

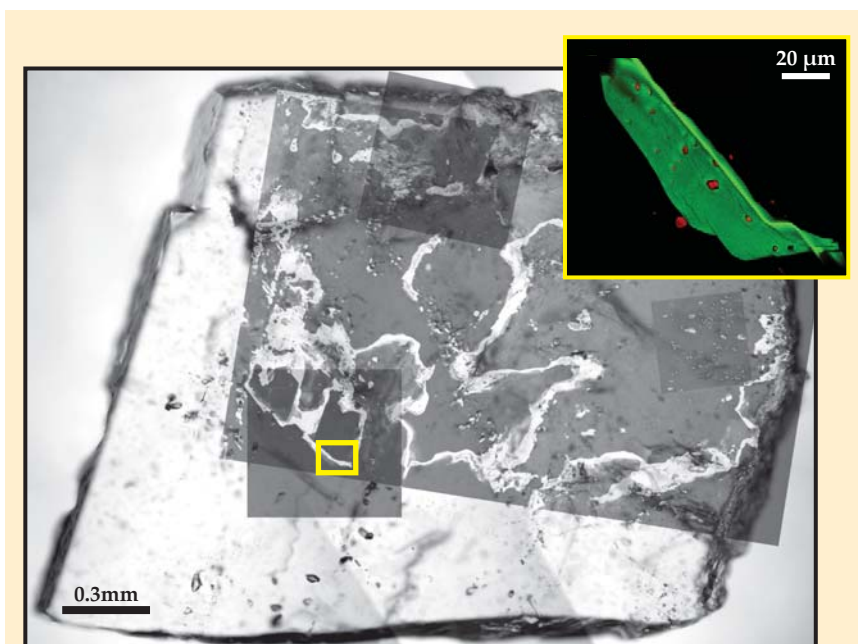


Figure 2. A quartz sample contains more than meets the eye. Superimposed on this microscope image are four images (the dark rectangular frames) produced by detecting a frequency-doubling effect known as second harmonic generation. The SHG images reveal the sample's internal web of facets and fractures. In the inset—which corresponds to the area outlined in yellow—the SHG signal (green) reveals a microfracture and the coherent anti-Stokes Raman scattering signal (red) reveals pockets of trapped methane. (Image courtesy of Robert Burruss; inset adapted from ref. 2.)

generation (SHG): At interfaces within the material, occasionally two photons of frequency ω_p are converted to one photon of frequency $2\omega_p$. By mapping

spatial variations in that frequency-doubled signal, the team could construct images of a sample's internal microstructure.

Figure 2 shows four SHG images of a quartz sample superimposed on a conventional microscope image. The SHG images reveal inclusion walls, microfractures, grain boundaries, and other microstructures. Paired with CARS, an SHG image allows one to determine not just the contents of an inclusion, but also whether the inclusion is associated with a particular fracture event. For example, the composite SHG–CARS image in figure 2 shows methane-rich inclusions embedded along a healed microfracture.

Burruss envisions several new applications for CARS microscopy, including visualizing how different minerals and crystalline domains intermingle inside rocks. Broadly speaking, he draws an analogy with atomic force microscopy: “When geoscientists first found out about AFM, they said, ‘Wow! This could be really useful for learning about minerals,’ and now AFM techniques are used extensively in the geosciences. I think there’s a similar opportunity with CARS.”

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References

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physics update

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

A single-atom qubit in silicon. The up or down spin of an electron makes it a natural qubit to use in an eventual quantum computer. One difficulty in any qubit system is preserving the qubits' fragile phase coherence long enough to perform a sequence of quantum calculations. Another is scalability. For instance, qubits made from isolated atoms offer long coherence times but are hard to scale up into macroscopic devices, whereas those made from bulk semiconductors are scalable but usually suffer from high decoherence rates (see *PHYSICS TODAY*, March 2006, page 16). A research group led by Andrea Morello and Andrew Dzurak (both from the University of New South Wales in Australia) have now combined the advantages of both architectures by fabricating a qubit based on a single atom's electron spin. Ordinarily, a phosphorus atom embedded in silicon donates an electron that enhances Si's electrical conductivity, but at cryogenic temperatures the electron becomes trapped around the P nucleus. The qubit formed by the spin of the electron is protected from decoherence thanks to weak spin–orbit coupling and a near absence of nuclear spin in the surrounding Si lat-

tice. After implanting P in a Si chip, the researchers also fashioned on the chip a transistor to initialize and read out the qubit's spin state. Between those operations they used microwave pulses resonant with the spin transition frequency to coherently manipulate the qubit's state over about 200 μ s; that's long enough to enable more than 1000 qubit operations. (J. J. Pla et al., *Nature* **489**, 541, 2012.) —RMW

Interacting solitary waves. Ever since John Scott Russell first reported a large, long-lived, solitary wave of constant shape on a Scottish canal in 1834, such waves have been an active area of research in diverse fields that include not only oceanography but also optics, cosmology, plasma physics, and even biophysics. Dubbed solitons, solitary waves are inherently nonlinear, and their velocities depend on amplitude. When two collide in one dimension, they can appear to bounce off each other or to have the faster one jump over the slower one. In 2D, even more complex interactions can occur. Mark Ablowitz and Douglas Baldwin of the University of Colorado Boulder report observing surprisingly frequent, varied nonlinear interactions between multiple solitary water waves at two flat beaches; the photo is an example of the aptly named “Y-type” interaction. (Additional photos and videos of