Coherent phonon-induced gigahertz optical birefringence realized in strontium titanate

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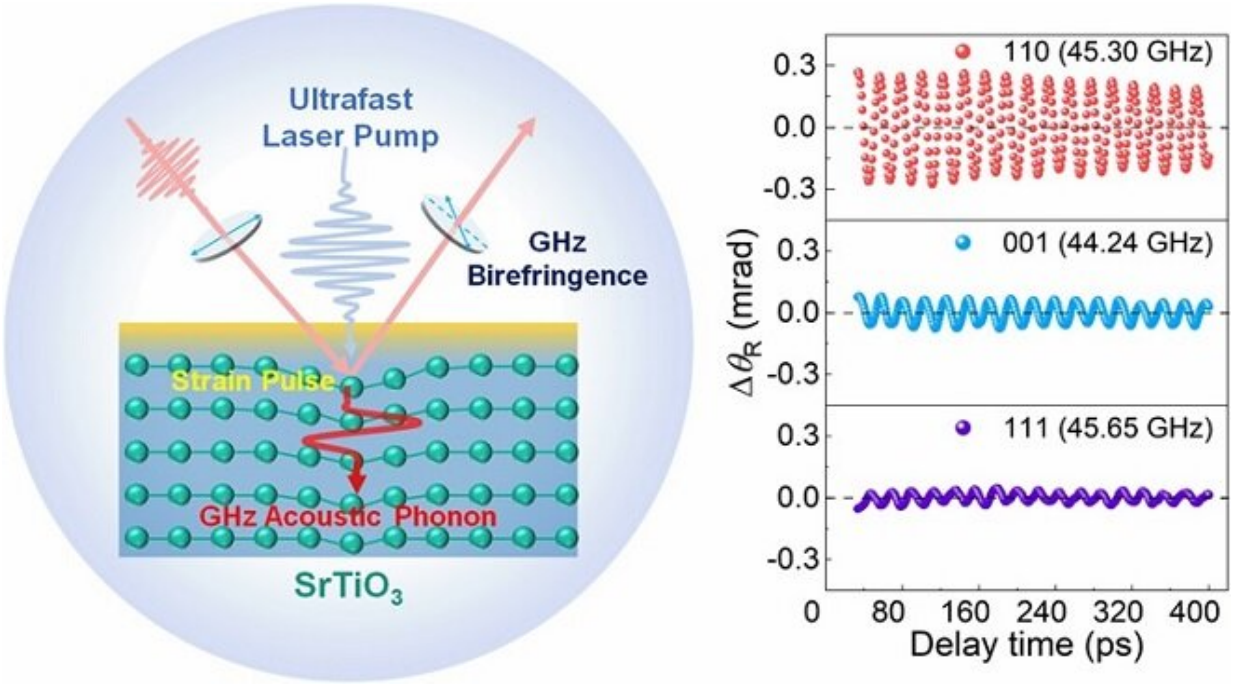

Schematic diagram of the principle of coherent acoustic phonon induced GHz frequency optical birefringence (left); Behaviors of optical birefringence with different lattice orientations of STO (right). Credit: Sun Tao

Using ultrafast time-resolved pump detection technology, researchers led by Prof. Sheng Zhigao from the Hefei Institutes of Physical Science (HFIPS) of the Chinese Academy of Sciences have realized the gigahertz (GHz) frequency birefringence modulation induced by

ultrafast coherent phonons in strontium titanate ($SrTiO_3$) crystals.

According to the researchers, the operating frequency was found to be much higher than the cutoff frequency of the commercially available photoelastic modulators.

The study was published in *Advanced Science*.

A special material with birefringence can shape light. The photoelastic modulator based on birefringence modulation technology is one of the core components of modern optical technology. At present, most photoelastic modulators use the mechanical stress provided by piezoelectric materials to drive photoelastic crystals to achieve birefringence modulation, and their operating frequency is limited by the resonant frequency of photoelastic/piezoelectric crystals, which is generally in the order of kilohertz (kHz). Therefore, there is an urgent need to develop birefringent materials and modulation techniques with GHz operating frequency.

"We found the GHz optical birefringence effect induced by ultrafast coherent phonons in perovskite $SrTiO_3$ crystals and optically manipulated it," said Sheng Zhigao, corresponding author of the study, "using the ultrafast pump-probe system in our high magnetic field magneto-optical laboratory."

First, they used ultrafast laser pulses to generate coherent acoustic phonons with low damping in the transducer/$SrTiO_3$ heterostructure.

After screening a series of materials, they found that $LaRhO_3$ semiconductor thin films as transducers could obtain relatively high photon-phonon energy conversion efficiencies.

Then, in the optimized heterostructure, it is found that ultrafast coherent

acoustic phonons can induce optical birefringence with GHz frequency in stress-sensitive $SrTiO_3$ crystals.

In addition, the researchers realized the optical manipulation of coherent phonons and their induced GHz birefringence using a double-pump technique.

This discovery reveals a mechanism of ultrafast optical birefringence modulation and provides a technical basis for the application of high-frequency GHz acousto-optic devices.

More information: Tao Sun et al, Coherent Phonon-Induced Gigahertz Optical Birefringence and Its Manipulation in SrTiO 3, *Advanced Science* (2023). DOI: 10.1002/advs.202205707

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