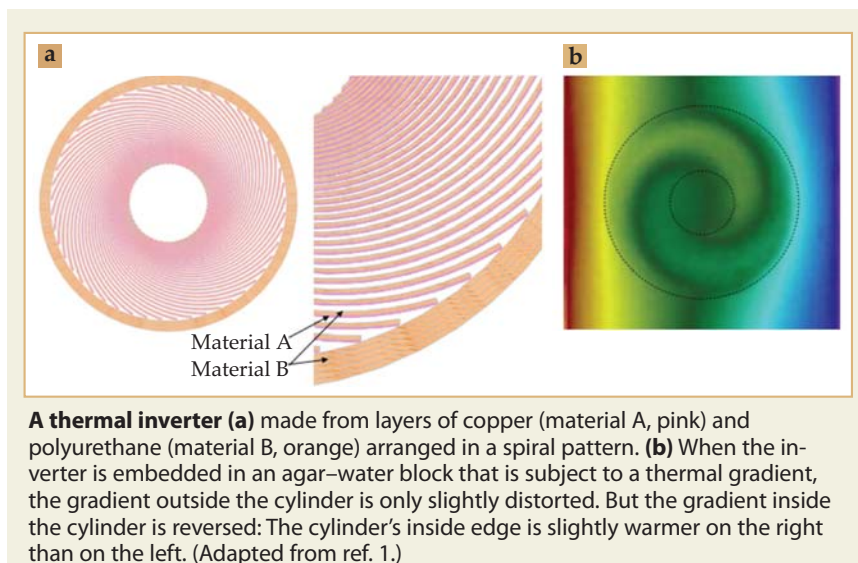


Now Yuki Sato and his postdoc Supradeep Narayana, of the Rowland Institute at Harvard University, have used techniques from the field of metamaterials in order to manipulate heat flux.¹ Inspired by work on devices that “cloak” regions from electromagnetic waves (see *PHYSICS TODAY*, February 2007, page 19), acoustic waves, static fields, and other signals, they set themselves the challenge of designing a hollow, thick cylinder that, when embedded in a material with a uniform thermal gradient perpendicular to the cylinder axis, could drastically alter the heat flux inside the cylinder without disturbing the flux outside.

They quickly realized that no ordinary substance would do the trick. A hollow cylinder of a material with thermal conductivity much higher or much lower than the background material could lessen the thermal gradient inside, but at the expense of severely distorting it outside. “We started out by going back to basics,” says Sato, “drawing up thought experiments to challenge our understanding of thermodynamics and to push the envelope a little and then trying to design physical systems to mimic them.”

What they needed, the researchers found, was a material with anisotropic thermal conductivity. To make it, they stacked many alternating thin sheets of two ordinary materials, one a good thermal conductor and the other a good thermal insulator. Perpendicular to the planes of the sheets, their thermal resistances add in series; parallel to the planes, they add in parallel. With a suit-



able choice of the two materials—the product of their thermal conductivities must equal the square of the background material’s conductivity—the stacked layers blend into the background material and induce almost no distortion in the surrounding thermal gradient.

By arranging the layers in concentric circles, Narayana and Sato created a thermal shield that isolates the region inside from any measurable thermal gradient at all. Arranging the layers as radial spokes did the opposite: It enhanced the thermal gradient in the region inside the cylinder, a useful task in many energy applications.

But when they arranged the layers in a spiral pattern, as shown in panel a of the figure, they achieved perhaps the most counterintuitive effect of all: local

inversion of the flux direction so that heat flows from right to left inside the cylinder in response to a left-to-right flux outside. Panel b shows the temperature map as imaged with an IR camera. Heat still flows from hot to cold (as it must), but the positions of the heat source and sink inside the cylinder are reversed.

Narayana and Sato are working on incorporating other materials engineering techniques into their toolbox for designing their thermal materials. They’d also like to explore the potential of materials with strongly temperature-dependent thermal conductivities.

Johanna Miller

Reference

1. S. Narayana, Y. Sato, *Phys. Rev. Lett.* **108**, 214303 (2012).

physics update

These items, with supplementary material, first appeared at <http://www.physicstoday.org>.

Spin correlation in top-quark pairs. Almost 200 times heavier than the proton, the top quark is by far the most massive of the six quark species that, together with their anti-quarks, are the building blocks of the hadrons. But because it’s so massive, a top quark (or its antiparticle) decays within 10^{-24} seconds of its creation—too fast to be affected by the processes that ordinarily clothe a quark in hadronic garb. So top–antitop pairs produced in CERN’s Large Hadron Collider (LHC) provide a unique opportunity for studying the production and decay of quarks without the obscuring hadronic complications. Now the team that runs the LHC’s gargantuan ATLAS detector has reported an analysis of correlation between the spin orientations of the top and antitop quarks in some 4000 identifiable top–antitop pairs produced in 10^{14} collisions between 3.5-TeV protons. The spin correlation is

deduced from the directional correlations of high-energy decay leptons. The standard model (SM) of particle theory predicts that the top and antitop spins prefer to emerge with the same rather than opposite helicities (spin projections along the momentum direction). The team measured the correlation parameter A (same minus opposite fraction of all pairs) to be $(40 \pm 8)\%$, in reasonable agreement with the SM prediction. If, as some theories suggest, nonstandard Higgs bosons are involved in the production or decay processes, A could differ from the SM prediction. (G. Aad et al., ATLAS collaboration, *Phys. Rev. Lett.* **108**, 212001, 2012.) —BMS

Theory meets experiment in the blink of an eye.

A healthy human eye has a thin, moist tear film that protects it, removes waste, and provides a smooth optical surface. The film—containing layers of lipids, water, and mucin—evaporates as the eye stays open and is replenished with a blink. Mathematical models typically show that the film warms between blinks. But precise noncontact laboratory