PHASE TRANSFORMATIONS AND LATTICE DYNAMICS STUDIED BY FEMTOSECOND X-RAY DIFFRACTION

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During the last few years a variety of new X-ray sources for the generation of extremely short X-ray pulses have been under development. The examples include X-ray sources based on femtosecond laser-produced plasmas, which provide multi-kilovolt subpicosecond pulses, typically from atomic K_α-lines. This incoherent X-ray emission can be collected and focused onto a sample and brought into temporal and spatial overlap with an optical pulse. It is thus possible, for example, to optically excite a specimen and use X-ray diffraction to study the subsequent structural changes induced by the optical excitation.

One of the first applications of optical pump/X-ray probe experiments was the study of electronically induced solid-to-liquid phase transformations in semiconductors [1]. Recent X-ray diffraction measurements [2] have confirmed that a transition to the liquid state takes place in a few hundred femtoseconds, following intense photoexcitation of the semiconductor material. These time-resolved X-ray diffraction measurements of ultrafast non-thermal melting processes have demonstrated the sub-picosecond time resolution capability of X-ray experiments using laser-driven X-ray sources [3].

The relaxation of the short-lived, highly non-equilibrium electronic states that can be excited by femtosecond optical pulses generates strong lattice vibrations of both acoustic and optical type. Using time-resolved X-ray diffraction we were able to monitor the rapid changes of the atomic configuration associated with the lattice waves. Examples include picosecond dynamics of laser-induced acoustic perturbations and the observation large amplitude coherent optical phonons.

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