Ultrafast X-ray Science at the Stanford Linear Accelerator

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I will report the first results from the Sub-Picosecond Pulse Source at the Stanford Linear Accelerator. This new source of synchrotron radiation produces the brightest ultrafast x-ray pulses in the world, through pulse compression of the relativistic electrons. Ultrafast hard x-rays (E ~ 9keV) at SPPS can probe matter on the length scale of a chemical bond, and capture the quantum dynamics of single molecular vibrations or map chemical reactions as they evolve.

At SPPS we use electro-optic sampling (EOS) to time the arrival of x-ray pulses for time-resolved experiments[1]. An ultrafast laser pulse (135 fs) passes through an electro-optic crystal adjacent to the electron beam. The refractive index of the crystal is distorted by the strong electromagnetic fields of the ultra-relativistic electrons, and this transient birefringence is imprinted on the laser polarization. A polarizer decodes this signal, producing a time-dependent image of the compressed electron bunch. Our measurements yield the relative timing between an ultrafast optical laser and an ultrafast x-ray pulse to within 60 fs, making it possible to use the SPPS to observe atomic-scale ultrafast dynamics initiated by laser-matter interaction.

SPPS has been used to investigate the dynamics of laser-induced melting of InSb[2]. The x-rays probe atomic displacements that show directly the transition from a crystalline solid to a disordered liquid. We have found that at short times the dynamics are inertial, with initial conditions set by room temperature thermal motion

[1]A. Cavalieri, et al., Phys. Rev. Letters (in press, 2005).
[2]A. Lindenberg et al, Science (in press, 2005)