Ultrafast x-ray diffraction from coherent phonons

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Using pump-probe x-ray diffraction, we have studied picosecond coherent acoustic phonons generated impulsively by an ultrafast laser. Our results show this technique can be used to measure the strain amplitude during its propagation into the bulk of a single crystal[1]. In the Bragg geometry, the probe length is limited by the shorter of the x-ray absorption and extinction depths. For our example of 10 keV x-rays diffracting from InSb, the probe depth ranges from a few microns for a strong reflection to a few tens of microns for weak reflections. In the Laue geometry, the probe depth is increased to the entire bulk of the crystal. Here, we demonstrate new dynamical effects following ultrafast laser excitation in germanium. This includes the loss (and revival) of anomalous transmission of x-rays in a time < 100 ps, and the generation of Pendellösung oscillations in the diffracted and transmitted (forward-diffracted) beams (Fig 1). These oscillations are interpreted in terms of a multiple crystal model where the length of the crystals increases or decreases at the speed of sound as the coherent acoustic phonon pulse traverses the crystal. Finally, we discuss the possibility of using coherent optical phonons in order to modulate the x-ray pulse on a femtosecond time scale.

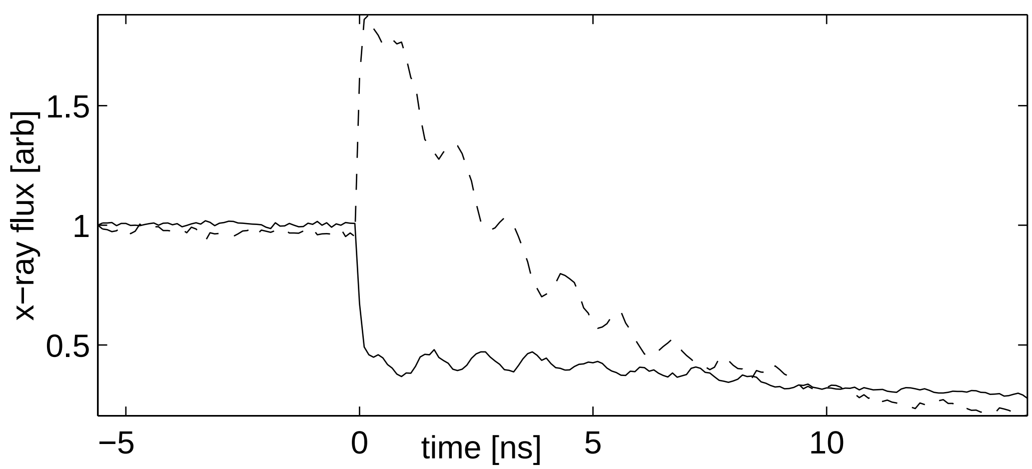

Figure 1: Rapid loss and transient gain in the x-ray transmission (solid) and diffraction (dashed) and Pendellösung oscillations induced by a picosecond coherent acoustic phonon pulse in a 400 micron thick germanium crystal. Not shown is the revival of the anomalous transmission at $\sim$80 ns corresponding to the phonons' arrival at the opposite face of the crystal

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[1] D. A. Reis, M. F. DeCamp, *et al.*, Probing impulsive strain propagation with x-ray pulses, *Phys. Rev. Lett.*, 86(14): 3072–3075, 2001