

ply sealed the Vycor glass with epoxy. And the new torsion rod no longer has a hollow core to convey liquid helium. That function is replaced by a narrow fill line from below.

Figure 2 compares Chan's old and new results. The abrupt 18-ns period drop seen in the old experiment as the sample was cooled below 200 mK is gone. The only surviving steep feature, the period drop as the system is cooled to 1 K, is fully explained by the freezing of the initially liquid  $^4\text{He}$ . The now very gradual period change below 1 K is accounted for by the stiffening of the Vycor itself. To facilitate comparison, period drops for all the curves in figure 2, with Vycor pores full or empty, use the period at 1 K as their zero reference.

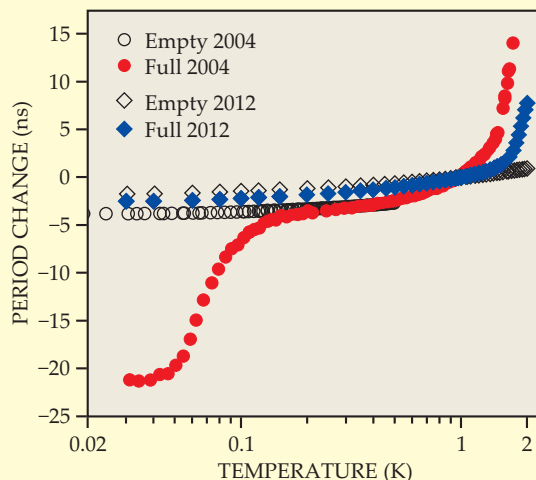
Based on their numerical simulations, Chan and company now attribute the period drop in the old data primarily to stiffening of the thin Be-Cu cover plate by an adhering solid  $^4\text{He}$  layer about 50  $\mu\text{m}$  thick. "In the new experiment, we see no remnant of the evidence for supersolidity," says Chan. "Playing detective has been interesting, but there are still loose ends to be resolved."

## Loose ends

In 2010 a team at the Korea Advanced Institute of Science and Technology led by Chan's 2004 coauthor Eunseong Kim carried out a different sort of TO experiment, designed to distinguish evidence of supersolidity in bulk solid  $^4\text{He}$  from mere elastic stiffening. Velocity fields in supersolids, just as in superfluids, should be perfectly irrotational (curl free). Therefore, a steady "DC" rotation of the entire oscillator apparatus—at a few radians per second—should measurably affect a real transition to supersolidity but not simple material properties like a shear modulus.

And indeed, Kim's team found a dependence of the oscillation-period drop on the rotation rate—and a lack of any

**Figure 2. Changing resonant period** of the torsion oscillators in figure 1 as the helium-4 in the porous Vycor glass disk was cooled below 2 K. The initial period drops above 1 K are explained by solidification of the  $^4\text{He}$ . The second drop, below 200 mK in the 2004 data, was attributed to the onset of a supersolid phase. But the 2012 repetition, with modifications designed to eliminate inadvertent bulk solid  $^4\text{He}$  outside the glass, exhibits no such drop. Also shown are resonant-period curves with the Vycor glass empty. For comparison, all the curves are set to zero at 1 K. (Adapted from ref. 2.)



such dependence in the shear modulus—that hints at transition to a supersolid phase.<sup>3</sup> New TO experiments with DC rotation are currently in the works.

Beyond the experimental confines of torsion oscillators, heat-capacity measurements carried out by the Penn State group raise issues still unresolved. In 2009 Chan and company found that the specific heat of bulk solid  $^4\text{He}$  peaks near 100 mK in a way that suggests a phase transition.<sup>4</sup> "We're still investigating that," says Chan. "If it's not supersolidity, we'd like to know what it is."

Robert Hallock and coworkers at the University of Massachusetts Amherst have undertaken experiments of a different kind in search of atom transport through bulk solid  $^4\text{He}$ . They attach reservoirs of superfluid  $^4\text{He}$  to opposite ends of a long block of solid  $^4\text{He}$ . Imposing a temperature difference between the reservoirs to create a chemical-potential difference, they look for evidence of resulting mass flow through the block.

The small mass flux observed in those experiments suggests that a network of edge dislocations in the  $^4\text{He}$  lattice provides one-dimensional super-

fluid cores for the transport of atoms through the solid.<sup>5</sup> "The relationship between the mass flux we seem to see and the torsion-oscillator results is unclear," says Hallock. "Its dependence on the imposed chemical potential is quite different from what one would expect from the quantum condensation of lattice vacancies proposed in the 1970s."

"Hallock's mass flux is much too small to produce an observable period drop in the torsion-oscillator experiments," says Chan. "And it happens at higher temperatures—around 600 mK. Maybe they're seeing the real supersolidity transition that our experiments are not sensitive enough to notice."

**Bertram Schwarzschild**

## References

1. E. Kim, M. H. W. Chan, *Nature* **427**, 225 (2004).
2. D. Y. Kim, M. H. W. Chan, *Phys. Rev. Lett.* **109**, 155301 (2012).
3. H. Choi, D. Takahashi, K. Kono, E. Kim, *Science* **330**, 1512 (2010).
4. X. Lin, A. C. Clark, Z. G. Cheng, M. H. W. Chan, *Phys. Rev. Lett.* **102**, 125302 (2009).
5. Y. Vekhov, R. B. Hallock, *Phys. Rev. Lett.* **109**, 04503 (2012); S. G. Söyler et al., *Phys. Rev. Lett.* **103**, 175301 (2009).

## physics update

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

**Ultracold chemistry in supersonic beams.** When two atoms or molecules interact at very low collision energies and therefore very cold effective temperatures, the reactants' de Broglie wavelengths become comparable to their separation. In that regime, theory says the classical notion of bouncing billiard balls breaks down; instead, one reactant can tunnel quantum mechanically—through an angular-momentum or energy barrier, for example—to chemically react with the other. But the experimental realization of such quantum effects lags far behind the theory, largely because of the difficulty of cooling neutral atoms and molecules. So quantum chemists make fast molecular beams of different species by letting high-pressure gas adiabati-

cally expand into vacuum through a small orifice. Researchers have set up reactive encounters by intersecting two such internally cold molecular beams. In that way, temperatures as low as 5 K have been reached, with hints of quantum behavior. Now a group of chemical physicists at the Weizmann Institute of Science in Israel have broken through to 10 mK and have seen clear quantum resonances. The trick? A beam of one species is magnetically curved to merge with a beam of the other species; in a comoving frame, the two reactants are practically motionless. The team looked at two systems: excited metastable helium in one beam and either molecular hydrogen or argon in the other. At ultralow energies, they saw well-resolved quantum-enhancement peaks in the reaction rates plotted against collision energy, for a process called Penning ionization. According to the group, the method should be applicable to many chemical reactions. (A. B. Henson et al., *Science* **338**, 234, 2012.) —SGB