological insulators are a class of materials whose bulk is insulating or semiconducting but whose surface is conducting. These conducting surfaces are topologically protected — which means they are robust against defects, impurities and other perturbing influences in their environment. As such they represent a promising platform for building spintronics or even quantum computers. It has also been suggested that integrating them with superconductors could give rise to exotic quantum states that mimic the behaviour of certain dark-matter candidates.

So far, only a handful of binary compounds (including HgTe, BiTe and BiSe) have been shown to behave as topological insulators. But two independent numerical studies, by Stanislav Chadov and colleagues and Hsin Lin and colleagues, suggest that several members of the so-called half-Heusler alloys — ternary compounds composed of at least one transition metal and one lanthanide — could soon be added to the list. Increasing the number of known topological insulators is vital to develop their practical potential and enables greater flexibility in integrating them with other materials.

Geometric heat cycle

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As our ability to design and manipulate nanometre-sized systems improves, new means of harnessing phenomena emerge that are not encountered in traditional devices. A case in point is the theoretical study by Jie Ren, Peter Hänggi and Baowen Li, in which they show that geometric-phase effects could be used to pump heat across a molecule-sized junction between two thermal reservoirs.

Molecular systems that transport heat against thermal gradients have been proposed before. But Ren *et al.* show that when nonlinear interactions are at work in these miniature heat pumps, then the heat flux can experience an effect that corresponds to acquiring a geometric (or Berry) phase. This effect in turn provides a mechanism for heat transport, in addition to the previously described mechanism based on suitable activation and relaxation dynamics in the molecule.

The geometric contribution can be activated, for example, by modulating the temperatures in the two reservoirs in a way that the trajectory in the plane spanned by the two temperatures describes a circle — in which case there is only a Berry-phase-induced, but no dynamical, current. Also, the geometric contribution can be reversed, unlike the dynamical heat flux.

Photon in a haystack

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Single photons play a central role in ultrasecure quantum communication protocols. A new technique could aid the retrieval of data-carrying photons even after they have passed through an environment full of light from different sources.

Spread-spectrum technology is used in classical communications to alleviate the deleterious effects of noise on a signal. As the name suggests, the idea is to broaden the bandwidth of an initially narrow-frequency pulse. Chinmay Belthangady and colleagues now show that this same concept can be applied even at the single-photon level.

A photon enters a so-called electro-optic phase modulator, which broadens the width of the photon from about 1 MHz to 10 GHz, before travelling along an optical fibre. A second modulator that works in antiphase with the first then reverses this broadening. However, the effect of the second modulator on any noise in the optical fibre — in this case, laser light — is very different. The modulator broadens the noise and reduces the intensity at the wavelength of the signal photon. Belthangady *et al.* show that this increases the signal-to-noise ratio by a factor of almost 50.

A shot in the dark

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Dark energy is driving the accelerating expansion of the Universe. It's the single largest component of the Universe, and although cosmological observations suggest an equation of state (or pressure to energy-density ratio) of $w \approx -1$, we know nothing of its origin.

Are there, for instance, perturbations of the dark energy? If it's not simply a cosmological constant, then yes, there should be, and these could reveal more about the nature of dark energy. Roland de Putter and colleagues have considered how this effect might be probed, through the sound speed of perturbations to the dark-energy pressure and energy density. A low sound speed, distinct from the speed of light, would lead to a clustering in the dark energy that may be detectable.

Unfortunately, the condition $w \approx -1$, in the standard cosmological model with negligible dark energy in the very early Universe, means that no clustering can be visible. But other models — ones that have, at early times, different values for w or non-zero dark-energy fractions — do allow the clustering to appear. There's still plenty of room for new physics, out there in the dark.

Cut-price GaAs

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If money were no object, all electronics would be made using gallium arsenide (GaAs) rather than silicon. GaAs has higher charge mobility, lower noise, is better insulating in its undoped state and is less susceptible to electrical breakdown and radiation damage. As a result, GaAs devices are faster, exhibit lower electrical loss and are more robust than their silicon counterparts. And, owing to its direct bandgap, optoelectronic devices such as light-emitting diodes and solar cells made from GaAs are more efficient.

Unfortunately, cost is usually a critical concern, and GaAs wafers are substantially more expensive and difficult to grow than silicon. Consequently, GaAs is only ever used for making devices that simply cannot be built with silicon, such as laser diodes and microwave electronics.

A new approach to growing GaAs wafers developed by Jongseung Yoon and colleagues could change that. First, they grow many alternating layers of GaAs and AlAs in square islands (200 × 200 μm each) by conventional metal organic chemical vapour deposition. Then, they chemically etch the AlAs to release the GaAs layers as thousands of square platelets. Once bonded onto wafers of silicon, these platelets can then be used to make high-performance GaAs circuits at a fraction of the usual cost.