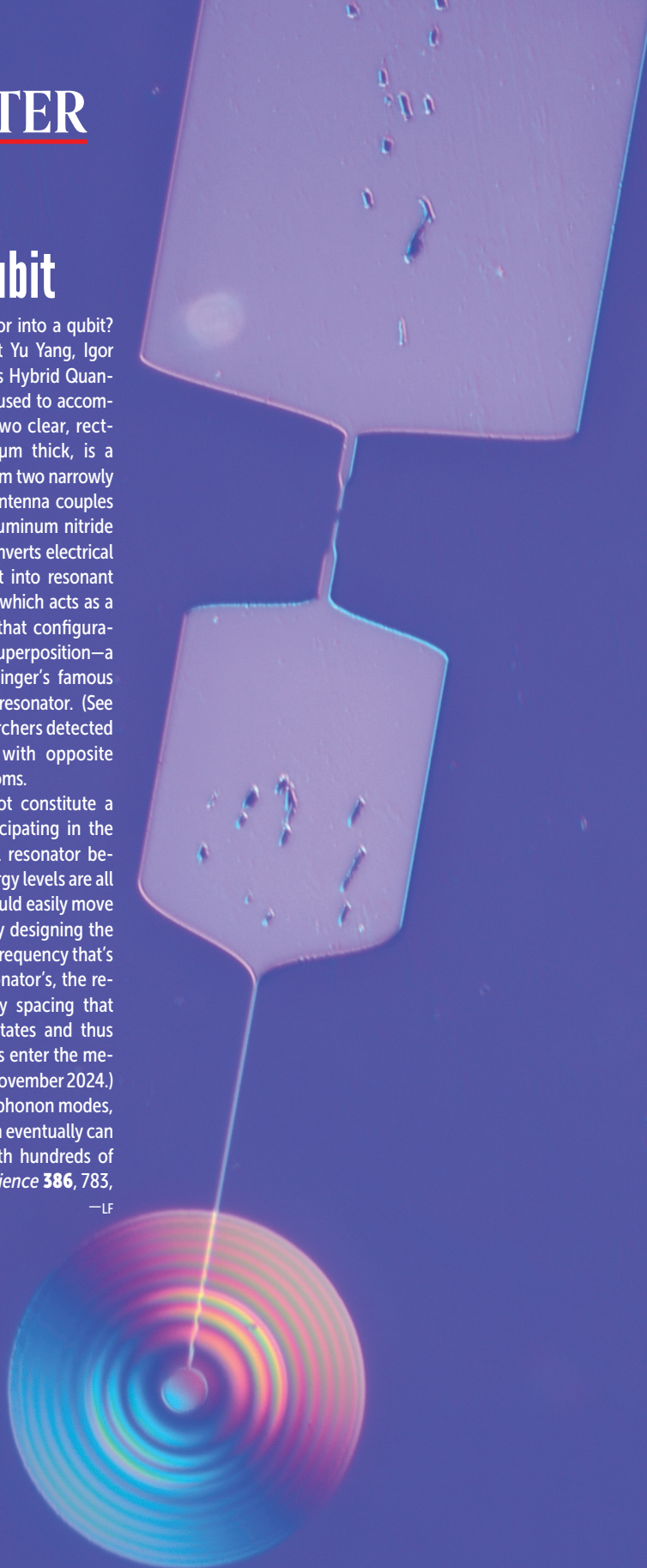


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A macroscopic qubit

How do you turn a mechanical resonator into a qubit? This micrograph shows the system that Yu Yang, Igor Kladarić, and colleagues in ETH Zürich's Hybrid Quantum Systems Group, led by Yiwen Chu, used to accomplish that task. Sandwiched between two clear, rectangular sapphire crystals, each 400 μm thick, is a superconducting qubit that is formed from two narrowly separated rectangles of aluminum. An antenna couples the qubit to a dome of piezoelectric aluminum nitride (at bottom, 400 μm in diameter) that converts electrical signals from the superconducting qubit into resonant vibrations in the upper sapphire crystal, which acts as a mechanical resonator. The team used that configuration in 2023 to generate a quantum superposition—a so-called cat state, after Erwin Schrödinger's famous thought experiment—in a mechanical resonator. (See *PHYSICS TODAY*, July 2023, page 16.) Researchers detected two oscillations, or phonon modes, with opposite phases in the upper sapphire crystal's atoms.

But superposed states alone do not constitute a qubit, which has only two states participating in the superposition. Because the mechanical resonator behaves like a harmonic oscillator, the energy levels are all evenly spaced. As a result, the system could easily move between multiple phonon states. But by designing the superconducting qubit with a resonant frequency that's slightly offset from the mechanical resonator's, the researchers induced variations in energy spacing that enabled them to isolate two energy states and thus make the resonator a qubit. (See "Qubits enter the mechanical world," *PHYSICS TODAY* online, 19 November 2024.) A single resonator can host hundreds of phonon modes, and the researchers hope that the system eventually can be used to build a quantum circuit with hundreds of qubits on just one chip. (Y. Yang et al., *Science* **386**, 783, 2024; image courtesy of Yu Yang.) —LF



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