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Ultrafast Angle-Resolved Light Scattering Metrology of Quantum Materials[1]

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Time-domain studies of nonequilibrium dynamics in quantum materials are critical to obtaining accurate information about electronic and structural degrees of freedom. The understanding of excited states in these materials is the subject of great interest in theoretical and experimental condensed matter physics. Here we report on ultrafast optical and structural dynamics of correlated vanadium oxides and plasmonic materials. Using time- and angle-resolved light scattering techniques, we trigger the insulator-metal transition and probe excited states with femtosecond resolution. 3D light scattering enables visualization of nonequilibrium dynamics, including coherent phonon response, of local mesoscale domains with different sizes and orientations. It is shown that the tensile and compressive strain in epitaxial films shifts the phase of phonon oscillations in different domains with respect to their elastic deformation. The higher misfit strain in smaller grains of epitaxial films changes the rate of insulator-metal transition. The observation of phonon mode softening in quasi-equilibrium process together with phonon dynamics upon ultrafast photoexcitation is a key step towards understanding of symmetry-breaking phenomena. To separate and characterize the ultrafast electronic and structural dynamics of phase-change-materials we developed a novel ultrafast diffraction conoscopy technique, which is based on polarization analysis of time- and angle-resolved hemispherical elastic light scattering. At room temperature, the insulator-metal transition can be observed only for a very limited range of materials, while light-induced phenomena in superconductors and other correlated materials require cryogenic temperatures. Therefore we built the ultrafast scatterometer which incorporates a 50-cm-in-diameter elliptical mirror and operates at low temperatures, down to 7K, offering new possibilities for ultrafast scattering imaging and diffractive conoscopy of quantum materials.

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