Ringing to a single proton's magnetic nudge

A proton behaves as if it were a miniature bar magnet twirling like a top. This combination of spin and magnetism has permitted researchers to develop a variety of sophisticated techniques — based on a phenomenon known as nuclear magnetic resonance — for determining the composition and structure of molecules in pure samples and for picturing complex processes such as blood flow through the heart.

A medical physicist has now suggested an alternative, potentially more sensitive means of extracting information from a nuclear magnetic resonance experiment. His calculations show that, under the proper conditions, a single proton's interaction with a magnetic field may be strong enough to set a nearby, microscopic sliver of quartz quivering in much the same way that a tuning fork begins to ring when bathed in sound waves of just the right frequency. By monitoring these induced vibrations, researchers could, in principle, detect and locate single protons deposited on a surface.

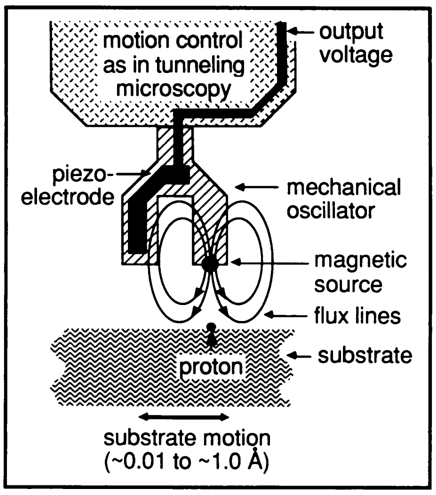
"It turns out that the predicted signal levels are well above quantum and [thermal] noise limits," says John A. Sidles of the orthopedics department at the University of Washington School of Medicine in Seattle. Although little is known about fabricating mechanical oscillators small enough to work in such an experiment, the technique may eventually allow the imaging of individual biological molecules — a level of resolution not possible with conventional magnetic resonance imaging.

"Sidles' idea is kind of revolutionary in the field [of nuclear magnetic resonance imaging]," says physicist Myer Bloom of the University of British Columbia in Vancouver, who studied a related effect in the 1960s. "I don't see why the idea shouldn't be right, but I'm not completely sure that the claimed sensitivity can be achieved."

Sidles presents the theoretical basis of his proposed technique in the Feb. 24 PHYSICAL REVIEW LETTERS. Through a quirk of the review process, a subsequent paper describing possible designs for such a detector appeared last summer in the June 17 APPLIED PHYSICS LETTERS.

Sidles' scheme ingeniously combines nuclear magnetic resonance techniques with the kind of technology that made possible both the scanning tunneling microscope and the atomic force microscope (SN: 4/1/89, p.200; 2/29/92, p.135). Already used to measure tiny variations in magnetic force across a surface, these scanning methods—when further refined and developed — could form the basis for detecting single-proton magnetic resonance.

In such an experiment, a miniature mechanical oscillator would ride just a few angstroms above a surface dotted with protons. When the distance between a proton and the oscillator reached a certain critical value, the oscillator would begin to vibrate, generating a detectable signal. Successive scans could produce enough information to reconstruct the three-dimensional structure of a protein or some other complicated molecule.



Sidles/APPLIED PHYSICS LETTERS

A single proton sitting on a quartz slab interacts with the magnetic field generated by a spherical permanent magnet attached to a quartz oscillator resembling a tuning fork. When the slab supporting the proton moves back and forth at an appropriate frequency, the proton exerts a force that induces vibrations in the oscillator.

"I hope my work will establish ... molecular imaging [via nuclear magnetic resonance] as a legitimate, publishable area of research," Sidles says. "Even if the approaches I have described prove impractical, perhaps other, more ingenious scientists will be encouraged to do better."

"It may be hard to make the thing work properly, but it has the potential of being very important," Bloom says. "It gives you a different way of thinking about fundamental measurements."

— I. Peterson

Device sounds out *Salmonella*-infected eggs

Picture thousands of large, white Grade AA chicken eggs rolling gently down a conveyor belt. As they roll by, a device zaps each one with sound waves and scans it for the telltale sign of *Salmonella.*

Bingo. An infected egg is yanked from the assembly line.

This fictional scenario may one day become reality if a team of New Mexico researchers perfects an acoustic device capable of detecting eggs contaminated with *Salmonella enteritidis*, a bacterium responsible for many outbreaks of food poisoning in the United States. Raw or undercooked eggs sometimes prove the culprit in cases of *Salmonella*-linked human illness (SN: 8/18/90, p.109).

Physicist Roger G. Johnston and his colleagues at the Los Alamos (N.M.) National Laboratory began their study with the knowledge that all objects will vibrate at certain natural resonance frequencies. Los Alamos researchers have used this knowledge in the past to design a means of distinguishing between artillery shells filled with explosives and those filled with noxious chemicals.

For this experiment, Johnston's team bought scores of white Grade AA chicken eggs from the grocery store. The researchers gently placed each egg between two small transducers. One transducer converts an electrical signal into sound waves that pass through the egg. The second transducer picks up the resulting vibration and converts it back into an electrical signal.

When the scientists tested 36 eggs in pristine condition, they discovered a single resonance at about 830 hertz, which they believe to be the natural resonance frequency of uninfected eggs. They cultured the eggs right after their acoustic experiments and found no sign of *Salmonella* or any other bacterium.

Next, the scientists wanted to find out whether infected eggs would show a different acoustic resonance. First, they dipped a syringe into a liquid teeming with *S. enteritidis.* Then they gently inserted the needle through the eggshell and into the egg white.

The researchers incubated the resulting 17 *Salmonella*-infected eggs for a day and then tested them with the acoustic device. These eggs also showed the characteristic vibration at about 830 hertz. However, four of the infected eggs (24 percent) showed a second resonance — this one at a higher frequency.

The team believes that as *Salmonella* organisms make their way through the egg white and into the yolk, the breach in the yolk membrane changes the egg's acoustic properties and thus produces the second vibration.

Johnston suggests chicken farmers may one day use the marker resonance to screen eggs for *Salmonella* infection. A paper describing the team's preliminary data will appear in the May BIOTECHNOLOGY PROGRESS.

The researchers hope to nab closer to 100 percent of the infected eggs by fine-tuning their device. Yet even a 24 percent success rate is better than the system currently in use. About the only way to spot a bad egg now is to crack it open and culture the yolk, a process that takes about a day — and spoils the egg.

— K.A. Fackelmann

Science Service, Inc. is collaborating with JSTOR to digitize, preserve, and extend access to *Science News.*
www.jstor.org