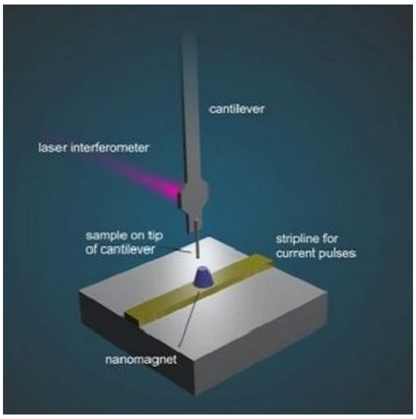
Advances in NanoMRI Imaging



Researchers from ETH Zurich (Switzerland) have developed a technique that greatly accelerates the speed of nanoMRI measurements — meaning a typical nanoMRI scan of two weeks can now be compressed to within two days. Their work, reported in the journal *Applied Physics Letters*, boosts nanoMRI's viability as a powerful tool for researchers and companies exploring the shape and function of biological materials such as viruses and cells.

With the "parallel measurement" technique, information that normally would be measured sequentially (ie, one bit after another) can now be measured at the same time with a single detector. This can be likened to the way our eyes process green, red, and blue information at the same time using different receptors, according to researchers.

"Our research overcomes one of the major obstacles toward practical high-resolution nanoMRI, namely the forbidding time scales required for sequential measurements," says Alexander Eichler, a postdoctoral researcher and teaching assistant in Professor C. Degen's group within the Department of Physics at ETH Zurich. "It brings us closer to the commercial implementation of nanoMRI."

Parallel measurement is also called "multiplexing." After the scan, the researchers have to distinguish where each bit of information belongs in the final picture. For this reason, "different bits of information are encoded in the detector using different phases," Eichler explains. "The term 'phase' refers to a lag in a periodic signal. The phase can be used to differentiate between periodic signals in a way similar to how colour is used to differentiate between light signals in the eye."

Magnetic resonance imaging makes use of the fact that certain atoms — such as 1H, 13C, or 19F — have nuclei that act like tiny spinning magnets. When these atoms are brought into a magnetic field, they rotate around the field axis in much the same way a spinning top rotates around its vertical axis when it is not perfectly balanced.

"When you look at a clinical MRI picture, you see bright pixels where the density of atoms — typically 1H — is high, and dark pixels where the density is low," says Eichler. The magnetic strength of a single atom is vanishingly small. "Clinical MRI is only possible because a single 3D pixel — a "voxel" — contains about 1,018 atoms," Eichler points out. "With nanoMRI, we want to detect voxels with only a thousand atoms or less, meaning that we need a sensitivity at least a quadrillion [10^15, or a million billion] times better."

The researchers demonstrated phase multiplexing with a particular nanoMRI technique called "magnetic resonance force microscopy" (MRFM), in which the atomic nuclei experience a tiny magnetic force that is transferred to a cantilever acting as a mechanical detector. In response to the magnetic force, the cantilever vibrates and then, in turn, an image can be assembled from the measured vibration.

By demonstrating parallel measurements of six data points, the team has shown that a normal scan of two weeks can now be completed within two days.

"Acceleration is limited by technical issues such as the speed of spin reversal and the stability of phase-sensitive detection," Eichler notes. "But, in principle, phase multiplexing might allow compression rates of 10 or more. With commercial applications in mind, this time gain is crucial because it makes a huge difference to a pharmaceutical company if a virus can be characterised within three days rather than a month."

The team plans to work on nanoMRI measurements of biological systems. They want "to demonstrate a spatial resolution of better than 1 nanometre," Eichler says. "Taking into account that the number of atoms in a voxel scales with the cube of the length, this will require an improvement in sensitivity of more than 100 relative to prior work — the current record resolution is about 5 nanometres."

Source: American Institute of Physics
Image credit: B.A. Moores, ETH Zurich

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