XFD Beamline Instrumentation Competition Proposal

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Proposal: Tunable Laser for Femtochemistry at 7-ID-D

The femtosecond laser located at 7ID-D has enabled new research programs at APS in both ultrafast time-resolved solid-state physics and high field-strength atomic physics. We are proposing an expansion of the existing laser system to permit the gneration of *tunable* femtosecond-duration radiation in order to extend ultrafast time-resolved research at APS to a variety of chemical systems. Amplified 50 fs laser pulses from the existing laser system at a wavelength of 800 nm would be sent into a Non-collinear Optical Parametric Amplifier (NOPA) to produce < 30 fs tunable laser pulses throughout the visible range. Tunable ultrashort UV laser pulses could also be produced with additional optics.

The pioneering experiment demonstrating the marriage of femtosecond laser technology and x-ray radiation from 3rd generation synchrotron sources was performed at 7ID-D. The observation of laser induced modulation of x-ray diffraction in bulk semiconductors first seen in these experiments has become a widely used technique for transient strain analysis as well as a practical method for achieving four-dimensional beam overlap in studies of nonlinear laser/x-ray interaction with solids.

An APS sponsored Worskshop on Ultrafast Science held June 4-5, 2002 determined that the primary interest of the larger user community was femtochemistry, requiring a tunable femtosecond laser to excite chemical reactions which would then be dynamically observed using x-rays via a variety of techniques. Whereas the intense 10 GW peak power 800 nm pulses produced by the existing laser system in 7ID-D are ideal for current MHATT-CAT research which involves generating acoustic waves in solids or achieving high photon densities for atomic physics and nonlinear mixing experiments, femtochemistry with a 3rd generation synchrotron will require studying either native photo-excitable systems or alternatively the use of photo-excitable reagents with absorption lines scattered throughout the visible and ultraviolet spectrum. These include simple molecules, photoacids, photo-crosslinkers, or caged compounds such as caged ATP in biochemical systems. These reagents are now commonly used for experiments on millisecond to femtosecond timescales, usually in an optical pump / optical probe configuration We seek to appeal to the large and growing scientific community that is currently involved in this type of research, but would like to directly study the structural and chemical changes that follow photo-excitation utilizing synchrotron radiation techniques rather than limit observations to secondary signals that happen to be experimentally accessible because they have optical frequencies.

The existing laser system uses a 20 fs laser oscillator synchronized to the circulating current in the APS storage ring to provide a seed pulse for a Chirped-Pulse Amplifier (CPA). Titanium doped Sapphire is used as the gain medium in both the oscillator and amplifier, and only permits a few nanometers of wavelength tuning (and then only with significant operator intervention). The NOPA device that is proposed here instead takes the output of this amplifier (up to 100 GW of peak power) and generates a femtosecond supercontinuum whose temporal phase is controlled using a diffraction grating based shaper to produce a chirped seed signal. The "pump" pulses are tilted to match the "signal" pulses in a nonlinear crystal. The noncollinear geometry allows the use of higher pump energy, which improves the conversion efficiency and therefore the output power. Pulse compression is accomplished using a bulk material with positive group velocity dispersion. A computer is used to tune the NOPA continuously accross the visible range so that the pulsewidth and conversion efficiency are always optimized. The output pulsewidths are under 30 fs, and usually under 20 fs. Over 40 microJoules of energy are available across most of the visible spectrum (hundreds of nm). The repetition rate will be the same as the existing laser system, generally near 1000 Hz, which is commensurate with reasonable data rates and detector speed for a wide variety of experiments.

The NOPA device has a compact design that would comfortably sit on existing optical table space in 7ID-D and would require only minimal changes to laser safety procedures. Broadband visible mirrors are also requested to permit delivery and focusing of the tunable radiation to different experimental setups within 7ID-D.