Coherent atomic motions in a semiconductor superlattice studied by femtosecond x-ray diffraction

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We report on the first nondestructive femtosecond x-ray diffraction measurements of minute reversible structural changes in a nanostructured solid. As a prototype sample representative for a larger class of inorganic and organic nanostructures, we chose a GaAs/AlGaAs superlattice. We directly measured coherent lattice plane motions with sub-picosecond and sub-picometer accuracy[1].

The spatially periodic femtosecond excitation of the lowest suband in the wells of the superlattice results in coherent lattice motions with a 3.5 ps period, directly monitored by a novel kHz femtosecond-XRD setup. Small changes $\Delta R/R_0 = 0.01$ of weak Bragg reflexes ($R_0 = 0.005$) were detected shown in the figure below. The phase and amplitude of the XRD signal demonstrate the displacive excitation of zone-folded longitudinal acoustic phonons as the dominant mechanism for strong excitation. This result is in contrast to all optical pump-probe experiments on the same material in the weak excitation regime which was shown to be impulsive Raman excitation[2].

Our experiments pave the road to highly sensitive ultrafast X-ray diffraction from nanostructures and biological samples.

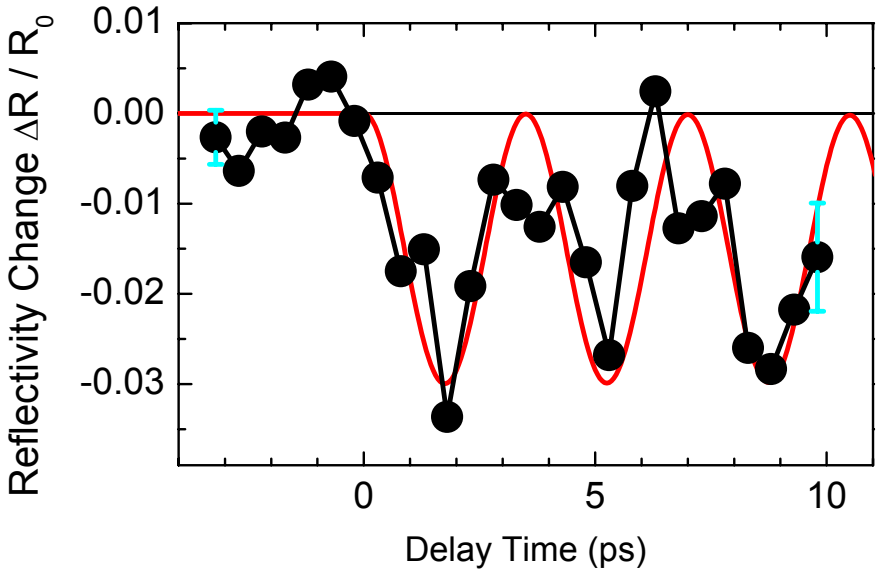

Fig. 1. Transient reflectivity change of the 002 Bragg reflex as a function of the delay time between optical pump and x-ray probe pulses.

[1] Bargheer et al., "Coherent Atomic Motions in a Nanostructure Studied by Femtosecond X-ray Diffraction", Science, **2004**, 306, 1771-1773

[2] A. Bartels et al., "Zone-Folded Longitudinal Acoustic Phonons in Semiconductor Superlattices: Excitation and Detection", Phys. Rev. Lett., **1999**, 82, 1044-1047