The SRI2007 Invited Speaker List: the following speakers and topics have been elected by the conference program committee.  Version 12/14/06

# The Cornell Energy Recovery Linac

**Kenneth Finkelstein** (CHESS - Cornell University)

Cornell University physicists have been studying the properties of a new type of synchrotron radiation source, the Energy Recovery Linac (ERL), based on a superconducting linac and one-turn return arc containing undulators and electron optics similar to a storage ring. A full scale prototype of the electron source and essential test sections of the superconducting linac are currently being constructed and tested. The long term goal is to build a 5 GeV, 10 to 100 mA ERL source that can be flexibly operated in high coherence, high flux, and short pulse modes. In high coherence mode, it would provide hard x-ray beams with nearly diffraction limited transverse coherence up to 10KeV. Parts of the ring would include bunch compressors to provide sub-picosecond x-ray pulses. The ERL x-ray pulse structure could range between 2 picosecond width at 1.3GHz to <100 femtoseconds at 1MHz. We provide a brief introduction to the ERL, an update on development of the prototype, a vision of a full scale ERL at Cornell, and examples of the science that could be done with this new source.

# The Compact Light Source: A Miniature Synchrotron for the Home Lab

**Ronald Ruth** (Lyncean Technologies, Inc.)

Past research at Stanford Linear Accelerator Center has introduced a new x-ray source concept, a miniature synchrotron light source [1].  This early research led later to the formation of corporation, Lyncean Technologies Inc., which has recently completed development of the Compact Light Source (CLS)[2].  The CLS is a near-monochromatic, tunable, homelab-size x-ray source with up to three beamlines that can be used like the x-ray beamlines at the synchrotrons--but it is about 200 times smaller than a synchrotron light source.  The compact size is achieved using a laser undulator and a miniature electron-beam storage ring, in other words--inverse Compton scattering from an electron beam in a miniature storage ring.  The CLS is designed to produce a photon flux on sample that is comparable to the flux of highly productive synchrotron beamlines. This presentation will first introduce the basic principles of the Compact Light Source and show how it can bring the quality, tunability and flux of a synchrotron beam line into an x-ray scientist's local laboratory.  The construction of the production-prototype CLS, funded by the NIGMS Protein Structure Initiative, is now complete, and the commissioning and testing phase of the CLS prototype is well advanced.  The presentation will show details of the storage ring, laser system and x-ray optics, and will conclude with results of the testing of the prototype CLS and x-ray optics.

References

[1] Z.Huang and R.D.Ruth, "Laser-Electron Storage Ring", Phys. Rev. Lett., 80:976-979, 1998.

[2] Supported by the National Institute of General Medical Sciences, the National Institutes of Health, R44 GM665011 and R44 GM074437.

# The Linac Coherent Light Source

**John Galayda** (Stanford Linear Accelerator Center)

The Status of the $379M Linac Coherent Light Source (LCLS) Project will be reported, including first results from commissioning the LCLS Injector Linac.

The Linac Coherent Light Source Project will construct and commission the world's first "hard" x-ray laser, operating in the wavelength range 0.15-1.5 nanometers. It will produce short, intense pulses of x-rays ($10^{12}$ photons in 100-200 femtoseconds) at 120 Hz. The LCLS will enable real-time observation of chemical dynamics and structural changes in molecules and materials, on the time and distance scales characteristic of atomic motions.

The LCLS will make use of the last kilometer of the 3 km SLAC linac to produce a highly collimated 3,000 ampere pulse of electrons, accelerated to 14 GeV. The electrons will pass through a 130 meter undulator system, inducing them to produce coherent x-rays. The x-rays will be delivered to experiment stations in two halls located 90m and 400m from the source. Argonne National Laboratory and Lawrence Livermore National Laboratory are institutional collaborators with SLAC in the LCLS Project. ANL is constructing the undulator magnet system and LLNL will provide the x-ray transport, optics and diagnostic systems. UCLA has participated in the LCLS since its conception through accelerator physics investigations of LCLS performance. The project is scheduled to be complete in March 2009. As of April 2007, the construction of the 135 MeV injector linac is complete and studies of its performance are in progress. All 33 undulators are delivered and civil construction of the experimental facilities is well underway.

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# Ultrafast diffractive imaging with the FLASH free-electron laser

**Henry Chapman** (Lawrence Livermore National Laboratory)

The ultrafast pulses of free-electron lasers, such as the EUV FLASH facility at DESY, allow high-resolution imaging of biological and other soft matter without the usual limitations imposed by radiation damage. We carried out high-resolution diffraction imaging of structures using single 25 fs duration, 32 nm wavelength pulses from FLASH. Our objects were placed in the focused FEL beam, with peak intensities up to 10^14 W/cm^2. The objects were heated to about 60,000 K by the pulse, but destruction only occurred after the pulse traversed the sample. We reconstructed images from the finely-sampled coherent diffraction patterns by phase retrieval using the Shrinkwrap algorithm. These images show no evidence of the effects of the pulse on the structure. We also performed quantitative measurements of the explosion of test particles in the focused FEL pulse, by recording their diffraction patterns. No motion occurred during the pulse and we followed the evolution of the explosion with a novel holographic time-resolved technique. Our results confirm the basic principles of flash imaging and lend great confidence to achieving molecular imaging at future short-wavelength X-ray FELs.

# Reflective Optics for Microdiffraction

**Gene Ice** (Oak Ridge National Laboratory)

Reflective microfocusing optics are undergoing a performance revolution that -together with intense synchrotron sources- will enable important new diffraction opportunities for a wide range of science including fundamental materials physics, geology, high-pressure research, and energy materials research. Although most x-ray diffraction is performed with monochromatic beams and precision sample rotations, spatially-resolved diffraction requires new approaches based on wide-bandpass or energy-tunable x-ray beams. Nondispersive focusing is essential for both these approaches and Kirkpatrick-Baez mirrors have emerged as the focusing choice for high-resolution microdiffraction beamlines. The potential of advanced reflective optics for microdiffraction and for other synchrotron science has led to a world-wide race to produce ever smaller x-ray beams with pioneering mirror-fabrication efforts centered in Osaka University, Japan, the European Synchrotron Radiation Facility, France and the Advanced Photon Source, U.S.A. Here we discuss novel beamline optics that allow for flexible microbeam parameters, emerging new technologies for producing ultra-accurate aspherical mirror surfaces and radical approaches required to extend microdiffraction into the 1-10 nanometer regime. We also discuss the expanding range of scientific opportunities based on ever-smaller x-ray probe size. Particular emphasis is placed on science using polychromatic microdiffraction methods for investigating the underlying physical structures and dynamics that determine materials behavior.

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# The use of fast-modulated elliptically polarized soft x-rays in the detection of small polarization signals

**C. Sánchez-Hanke**, S.L. Hulbert, C.-C. Kao (National Synchrotron Light Source)

The availability of high quality circularly- and linearly-polarized soft x-rays from insertion devices has driven the use of powerful experimental tools such as Magnetic Circular Dichroism (MCD) and Magnetic Linear Dichroism (MLD) in the study of magnetic materials. Almost every storage ring has, or is planning to have, at least one beamline delivering elliptically polarized soft x-rays to a variety of experiments. It has become popular to utilize the contrast provided by MCD and MLD in many types of synchrotron measurements, including spectroscopy, scattering, and microscopy.

A unique Elliptically Polarizing Wiggler (EPW) is installed in the X13 straight section of the 2.8 GeV X-ray ring at the National Synchrotron Light Source, Brookhaven National Laboratory. The current in the EPW electromagnets can be sinusoidally driven at rates up to 100 Hz, delivering left and right elliptically polarized x-rays at the modulation frequency. At present, the switching frequency used for standard operations is 22Hz, the fastest operational rate achieved by an

insertion device, and tests at higher frequencies are currently underway. Modulating the polarization at frequencies higher then a few Hz facilitates the implementation of a phase sensitive detection scheme via the use of lock-in amplifiers. Increasing the switching rate improves measurement sensitivity, thereby enhancing the ability to measure small induced magnetic moments, low concentrations of magnetic materials. Phase sensitive detection also allows one to measure, in a single scan, the sum and difference signals of left and right elliptical polarizations, which provide charge and magnetic information, respectively. By selecting the incident photon energy close to an absorption edge of one of the elements present in the sample, one can perform resonant magnetic experiments.

The NSLS X13A beamline utilizes the EPW source to perform soft x-ray spectroscopy, scattering, and element-specific hysteresis measurements in a high-vacuum endstation which features a two-circle diffractometer and the capability to cool samples to ~20K and to apply magnetic fields up to 0.2T to the sample. Experimental data demonstrating the sensitivity of fast-switching polarization measurements will be shown, including the improvement in sensitivity with increasing switching frequency.

Other schemes for generating fast-switching elliptically polarized soft x-rays exist, including the use of two canted fixed-polarization elliptically polarized undulators and a mechanical chopper in the beamline. A comparison of the various schemes will be discussed.

# Sub-meV Hard X-ray Optics

**Thomas S. Toellner** (Argonne National Lab)

High-resolution spectroscopies that use hard X-rays like nuclear resonant scattering and inelastic X-ray scattering require monochromatization to the meV level or better. Monochromators that produce meV and sub-meV bandwidths in the 10-40 keV energy range typically exhibit degraded performance due to thermally-induced deformations within the diffraction material (silicon). The premonochromated x-ray beam, which produces a "mini-heat load", and other heat sources are responsible for the offending temperature variations. Cooling the silicon to its zero-thermal-expansion-coefficient temperature (123 K) is a way to mitigate the thermally-induced deformations and their effects. Reducing the operating temperature also enhances the intrinsic reflectivity. Due to the very fine angular control needed (25 nrad) for monochromator operation any usable cryostat must be practically vibration free. A low-vibration cryostat has been developed and implemented into a number of meV-monochromators with very beneficial results. The performance of cryogenically-stabilized high-resolution monochromators and the implication of cryogenic-stabilization for substantially improving energy resolution will be discussed.

This work is supported by the U.S. Department of Energy, Office of Science, Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

# Specialized new Soft X-ray Beamlines for the Advanced Light Source

**Tony Warwick**, Malcom Howells, Howard Padmore (Advanced Light Source)

New soft x-ray beamlines for the Advanced Light Source are designed and implemented for special purposes. For PEEM, a new beamline is operational with high precision energy reproducibility. Two new beamlines are planned for coherent scattering and diffractive imaging. These must preserve the recently improved brightness of the synchrotron source, and deliver the coherent fraction at modest spectral resolution. For photoemission a new beamline will provide higher resolution (1:30,000) at low energy (below 100eV) for ARPES, and deliver the coherent fraction for zone plate nanoARPES. These designs involve the use of elliptically polarizing undulators, some varied line space gratings, advanced optic substrates for cooling, high precision profile monitors and high precision brightness-preserving optics. The upgraded Advanced Light Source, with top-off injection, places exciting new demands on beamlines, and drives their development.

# New Opportunities with VUV and Soft-X-Ray Free Electron Lasers: Biological Systems

**Robert Austin** (Princeton Univ.)

Biology is deeply influenced by the structure of biomolecules, the dynamics of biomolecules, the way that biomolecules interact with each other, and how the cellular architecture is influenced by the structure and dynamics of the molecular components. At its most fundamental level, the length scale of these structures and dynamics of primary biological components is on the 1-100 nm length scale. Although there are ingenious optical techniques that reach into that length domain, they involve highly specific and robust optical probes and averaging techniques to find the standard deviation of the mean, greatly limiting our ability to observe the real-time dynamics of cell components at a fundamental level. It is now clear that unraveling the response of cells to ionizing radiation is critical for understanding many fundamental problems in biology, from aging to apoptosis (programmed cell death) to the origins of cancer. Since a cell is spatially highly heterogeneous, simply irradiating cells results in the activation of many different biological pathways. The high brightness of a coherent X-ray/VUV light source would allow irradiating cell components with 100 nm or better spatial resolution, which would be a major step forward in unraveling the response of cells to genomic and component damage.

# The BioMedical Imaging and Therapy Beamlines at the Canadian Light Source – Building the Scientific Program

**Dean Chapman** (University of Saskatchewan)

The BioMedical Imaging and Therapy (BMIT) beamlines project is presently under construction at the Canadian Light Source in Saskatoon, Saskatchewan, Canada. The project includes a bend magnet beamline, insertion device beamline as well as a biomedical laboratory complex to support the broad range of research planned. The systems which can be investigated will include live animals and ultimately human studies. First light on the bend magnet beamline is expected in the summer 2007 followed by the insertion device beamline in the late fall of 2007. This presentation will briefly touch on the layout, present status and ultimate facility capabilities and arrangement. Also, some discussion on where this facility fits in world-wide with regard to other synchrotrons. Most of the discussion will be on the building of the scientific program for BMIT presently underway using other facilities and other CLS beamlines. These programs are in the area of cancer therapy research, imaging of tumor cell migration or metastasis, imaging of growth plate fractures, spinal column fusion research and gene expression imaging research.

# New x-ray spectroscopy and imaging detector developments at BNL

**D. Peter Siddons** (National Synchrotron Light Source)

The talk will describe ongoing developments at BNL in the two fields of x-ray spectroscopy and x-ray imaging detectors. The new spectroscopy system is primarily aimed at the synchrotron x-ray microprobe community, and is an integrated system consisting of multi-element silicon detector, scanning system and real-time data deconvolution and processing. The imaging detectors under development are designed specifically to satisfy the needs of the LCLS project at Stanford. These same devices will, however, be powerful detectors for synchrotron users, and we will discuss their design and current state of development.