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Probing of Ultrafast Attometer Displacement in a Polaritonic Nanostructure

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Photoinduced ultrafast processes in crystalline solids are accompanied by a response of the crystal lattice due to the local generation of stress. Examples for such ultrafast processes occurring on the time scale of less than one picosecond are photoinduced phase transitions, electron gas heating in metals, excitation of carriers in semiconductor nanostructures or modifications in the magnetic order in magnetically-ordered materials. Common methods for directly visualizing the lattice dynamics caused by these processes are X-ray or electron diffraction techniques, which are applied to resolve atomic motion with a corresponding displacement of atomic planes down to the picometer scale. In order to detect atomic motion of even smaller magnitudes, we focus on the coherent acoustic pulse, which is generated by spatially localized stress and injected into the surrounding volume.

In the pump-probe experiment, we detect picosecond coherent acoustic pulses generated by an ultrafast heating of a 100-nm Al film. The pulses injected into a multi-quantum well structure induce the modulation of the optical reflectivity probed in the spectral vicinity of the narrow polariton resonance. It provides us with superior detection sensitivity, which allows resolving the thermal expansion of the Al film as small as 100 attometers due to the increase of its temperature on ~0.1 K [1]. When attempting to reach stronger modulation by increasing the number of probing photons, i.e. the probe fluence, we observe a drop in sensitivity due to polariton-induced transparency [2].

[1] Karzel, M., Samusev, A. K., Linnik, T. L., Littmann, M., Reuter, D., Bayer, M., Akimov, A. V. and Scherbakov, A. V., Polariton probing of attometer displacement and nanoscale strain in ultrashort acoustic pulses. DOI: 10.21203/rs.3.rs-4523925/v1.

[2] Karzel, M., Samusev, A. K., Linnik, T. L., Littmann, M., Reuter, D., Bayer, M. Scherbakov, A. V., and Akimov, A. V., Polariton-Induced Transparency in Multiple Quantum Wells Probed by Time Domain Brillouin Scattering. *ACS Photonics*, 2024. Doi: 10.1021/acsphotonics.4c01357