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Ultrafast X-ray Science at the Advanced Light Source: Recent Results and Future Plans

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An important frontier in ultrafast research is the application of femtosecond x-ray pulses to investigate structural dynamics associated with chemical reactions, phase transitions in solids, and rapid biological processes. The fundamental time scale for such processes is an atomic vibrational period, ~100 fs, which is nearly three orders of magnitude beyond the present capabilities of synchrotrons. We have developed a novel technique for generating femtosecond x-ray pulses from the Advanced Light Source (ALS) using ultrashort laser pulses to manipulate the temporal and spatial structure of stored electron bunches[1, 2]. The electron beam is modulated via co-propagation with the laser pulses in a resonantly-tuned undulator. Subsequently, the modulated femtosecond-duration electron bunch is spatially separated from the main bunch by means of a local vertical dispersion bump in the storage ring. Finally, femtosecond x-rays generated from the displaced electrons passing through a second undulator, are imaged onto a pair of slits to discriminate against the long-pulse background x-rays.

Based on this technique, we have constructed a simple bend-magnet beamline for time-resolved x-ray spectroscopy. Current research on this beamline is focused on time-resolved NEXAFS measurements in the correlated electron system VO_2 and on molecular crystals of the spin-crossover complex $[Fe(tpen)]^{2+}$. VO_2 undergoes an insulator-metal transition, accompanied by a structural transformation from monoclinic to rutile, which can be optically induced on the sub-picosecond time scale. The Fe(II) complex undergoes a $\Delta S=2$ spin transition within 500 fs of optical excitation, and this is accompanied by a dilation of the ligand cage of the Fe ion. The goal of our present research is to apply NEXAFS and EXAFS spectroscopy on the femtosecond time scale to elucidate the relationship between electronic and atomic structural dynamics in these systems.

In order to meet the stringent flux requirements for future x-ray spectroscopy on the femtosecond time scale, we are developing an undulator beamline (the Ultrafast X-ray Science Facility) at the ALS, which will be dedicated for time-resolved x-ray research. The facility will consist of a 1.5 T undulator/wiggler, an x-ray beamline operating in the 0.3-10 keV range, and a high repetition rate femtosecond laser systems with an average power approaching 100 W. This contribution will provide a status report of the development of this facility which will provide ~200 fs duration x-ray pulses for a wide range of experiments in ultrafast x-ray science.

References

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