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Time-resolved x-ray scattering study on polar topolgical structures using XFEL

Topological structures such as polar vortices have been found in PbTiO3/SrTiO3 multi-layer thin films, which have the advantage of being easily manipulated by temperature or electric field, and are known to exhibit collective domain motion in the THz region, attracting great interest as candidates for next-generation functional devices. Since the polarization vectors in this structure strongly interact through electrostrictive coupling with strain, it is possible to manipulate this structure using a strong strain pulse, as is the case with magnetic topological structures. In this study, the interaction between the polar vortex structure and dynamic strain is investigated using an x-ray free electron laser (XFEL). An optical pump laser was used to excite a metallic capping layer deposited on the sample surface to generate coherent acoustic phonons (CAP), and the interaction process between CAP and vortex was observed in ps using XFEL. To interpret the experimental results quantitatively, we used dynamic phase-field simulations in combination with our recently developed X-ray resonance elastic scattering calculation method. The results show that after the shape of the polar vortex is significantly deformed by the CAP, a vibrational mode is excited in the vortex, which generates nano-patternend strain waves with the same period in the lateral direction of the vortex. The findings are expected to have applications in the development of devices for phonon engineering and THz electronics utilizing polar topological structures, as well as contribute to a deeper understanding of the interaction between strain waves and polar vortices.

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Dynamics of surfaces, interfaces, and nanostructures

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