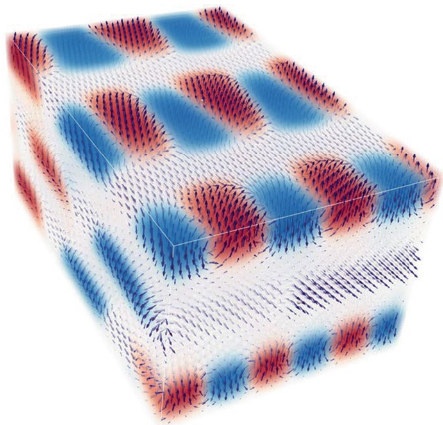
ULTRAFAST PHOTONICS

Supercrystal creation

Nat. Mater. **18**, 377–383 (2019)



Credit: Springer Nature Limited

Ultrashort pulses of visible light can convert superlattices of $PbTiO_3/SrTiO_3$ into a 'supercrystal' state that features ferroelastic, ferroelectric and polar vortex sub-regions that are ordered in three dimensions. The supercrystal phase studied by Vladimir Stoica and co-workers in the US appears to persist indefinitely under ambient conditions (tests indicate that it is stable for at least 1 year), but can be erased by heating above a critical temperature of 470 K. Characterization of the supercrystal phase by X-ray scattering and microscopy shows that the phase possesses a three-dimensional structure with polar, strain and charge-order with a period on the scale of 30 nm. The supercrystal is created by applying sub-picosecond pulses of blue light (shorter than 900 fs at 400 nm wavelength above a critical fluence of ~25 mJ cm^{-2}) onto the superlattice in order to modify elastic and electrostatic interactions. *RW*

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OPTOMECHANICS

Superfluid shake

Phys. Rev. Lett. **122**, 153601 (2019)

Signatures of quantum phenomena have been seen before in optomechanics, but, so far, the mechanical resonators have been composed of gases or solids. Now, researchers in the US and France have observed telltale signs of zero-point motion and quantum back-action in a liquid. The team monitored an acoustic standing wave in superfluid liquid He, which was coupled to an optical cavity, enabling Stokes and anti-Stokes scattering of light. The authors highlighted a number of possible advantages of using liquids. Superfluid He can carry 'impurities', for example electrons, ions and excimers, enabling hybrid quantum systems. From an optical standpoint, there is the tantalizing fact that superfluids can conformally coat, or fill, a photonic cavity, and alignment of the two systems (acoustic and optical) may not be needed. *DFPP*

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TIME REVERSAL

Rabi in reverse

APL Photon. **4**, 030806 (2019)

The technique of phase conjugation has long been used to perform time reversal of wavefronts in the frequency domain. More recently, linear approaches to time reversal of pulses in the time domain have been shown effective for microwave signals. However, the application of these approaches is technically challenging at optical frequencies. Now, a team at Kyoto University, Japan, has demonstrated linear time-reversal of infrared light in a planar photonic crystal system using a dynamic approach. The technique relies on fast, non-adiabatic tuning of coupled cavities. Three two-dimensional silicon photonic crystal resonators were fabricated with separations of 41 μm. Each cavity has a *Q*-factor of about 400,000, is coupled via waveguides and has its temperature controlled for initial tuning purposes. Two cavities were fixed to 1,546.8 nm and the third was detuned by +0.3 nm; rapid (dynamic) tuning was then provided via optical pulses. A pulsed Ti:sapphire laser and an optical parametric oscillator provided synchronized excitation pulses (~1,547 nm) and control pulses (~820 nm) and an optical Rabi oscillation was observed. Applying a control pulse to one cavity generates free carriers in the silicon slab, lowering the refractive index on a 3-ps timescale (satisfying the condition for non-adiabaticity) and enabling time reversal of the optical Rabi oscillation. *DFPP*

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TERAHERTZ PHOTONICS

Nonlinearity of water

Opt. Express **27**, 10419–10425 (2019)

The nonlinear refractive index of water can be as large as 7×10^{-10} cm^2 W^{-1} in the THz frequency range — a million times larger than the value in the visible and near-infrared, according to Russian researchers. The finding confirms earlier theoretical predictions that ionic vibrations in water generate large THz nonlinearities. Anton Tcypkin and co-workers from ITMO University in St. Petersburg used a broadband, pulsed THz beam and the *Z*-scan method to make the measurements. Terahertz pulses with a pulse energy of 400 nJ, a duration of 1 ps and a spectral width of 0.1–2.5 THz were generated by optical rectification of femtosecond laser pulses by a lithium niobate crystal. A parabolic mirror with a short focal length of 12.5 mm was then used to focus the THz pulses onto a 0.1-mm-thick water jet that traverses the THz beam at right angles. The water jet is scanned a distance of ±4 mm along the direction of the beam (*z* axis) so that it passes through the beam's focal point. After passing through the water jet the THz beam is collimated by a second parabolic mirror and detected by a Golay cell. *OG*

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NANOSCOPY

Imaging atomic density

Phys. Rev. X **9**, 021001 (2019)

Mapping atomic density with high spatial resolution is of importance for probing many-body effects in cold atomic and molecular systems. Mickey McDonald and co-workers from the US have now performed one-dimensional super-resolution imaging of ultracold atoms with a resolution of 32 nm (full-width at half-maximum) and a localization precision below 500 pm. The experiments involved cold caesium atoms trapped in a one-dimensional optical trapping lattice created by a standing-wave pattern from an infrared laser. An optical pumping lattice with a similar lattice constant is used to pump the atoms from the ground state to a different hyperfine state. Only atoms within a narrow window around the nodes of the optical pumping lattice, where the intensity vanishes, remain in the initial state. By sweeping the location of this window across the lattice and measuring the fraction of atoms in the unexcited state, the atomic density distribution can be mapped with a resolution given by the width of the window, which can be much smaller than the optical wavelength. *RW*

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