resonant frequency, the researchers excited the spins and subsequently measured their state. From the strength of their signal, they determined that the spin–circuit coupling should be strong enough to make spontaneous emission the dominant mechanism for spin relaxation.

To prove it, they measured the emission rate directly: To a sample cooled to 20 mK, they applied a microwave pulse to excite all the spins, waited an adjustable time *T*, then measured the fraction that remained in the excited state. In the absence of enhanced spontaneous emission, the excited-state population decays exponentially, via nonradiative mechanisms, with a lifetime of about half an hour. But when the spin-flip transition energy was tuned into resonance with the circuit, the excited-state lifetime dropped to just 0.35 s.

Nor was the enhancement all or nothing. By slightly detuning the transition from the circuit resonance, Bertet and company achieved a range of intermediate excited-state lifetimes, as shown in figure 3.

Reset button

Although specific applications may be a long way off, enhanced spontaneous emission from electron spins may find use in numerous areas. Of most interest to Bertet and colleagues is the ability to make ESR experiments faster and easier. In the current state of the art, once some spins are excited, there's no easy way to return the system to thermal equilibrium to begin again. Circuit-enhanced spontaneous emission could function as a kind of reset button that can be activated on demand.

PHYSICS UPDATE

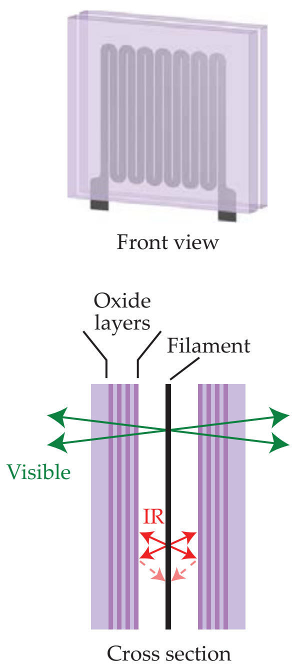
These items, with supplementary material, first appeared at www.physicstoday.org.

BORON NITRIDE NANOTUBES REINFORNCE POLYMER MATERIALS

One form of boron nitride is a white, lubricious, flaky material whose material properties resemble graphite's. By contrast, its nanotube form, like carbon's, is strong, tough, and light. Exploiting those desirable properties in a bulk material entails embedding the nanotubes in a lightweight matrix—provided the nanotubes bind strongly enough to the matrix material that they don't slip. Quantifying that binding was the goal of an investigation led by Changhong Ke of Binghamton University and Xianqiao Wang of the University of Georgia. The researchers created thin polymer films—of epoxy and of PMMA—and embedded them with boron nitride nanotubes (BNNTs). Cleaving the films left some BNNTs poking out from the surface. By welding a nanotube's protruding tip to an atomic force microscope, the team could determine how much force was needed to pull it out. For tubes buried deeper than about 200 nm, the force turned out to be 250 nN for the BNNT–epoxy composite and 190 nN for BNNT–PMMA. Less force was needed to extract carbon nanotubes (CNTs) from the same materials. Molecular dynamics simulations revealed the source of the BNNTs' stronger binding. Because BNNTs are made of two different elements—as opposed to one in the case of CNTs—their bonds are polar. And thanks to that polarity, BNNTs bind to the polymer matrix not just with van der Waals interactions but with Coulomb interactions too. Ke and Wang's findings suggest that BNNTs are excellent fillers for lightweight, high-strength composites. (X. Chen et al., *Appl. Phys. Lett.* **107**, 253105, 2015.) —CD

RECYCLING LIGHT

Conventional incandescent lightbulbs reach the 3000 K needed to emit in the visible range thanks to ohmic heating of a resistive tungsten filament. That process is extremely inefficient at producing light, though, because most of the spectrum of a 3000 K blackbody lies in the IR. Tailoring the spectrum by suppressing all but the wavelengths of interest can avoid the wasted energy. To that end, MIT researcher Ognjen Ilic, his postdoctoral adviser Marin Soljačić, and their colleagues surrounded the filament with interference filters that transmit visible light but reflect the IR. The idea of recycling unwanted IR emission to provide an additional source of heat to the filament isn't new. Two features distinguish the team's implementation: First, unlike earlier filters, which were designed for a single incidence angle, the MIT filters are made of thin layers of common oxides—ranging from the low-refractive-index silica to the high-index titania—that are effective over a wide range of wavelengths and angles. Second, the filament is planar, so it efficiently reabsorbs and reemits the reflected radiation; that shape also makes the filament interchangeable with advanced thermal emitters such as photonic crystals. The team's prototype, shown here, achieved a luminous efficacy—essentially the ratio of visible-light flux to consumed power—of 45 lum/W, roughly triple that of a conventional tungsten filament and approaching some commercially available compact fluorescent bulbs and LEDs. Numerical simulations predict that an optimized stack of 300 layers of four oxides can reach efficacies as high as 270 lum/W, far surpassing that of the best commercial lights. (O. Ilic et al., *Nat. Nanotechnol.*, in press, doi:10.1038/nnano.2015.309.) —RMW



NEUTRINO MAGNETOHYDRODYNAMICS

Neutrinos interact only weakly with ordinary matter. Yet in certain astrophysical contexts, such as supernova explosions, the coupled interactions between neutrinos and dense, highly ionized plasmas contribute significantly to a system's evolution. Modeling such systems is complicated enough even in the absence of neutrinos, and it normally requires analytic approximations or detailed numerical simulations. Adding neutrino effects entails further compromises; past approaches, for example, typically consider energy exchange between neutrinos and a neutral fluid. Now Fernando Haas and Kellen Alves Pascoal (Federal University of Rio Grande do Sul, Brazil) and Tito Mendonça (University of Lisbon, Portugal) propose a new framework for integrating relevant aspects of neutrino and plasma physics. Their approach, which they