figure 1. The liquid sample (methanol) was placed between two sets of Helmholtz coils, which produced a 260-μT field, $\mathbf{B}_r$, rotating at 9.6-kHz in the xy plane (with oscillating components B_{rx} and B_{ry}). A second set of coils on top of the B_{ry} coils produced a 3.3-μT static precession field B_p in the y-direction, which was used to measure the resulting spin polarization. No stationary field was applied in the z-direction. The SQUID was immersed in liquid helium-4 at 4.2 K while the sample, insulated in its double-walled glass insert, was kept at room temperature by heating coils. The entire apparatus was shielded from ambient magnetic fields so that the residual field was 0.24 μT.

Any magnetization induced by $\mathbf{B}_r$ is expected to persist after $\mathbf{B}_r$ is turned off, because the relaxation time of nuclear spins in the liquid is long, on the order of 1 second. The relaxation time was much shorter than 1 second in the 1957 Columbia experiment on electrons.

Once $\mathbf{B}_r$ was turned off, the static precession field B_p was turned on, causing the induced magnetization vector to precess around the y-axis. The SQUID recorded the resulting variations in flux through its pickup coils. With time, the amplitude of those variations decreased due to the decay of the magnetization.

Figure 2a shows the magnetization induced in the protons of the methanol as a function of the time that the rotating field is left on. The magnetization saturates with a time constant (350 ms in this case) that is not very different from the longitudinal relaxation time for the protons in the liquid. Figure 2b shows $\mu_0 M$ as a function of the strength of the rotating field. The solid curve is not a fit to the data but is calculated from the modified Bloch equations with no fitting parameters.

Possible applications

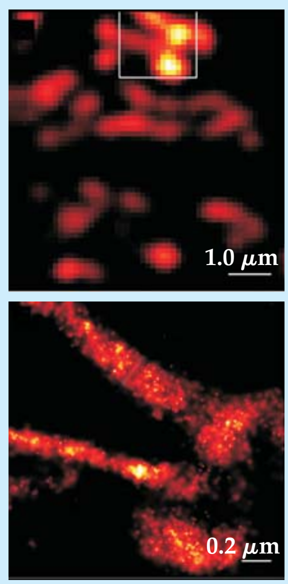
The magnetizations produced are extremely small, and the measurements are quite daunting. Nevertheless, the Berkeley researchers still mention one possible application in their paper, and have tested for it. They point out that polarizing nuclei with a rotating field might be particularly advantageous for NMR measurements on a liquid in the presence of magnetic materials. As an example from the field of geochemistry, one could determine the diffusion rate of water in iron-containing rocks by measuring spin echoes on the induced proton polarization. In turn, the diffusion rate provides information on the porosity of the rock, which is of considerable interest in evaluating potential oil wells. The rotating-field technique helps avoid complications of time-dependent, inhomogeneous fields due to remanent magnetization of the rock.

physics update

Supplementary material related to these items can be found at www.physicstoday.org.

Dune tunes. World travelers, including Marco Polo and Charles Darwin, have occasionally come across sand dunes that issue loud sounds, sometimes of great tonal quality. Now, a team of scientists has proven that the sounds come not from some musical resonance such as vibrations of the dune as a whole, but rather from the relative motions of sand grains in avalanches larger than a critical size. Using field studies and controlled experiments, the scientists—from the University of Paris VII (France), Harvard (US), the CNRS (France), and the University Ibn Zohr (Morocco)—also found that the grains couple into synchronized layers that vibrate like a musical instrument's soundboard, creating a pressure wave. It takes only a few layers to generate the observed acoustic power of about 110 dB. The mechanical coupling depends crucially on the grains' surfaces, which in singing dunes were found to have a silica gel coating known as desert glaze. The online version of this update item has links to sound files. (S. Douady et al., *Phys. Rev. Lett.* **97**, 018002, 2006.) —PFS

Optical molecular microscopy. In recent years, several techniques have been developed to beat the diffraction limit for optical microscopy. Two independent teams of researchers have now developed another diffraction-beating technique, based on a workhorse of modern cell biology—a fluorescing molecule, or fluorophore, that can be made to attach to a variety of targets in a cell. In the new technique, the fluorophores are photo-switchable; when dimly and briefly illuminated at an appropriate wavelength, only a few in the field of view are activated at any one time. The brightest ones can then be localized to within a few nanometers. By repeatedly imaging the same area and adding up many such sparse images, researchers build a composite that displays the entire field of view with near-molecular resolution. A group led by Eric Betzig (Howard Hughes Medical Institute [HHMI], Janelia Farm Research Campus, in Ashburn, Virginia) and Harald Hess (NuQuest Research LLC in La Jolla, California) calls the technique PALM, for photoactivated localization microscopy. A PALM image can be acquired in 2–12 hours. Shown here is a standard fluorescence microscopy image (top) of mitochondria in a frozen thin slice of a cell; the boxed area is enlarged in the PALM image below, in which more than 5500 molecules were localized. Meanwhile, a group led by Xiaowei Zhuang (Harvard and HHMI) calls the technique STORM, for stochastic optical reconstruction microscopy, and acquires complete images in minutes. Zhuang's group uses fewer molecules than the other group but still resolves 10–20 of them within a normally unresolvable area. An additional complication Zhuang's group solved involves using a fluorophore that can be switched on and off hundreds of times. (E. Betzig et al., *Science*, DOI:10.1126/science.1127344, 2006; M. J. Rust et al., *Nature Methods*, DOI:10.1038/nmeth929, 2006.) —SGB



A BEC magnetometer. Physicists at the University of Heidelberg have used a highly elongated Bose–Einstein condensate as a sensitive probe of the magnetic field emanating from a nearby sample. Where the field is weaker, more atoms within the BEC pile up in the trap, which hovers just a few microns from the surface under study. The density of atoms in the BEC can thus be converted into a map of the field at the sample surface. The sensi-

Another possible application is the detection of the state of water in reinforced concrete, where the steel bars could be strongly magnetic.

Lee, Hahn, and Clarke repeated their measurements of spin polarization with their liquid sample mounted on a ferrite ring. The presence of the ferrite prevented detection of proton spins prepolarized by a fixed field but did not impact the measurement of proton spins polarized by a rotating field.

Hahn is interested in further testing the modified Bloch equations. What happens when the transverse and longitudinal relaxation times T_2 and T_1, assumed equal in the recent Berkeley experiment, are not equal and not very large? How does the transient magnetization build up from zero to equilibrium? Additional physics to plumb includes nuclear spin coupling in liquids and solids. The mechanism of the induced static polarization in the liquid case bears a resemblance to the Barnett effect—the spontaneous magnetization of a ferromagnetic or paramagnetic body when spun on its axis.[7]

Barbara Goss Levi

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tivity of this process is given by the energy scale of the BEC's transverse confinement and is limited largely by atomic shot noise, the noise arising from fluctuations in the number of atoms at a specific location in the trap. Thus far, nanotesla field sensitivity and 3-μm spatial resolution have been achieved with the device. Some methods (such as with scanning Hall probe microscopes) can attain finer spatial resolution, and other methods (such as with superconducting quantum interference devices, or SQUIDs) can attain greater magnetic sensitivity, but the Heidelberg device has a region of sensitivity–resolution space all to itself. (S. Wildermuth et al., *Appl. Phys. Lett.* **88**, 264103, 2006.) —PFS

Predicting crystal structures with evolution. Even for simple solids, calculating the arrangement of the constituent atoms from first principles is exceedingly difficult, partly because of the need to sort through an astronomical number of possible ways that atoms can compose a basic repeatable unit cell—roughly 10^{39} different arrangements for 30 identical atoms. Enter Artem Oganov, a materials scientist at ETH Zürich, and Colin Glass, a PhD student, who approached the problem by combining electronic structure calculations and a specifically developed evolutionary algorithm that requires only the chemical composition; no additional input from experiment is needed. In exploring the myriad possibilities, the algorithm proceeds in a step-by-step, continual-optimization fashion that avoids configurations less likely to succeed. The algorithm is efficient and robust: In their first tens of tests, over a range of extreme pressure and temperature conditions and with up to 40 atoms per unit cell, Oganov and Glass have reproduced experimentally known structures with nearly perfect success and predicted several new structures. For example, calcium carbonate ($CaCO_3$) is known to be stable at pressures above 40 GPa and is thought to be a major host of carbon in Earth's lower mantle. But the structure of that high-pressure phase of $CaCO_3$, called postaragonite, was completely unknown until the new algorithm predicted it, along with a higher-pressure form with unusual tetrahedral carbonate ions. Both structures (shown here) have since been experimentally confirmed by Japanese colleagues. The ETH researchers have also found stable and metastable phases of carbon, oxygen, hydrogen, and other elements and compounds. (A. R. Oganov, C. W. Glass, *J. Chem. Phys.* **124**, 244704, 2006.) —PFS ■