Coherent Optical Coupling to Surface Acoustic Wave Devices

RESEARCHERS

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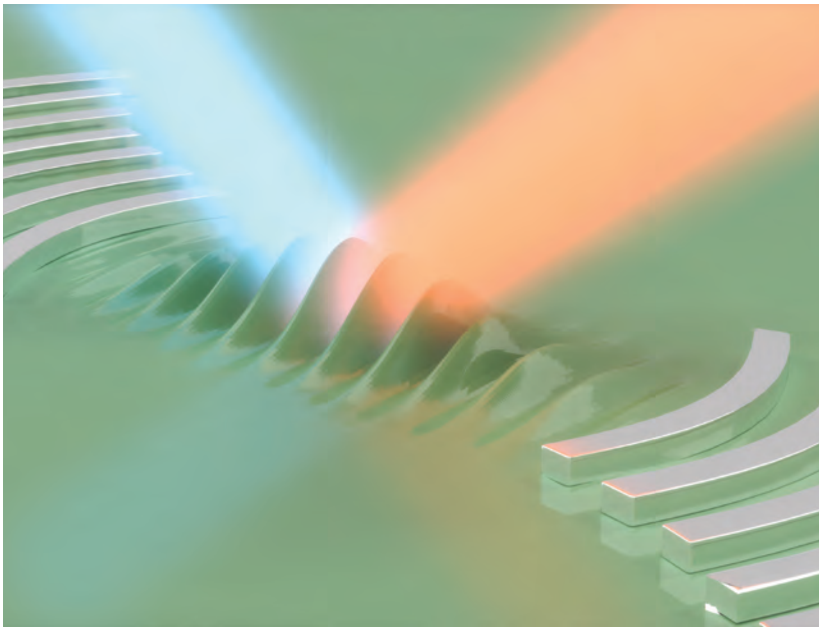
Surface acoustic waves (SAWs) are vibrations that glide along the exterior of materials like a wave in the ocean or tremors along the ground during an earthquake. SAW devices based on electrically driven piezoelectric materials are essential to modern technologies, including those for communications and chemical and biological sensors.[1,2] More recently, SAWs and associated devices have been identified as promising candidates for enabling robust and versatile hybrid quantum systems, owing to their strong coupling to virtually any quantum system, including many different qubits, superfluids and 2D materials.[3] Combining the individual strengths of several heterogeneous quantum elements is widely recognized as a key to simultaneously storing, processing and transmitting quantum information.[4]

Coupling these enabling SAWs to optical fields has likewise been identified as critical to establishing long-distance quantum links. An optical–SAW coupling technique would also help with the limitations of traditional electromechanical techniques, which are restricted to specific materials and introduce undesirable acoustic losses. However, flexible, simple and efficient optical coupling to SAWs remains a challenge for the field.

In work published this year, we showed that with nonlinear optical interactions related to stimulated Brillouin scattering, one can engineer frequency-tunable optical coupling to integrable SAW devices that is direct, coherent, power-tolerant and efficient.[5] The resulting system is remarkably simple, with a Gaussian SAW resonator coherently interacting with two appropriately aligned optical beams.

In contrast to previous couplings to SAW resonators, the demonstrated technique does not require piezoelectricity and can be applied to practically any crystalline media, which we demonstrated by optically driving SAWs on piezo-inactive materials. The noncontact nature of the optical technique enables controlled analysis of dissipation mechanisms and access to pristine Gaussian mechanical resonators with small mode volumes and record-high acoustic lifetimes. Finally, optical coupling offers exquisite spatial control of the mechanical resonator not available to electromechanical devices, which enables new prospects for spatially resolved sensing.

The SAW-mediated optomechanical system's desirable features include record mechanical lifetimes and coherence, strong optomechanical coupling, integration with most quantum systems, material independence, simple fabrication, contact-free interrogation and high power handling. We thus believe that the optically controlled SAW platform is ideal for next-generation chemical/biological sensors, clocks, filters for wireless 5G and beyond, and hybrid quantum devices. OPN



Two optical beams couple to a SAW cavity consisting of metallic reflectors deposited on a single-crystal substrate. The authors believe the platform's simplicity and versatility make it ideal for the next generation of devices for classical and quantum applications.

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