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Publication Date

2001-12-01

Ultrafast X-ray Science: Techniques and Applications

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An important research frontier is the application of x-ray techniques such as diffraction and absorption spectroscopy (XAS, EXAFS, XANES) to investigate structural dynamics (i.e. atomic motion and the making and breaking of chemical bonds) which drive phase transitions in solids, chemical reactions, and rapid biological processes. The fundamental time scale for such processes is an atomic vibrational period, ~ 100 fs. While powerful x-ray structural probes are widely used at modern synchrotrons for probing the “static” structure of materials, the time resolution of synchrotron sources is limited by the duration of the stored electron bunches, typically >30 ps. This tutorial will discuss recent techniques for generating tunable femtosecond x-ray pulses, focusing primarily on approaches which combine femtosecond lasers and relativistic electron beams. In addition, this tutorial will provide an overview of current and proposed scientific applications and associated measurement techniques which use femtosecond x-rays to probe structural dynamics in condensed matter.