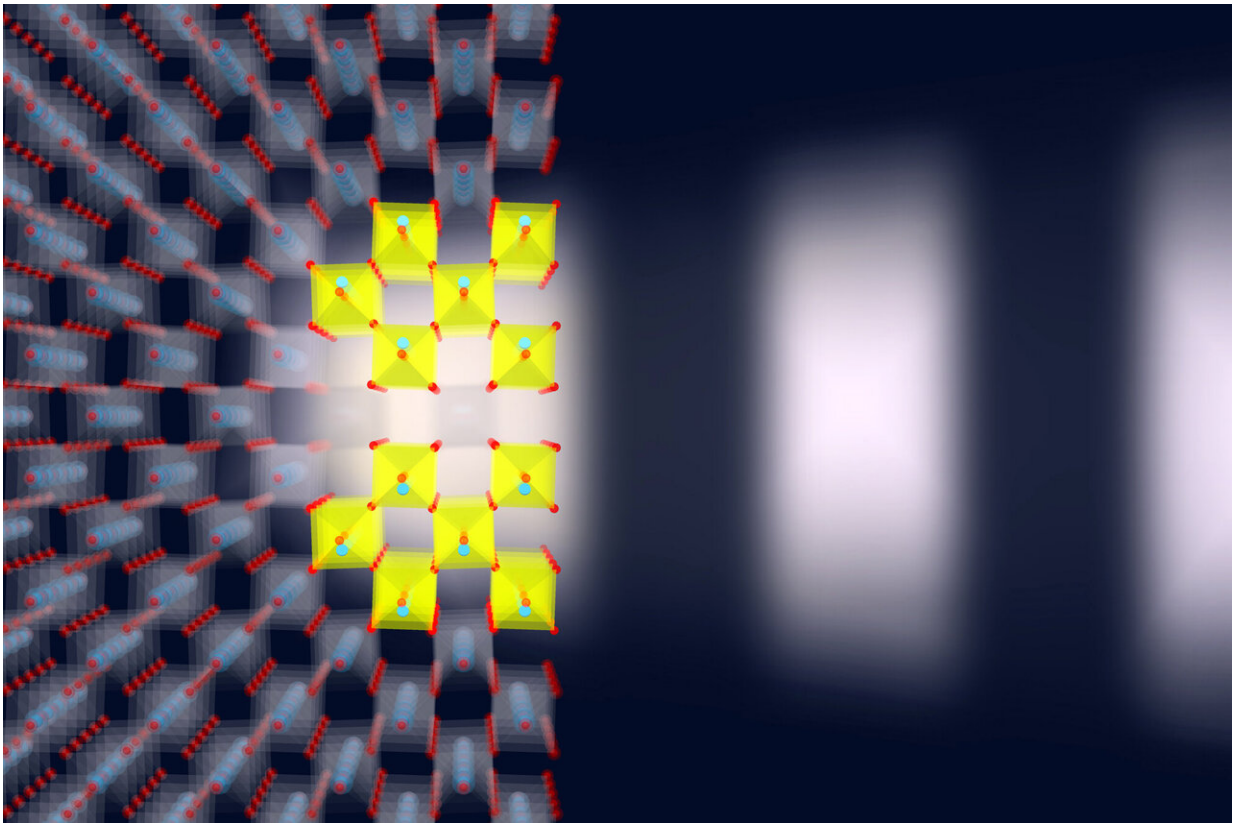


Discovery of light-induced ferroelectricity in strontium titanate

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Ultrashort terahertz pulses create a ferroelectric phase in the paraelectric strontium titanate. An optically-induced deformation of the sample results in pairs of flexoelectric domains with opposing polarisations. Credit: Joerg M. Harms, MPSD

Light can be used not only to measure materials' properties, but also to

change them. Especially interesting are those cases in which the function of a material can be modified, such as its ability to conduct electricity or to store information in its magnetic state. A team led by Andrea Cavalleri from the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg have used terahertz frequency light pulses to transform a non-ferroelectric material into a ferroelectric one.

Ferroelectricity is a state in which the constituent lattice is polarized in one specific direction, forming a macroscopic electrical polarization. The ability to reverse polarization makes [ferroelectric materials](#) particularly suitable for digital information encoding and processing. The discovery of a light-induced ferroelectric is highly relevant for a new generation of high-speed devices, and is presented today in the journal *Science*.

Complex [materials](#) are special because their unusual macroscopic properties are determined by many competing tendencies. Unlike in more conventional compounds, such as the silicon crystals that make up current electronic devices, in complex materials one finds that more than one type of microscopic interaction favors more than one possible macroscopic phase.

Such competition leads then to a compromise, but one that is not unique and is often in precarious equilibrium. Hence, moderate perturbations, for example irradiating one such material with light, can induce radical changes in the properties of the solid.

Ultra-short terahertz laser pulses are especially useful because they couple directly to the crystal lattice and can deform atomic arrangements at high speeds. Coherent excitation of [lattice vibrations](#) has been shown in the past to cause changes of electrical properties or magnetic arrangements in a number of complex materials, including superconductors.

In their latest research, the scientists describe how they induced a ferroelectric order in a material, a property of solids that can be highly relevant to applications. Ferroelectricity describes the spontaneous alignment of electric dipoles, which leads to a macroscopic polarization akin to the magnetisation in a ferromagnet. Generally, ferroelectricity only occurs in a limited class of materials; however, the Hamburg group has discovered that even non-ferroelectric materials can be forced into a ferroelectric phase by light.

Strontium titanate (STO) is paraelectric at all temperatures and a long-range ferroelectric order never develops. Upon exciting vibrations in STO by light, the researchers observed characteristics in its optical and electrical responses typical of ferroelectricity. The origin of this surprising effect lies in the nonlinear nature of the crystal lattice. The driven phonon delivers some of its energy in the form of pressure to the solid, resulting in a spatially varying structural deformation within the excited area. In these conditions, a material property called flexoelectricity can be activated, resulting in a macroscopic polarization. Strikingly, the photo-induced state was found to survive for hours after being created, showing that the material transitioned to a new quasi-stable phase.

"The ability to induce and control ferroelectric states with light on ultrafast timescales could provide the basis for next-generation technologies", says Tobia Nova, first author of the paper. Ferroelectric materials are already at the core of devices in development, which exploit their spontaneous polarization to make stable memory chips or "always on" computers. Because the light-induced ferroelectric phase demonstrated in the Hamburg experiment operates at terahertz frequencies, electro-optic devices that work at such high speeds might be envisioned. Moreover, since flexoelectricity is a common material property, the ability to induce ultrafast flexoelectric polarizations extends far beyond the specific example of STO. Lastly, because STO is

routinely used as a substrate in complex heterostructures, the optical access to flexoelectric polarizations should find extensive applications in the manipulation of collective phenomena at interfaces.

More information: T. F. Nova et al. Metastable ferroelectricity in optically strained SrTiO₃, *Science* (2019). [DOI: 10.1126/science.aaw4911](https://doi.org/10.1126/science.aaw4911)

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