Switching chiral phonons with electricity

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Scientists from Paul Scherrer Institute PSI have used an electric field to reverse the handedness of atomic vibrations known as chiral phonons. Chiral phonons link magnetism with atomic motion. The ability to control them opens new possibilities for phonon-based information technologies.

Atoms in a material are rarely still. They jiggle backwards and forwards in collective lattice vibrations known as phonons. Their motion can also carry a rotational element: in 2023, scientists at PSI proved experimentally the existence of chiral phonons, which exhibit handedness, depending on which way they rotate.

Now, the same team of researchers have shown that an applied electric field can control the handedness of these phonons.

Making chirality switchable

Whereas the researchers made their initial discovery in quartz, in the latest study, they created a tiny device out of the material barium titanate ($BaTiO_3$). This material is ferroelectric, meaning that it possesses an electrical polarisation that can be reversed by an electric field. Collaborators in Taiwan created membranes of barium titanate just 40 nm thick and added miniature electrodes to create a tiny device, which was placed on a silicon substrate.

The researchers studied how the handedness of the atomic vibrations in the material changed as they flipped the electrical polarisation – back and forth. When they reversed the electrical polarisation, the handedness of the phonons reversed too.

Intriguingly, they found that the switched state persists after the electric field is removed. The electric field therefore provides a reliable way to control handedness of the phonons. Switching was achieved at room temperature and using a voltage of just 3 V – two factors that could help with future integration into devices.

Watching the handedness reverse

The team were able to read out the handedness of chiral phonons using circularly polarised X-rays at the European Synchrotron Radiation Facility (ESRF) in Grenoble. Here, the researchers used a technique known as resonant inelastic X-ray scattering (RIXS), which allowed them to resolve phonon chirality by seeing how angular momentum is transferred between circularly polarised X-rays and the lattice.

“We now know that phonon angular momentum is something that can be controlled by electricity. This opens a pathway towards phonon-based information technologies,” says Michael Grimes, first author of the paper from the PSI Center for Photon Sciences.

From fundamental questions of nature to future devices

Because chiral phonons include a swirling motion, they carry angular momentum. Magnetism is also closely linked to angular momentum, through the spin and orbital motion of electrons.

Chiral phonons therefore have the potential to interact with and influence electronic and magnetic states. “The ability to control the handedness of the phonons could, in principle, provide a means to manipulate magnetic states and therefore the information encoded in them,” explains Urs Staub, physicist in the PSI Center for Photon Sciences who led the study.

As well as the practical implications, the topic is part of a wider question about the origins of chirality in life.

“Chiral phonons are fascinating because they touch on a fundamental question in nature, which is very poorly understood: why does handedness occur?” adds Staub. “Biology is handed - but why is a mystery. Whether magnetism plays – or played – a role in this is hotly debated. Chiral phonons connect the motion of atoms with magnetism.”

About PSI

The Paul Scherrer Institute PSI develops, builds and operates large, complex research facilities and makes them available to the national and international research community. The institute's own key research priorities are in the fields of future technologies, energy and climate, health innovation and fundamentals of nature. PSI is committed to the training of future generations. Therefore about one quarter of our staff are post-docs, post-graduates or apprentices. Altogether PSI employs 2300 people, thus being the largest research institute in Switzerland. The annual budget amounts to approximately CHF 450 million. PSI is part of the ETH Domain, with the other members being the two Swiss Federal Institutes of Technology, ETH Zurich and EPFL Lausanne, as well as Eawag (Swiss Federal Institute of Aquatic Science and Technology), Empa (Swiss Federal Laboratories for Materials Science and Technology) and WSL (Swiss Federal Institute for Forest, Snow and Landscape Research). *(Last updated in June 2026)*

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Electric-field switching of g-wave phonon chirality in ferroelectric BaTiO3

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