Diffractive Optics for Femtosecond Manipulation of X-Rays

B. W. Adams

Argonne National Laboratory
Argonne, IL 60439
E-Mail: adams@mail.desy.de

X-ray beams propagating in a crystal under diffractive conditions can be manipulated through laser-induced controlled changes in the crystal diffractive properties. These changes can be very fast because a coherent motion of charges within Ångströms can already have a drastic effect on the crystal structure factors. Optical phonon oscillation periods are well below 1 ps and bond-breaking can occur within femtoseconds. In materials made of light elements, such as diamond, the majority of electrons is in the chemical bonds and a strong effect can be expected from the latter. Because the interaction of x-rays with electrons is relatively weak, interaction volumes must be much larger than the distance that x-rays travel within femtoseconds. It is therefore important to match the spatio-temporal profile of the crystal structure manipulation to the x-ray propagation itself, according to a time-dependent dynamical diffraction theory.

Such a theory, describing x-ray diffraction in a unified space-time approach and capable of describing cases where the time scale of the crystal structure changes is comparable to, or less, than the x-ray interaction time (reciprocal energy bandwidth or pendellösung time) is presented. Potential applications are shown, such as a femtosecond-resolving x-ray “streak camera”, working on the principle of ultrafast x-ray beam steering in a crystal.

Photon-Atom Interactions and Their Applications

Paul M. Bergstrom, Jr.

National Institute of Standards and Technology
100 Bureau Drive, Gaithersburg, MD 20899-8460
E-Mail: paul.bergstrom@nist.gov

Ionizing radiation is utilized in many industrial, medical and research applications. In trying to understand, enhance and develop technologies that utilize ionizing radiation, atomic data and tools to utilize these data sets are essential. This talk describes the evolution of data sets from exploratory experiments and computations to database development and finally to their use in applications. NIST's Ionizing Radiation Division's efforts in these areas are discussed.

Probing Dynamics from Within

N. Berrah[1], *R. Bilodeau*[1], *J. D. Bozek*[2] *and G. Ackermann*[2],
S. Canton[1,2], *and E. Kukk*[3]

[1]Physics Department, Western Michigan University, Kalamazoo, MI 49008
[2]Lawrence Berkeley National Laboratory, ALS, Berkeley, CA 94720
[3]Department of Physical Sciences, Oulu University, Linnanmaa, Oulu FIN-90570, Finland
E-Mail: berrah@wmich.edu

We have investigated with unprecedented levels of detail, processes and phenomena involving photodetachment of negative ions and photoionization of clusters using the brightness, spectral resolution, tunability and polarization of the Advanced Light Source at Lawrence Berkeley National Laboratory. In particular, we will report on investigations carried out in K-shell photodetachment of atomic Li^- and He^-, which exhibit structure differing substantially from corresponding processes in neutral atoms and positive ions, owing to the dominance of correlation in both the initial and final states. We will also report on a photoionization investigation in C_{60} that allowed observation of dynamic Jahn–Teller effect in free C_{60}^+.

Synchrotron Radiation based Perturbed Angular Correlation – An Application to Soft Condensed Matter Physics

Susanta Dattagupta

Bose Research Institute
Kolkata, India
E-Mail: sdgupta@bose.res.in

I will discuss a new technique SRPAC (Synchrotron Radiation based Perturbed Angular Correlation) and one application to soft condensed matter physics. The technique is to selectively excite a resonant nuclear level by X-ray and look at the angular distribution of the resonantly emitted gamma ray with respect to the direction of the incident synchrotron X-ray. The information can be used to study the extranuclear perturbation in the excited level. I will summarise an application to quadrupolar relaxation in a glass forming supercooled liquid.

Some Recently Found Interchannel Coupling Effects in Atomic Photoionization Processes

P. C. Deshmukh

Department of Physics
Indian Institute of Technology – Madras
Chennai – 600 036, India
E-Mail: phypcd@iitm.ac.in

Electron correlations resulting in interchannel coupling between ionization/excitation channels have been known to affect atomic photoabsorption processes. Alternate pathways produce interference effects that affect photoionization parameters in a dramatic and measurable manner. For several decades these effects have been known to play a crucial role toward the understanding of near-threshold (Johnson and Lin, 1979) phenomena in particular, and also photoionization at intermediate energies (Shanthi and Deshmukh, 1990). In recent years, interchannel effects have been found to influence photoionization processes that were not known for their sensitivity to such correlations. For example, relativistic dynamical effects were found to affect the photoelectron angular distribution parameter (Wang et al., 2001), and photoionization well-above ionization threshold (*which is normally believed to be described well-enough by the Independent Particle Approximation*) was also found to be influenced dramatically by interchannel coupling effects (Hansen et al., 1999; Amusia et al., 2001). This unusual 'high-energy' effect has been now found to be operational also in several ions in the Ne isoelectronic sequence (Chakraborty et al., 2003), though the effect becomes weak with increasing Z in the sequence. Likewise, strong correlation effects have been found in spin-orbit activated interchannel coupling effects (Amusia et al., 2002). Some of these recently found interchannel coupling effects are discussed in this paper.

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Synchrotron X-Radiation in Studies of Layered and Self-Assembled Structures

B. N. Dev

Institute of Physics, Sachivalaya Marg
Bhubaneswar 751005, India
E-Mail: bhupen@iopb.res.in

Layered synthetic microstructures (LSMs), consisting of thin layers of alternating elements or compounds, have unique structural, electronic and magnetic properties with a wide range of applications. These include x-ray astronomy, microscopy, spectroscopy and magnetic applications. Properties of these multilayer systems strongly depend on interface roughness and impurity concentrations in the layers. In a Co/Cu/Co/.. multilayer system the presence of a small amount (just a few percent) of Ni in the Cu spacer layers can drastically change the magnetic coupling and magnetoresistance. Co/Pt/Co/.. multilayers, when exposed to energetic ion beams, show a spin reorientation transition. Such systems are suited for patterned ultrahigh density recording media. Energetic ion beams cause atomic displacements across the multilayer interfaces, thereby roughening the interfaces and introducing one material into the other as impurities. As both these aspects affect the properties of LSMs, it is important to analyze these aspects. Analysis of periodic LSMs by a combined x-ray standing wave (XSW) and x-ray reflectivity measurement has been shown to provide information on both these aspects [1,2]. Use of synchrotron x-radiation (SXR) for the analysis of LSMs will be presented. It is also possible to tune the antinodal position of the XSW within the period of the multilayer and explore the local environment of the impurities at specific depths by combining EXAFS with XSW experiments.

It is possible to obtain resonance enhancement of x-rays in layered systems. Some applications of this enhancement will be discussed [3].

Self-assembled epitaxial nanostructures have some advantages over lithographic fabrication of lower dimensional (1D and 0D) nanostructures from 2D epitaxial layers. Especially, structures smaller than the limits of conventional lithography can be obtained by self-assembled growth. We grow self-assembled nanostructures by molecular beam epitaxy (MBE) [4]. Studies of MBE-grown self-assembled structures using SXR will be presented.

X-ray free electron laser (XFEL) will probably be available in the near-future. Use of XFEL for the studies of MBE-grown layers and other surface/interface related issues will be discussed.

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Attosecond Light Pulses

L. F. DiMauro

Brookhaven National Laboratory
Upton, NY 11973 USA
E-Mail: dimauro@bnl.gov

The invention of the laser over four decades ago has unquestionably led to this renaissance in science and technology. In this talk we will examine the frontiers of modern ultra-short light sources. We will discuss how the tailoring of a fundamental interaction of an intense laser with an atom in the laboratory can result in pulses of coherent light on the atomic time-scale (10^{-18} seconds) and signify the first direct probe of the electron's motion in the time domain.

Future Directions in High-Field and High Energy-Density Science Using Intense, Ultrafast Lasers

T. Ditmire

Department of Physics
University of Texas at Austin
Austin, TX 78712
E-Mail: tditmire@physics.utexas.edu

The increasing proliferation of 100 TW class ultrashort pulse lasers and the near completion of a number of petawatt class lasers world wide is opening a wide frontier in laser science. The applications of these lasers now span fields ranging from plasma physics to medicine. One of the new frontiers opened by these lasers is in high energy-density (HED) science. A multi-TW laser can create heated matter at temperature up to many keV at density reaching up to and beyond that of a solid. This capability now makes possible detailed study of an array of exotic physics, including Gbar pressures in heated solids, radiative hydrodynamics and nuclear fusion. Lasers with powers of a PW or more will make possible study of even more extreme conditions, including relativistic plasmas. This entire class of hot dense matter is interesting in its own right, but is also of great interest for the applications it opens, such as the ability to make bright sources of energetic particles (protons, neutrons, electrons and gammas) or the possibility to access astrophysically relevant conditions. In this talk I will review some of the recent advances in high energy density science made using high intensity short pulse lasers with illustrative examples from work performed in my group. I will also conjecture on some of the future directions in HED science that can be exploited with the latest petawatt laser technology.

Self-Assembly and Electronic Structure of Low-Dimensional Systems

F. J. Himpsel

Department of Physics
University of Wisconsin, Madison
Madison, WI 53706
E-Mail: fhimpsel@facstaff.wisc.edu, http://uw.physics.wisc.edu/~himpsel/

Two- and one-dimensional structures can be produced at surfaces by self-assembly, for example a two-dimensional electron gas, one-dimensional atoms chains, and an atomic scale memory where a bit is stored by the presence or absence of a single atom. This talk will show how synchrotron radiation can assist both in their fabrication and analysis. Near edge x-ray absorption fine structure spectroscopy (NEXAFS) is useful as a diagnostic tool in the synthesis and self-assembly. Examples are arrays of nanoclusters and self-assembled monolayers (SAMs) of organic molecules, including DNA. Angle-resolved photoemission is capable of providing the full complement of quantum numbers for two- and one-dimensional systems, including Fermi surfaces and energy bands. Exotic 2D and 1D structures are formed by gold on stepped silicon surfaces that exhibit intricate superlattice Fermi surfaces, tunable 2D/1D coupling, and fractional band filling.

Application of Laser Matter Interaction for Generation of Small Sized Materials

Alika Khare

Physics Department
Indian Institute of Technology, Guwahati 781039, India
E-Mail: alika@iitg.ernet.in or k_alika@yahoo.com

Synthesis of nano particles have drawn considerable interest in the recent past because of their ability to offer superior properties to those of bulk materials. For structures with dimensions below 100 nm, quantum confinement plays a crucial role in changing the optical, electrical mechanical, thermal and magnetic characteristics of the materials from its bulk behaviour and offer the tremendous scope in microelectronics, optoelectronics and photonics industries. Reduction into the size of the materials can be performed with great precision via laser matter interaction. We focus here on following three coming up schemes, **a**. Selective ablation of thin films via high power laser Interferometry, **b**. Synthesis of nano particles via laser liquid interaction and **c**. Manipulation of atomic trajectories via dipole force to manipulate the materials to dimensions of the order of nanometer using lasers. First two schemes are general and can be applied to any species (pure element, molecules, composites). In the selective ablation, the thin films of any material can be selectively ablated by illuminating with the interference pattern formed by interference of multiple beams from a pulsed high power laser. The interference patterns are periodic so the surface morphology will be modified into two-dimensional periodic arrays of sizes less than $\lambda/4$. In the second scheme a wide spectrum of nano particles can be synthesized via laser- liquid Interaction. A high power laser is focused in an appropriate liquid. This results into the breakdown of the liquid and plasma formation giving rise to a high pressure, high temperature bubble formation. This bubble contains vaporized solution and condenses into nanosized small particles of metal species and their compounds depending on the solute and the solvent. In the last technique the direct deposition of atoms and molecules are performed by focusing it in presence of dipole force exerted on to the atom/molecules because of intensity gradient in the near resonant light field. If the intensity gradient is created via interference of near resonant laser beam than the resulting deposited structure will be periodic. This technique is applicable to atomic beams and beams of stable molecules only.

Free-Electron Lasers: Physics & Potential

Srinivas Krishnagopal

Beam Physics & FEL Laboratory
Centre for Advanced Technology, Indore, India
E-Mail: skrishna@cat.ernet.in, skrishna@tifr.res.in

Free-electron lasers (FELs) are classical lasers that can provide intense, short-pulse, broadly tunable coherent radiation over the entire electromagnetic spectrum. There are a number of FEL facilities around the world in the infrared and far-infrared. FELs based on the Self Amplified Spontaneous Emission (SASE) principle are now being developed around the world as highly intense X-ray lasers and fourth-generation light sources. We discuss the physics of FELs, and their potential applications.

Dynamics of Intense, Femtosecond Laser- Matter Interactions

G. Ravindra Kumar

Tata Institute of Fundamental Research
Mumbai (Bombay) India
E-Mail: grk@tifr.res.in

The last decade has seen an explosion of activity in the area of intense, ultrashort light pulse-matter interactions. The ready availability of table-top terawatt lasers has sparked off this growth and interesting new physics continues to be discovered and pursued. Such lasers can create extremely excited states of matter and some of the phenomena that are being studied include – creation of 'supersolid' density plasmas with keV-MeV electron energies, relativistic nonlinear optics, and generation of femtosecond x-ray and γ-ray pulses. Some of the impressive spin-offs of this research include new particle accelerator schemes, real time monitoring of lattice dynamics in solids (with potential applications to biological systems like proteins), new schemes for laser induced fusion and experimental laboratory astrophysics[1].

At the Tata Institute, we have recently become interested in the study of such high-density plasmas with a special focus on the mechanisms of light coupling to the plasma, role of surface roughness in the coupling[2], study of the generated 'hot' electrons, x-ray emission processes and megagauss magnetic fields produced by this interaction. We have demonstrated[3] the ultrashort duration of megagauss magnetic 'pulses' and the role of anomalous turbulent resistivity in their damping. In addition, we have shown an order of magnitude enhancement in x-ray yields (10-300 keV region) in nanoparticle coated copper targets[4]. We have also mapped the solid-state properties from normal to the high temperature domain. In this talk, I will present some of these results after a brief introduction to the basic physics of intense light-matter interaction.

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Large Nondipole Effects in Atomic and Molecular Photoemission

Dennis Lindle

Department of Chemistry
University of Nevada, Las Vegas, NV 89154
E-Mail: lindle@unlv.edu

For decades, the electric-dipole approximation has been used routinely to simplify the description of atomic and molecular interactions with VUV and soft-x-ray photons. In the past few years, however, new experimental evidence has demonstrated significant breakdowns in the dipole approximation for photon energies as low as a few tens of eV. At these low energies, the breakdowns result primarily from first-order nondipole effects attributable to electric-quadrupole and magnetic-dipole interactions. To this level of approximation, the photoionization cross section remains unperturbed; the primary effect is a redistribution of the angular-emission pattern of photoelectrons, leading to forward/backward asymmetries with respect to the photon-beam direction. Such rearrangements of photoelectron emission patterns are ubiquitous in both atomic and molecular photoemission. For example, in N_2, a large nondipole core-level resonance appears just 70 eV above the *K*-shell threshold. It corresponds to approximately a factor-of-two forward/backward asymmetry in the photoelectron emission pattern and is related to bond-length-dependent terms in the nondipole interaction amplitudes. Even larger asymmetries occur just above core-level thresholds (~20 eV kinetic energy) for N_2 and other small molecules. A summary of these large, unexpected, and unexplained phenomena at low energies will be presented.

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Many-Body Effects and New Phenomena in Atomic and Molecular Photoionization

Steven T. Manson

Department of Physics and Astronomy
Georgia State University, Atlanta, GA 30303
E-Mail: smanson@gsu.edu

The interplay between theory and experiment has stimulated the uncovering and understanding of a broad range of new phenomena in atomic and molecular photoabsorption processes, brought about by the advent of third-generation synchrotron light sources, on the experimental side, and vastly enhanced computing power on the theoretical. Among the examples of the new physics explored involves nondipole effects in atoms and molecules at very low photon energies (tens or hundreds of eV) and the influence of many-body correlations on them, core level photodetachment of negative ions and the structure engendered by the photoelectron emerging through the charge cloud of the outer, loosely-bound electrons, and the photoionization of confined atoms and ions trapped, e.g., in a C_{60} cage, and the modifications to the photoionization cross section resulting from the confinement.

Irradiation of Atomic and Molecular Clusters by Strong Optical Fields

Deepak Mathur

Tata Institute of Fundamental Research
1 Homi Bhabha Road, Mumbai 400 005, India
E-Mail: atmol1@tifr.res.in

In the optical regime, light intensities larger than 10^{12} W cm^{-2} are termed "intense"; electric fields generated in such light are strong enough to cause non-perturbative effects in most atoms and molecules. Multiphoton and/or tunnelling effects force nearly every irradiated atom and molecule to ionize. Much effort has been devoted to studies of atoms and molecules in such fields. Among the dominant effects observed are above-threshold ionization (ATI), tunnelling ionization, high harmonic generation, molecular alignment, and enhanced ionization of molecules. Experiments that probe such phenomena are typically conducted under conditions such that the atoms and molecules respond independently to the laser field - the density is kept low enough so that each atom/molecule is "unaware" of the presence of others in the neighbourhood. This is not so for high-density solids, where macroscopic fields that are generated due to charge separation play a crucial role, and recourse has to be taken to plasma models to gain insight into the dynamics of laser-solid interactions. Gas-phase clusters act as a bridge between the low-density and high-density systems. Large atomic clusters, consisting of several hundred to several hundred thousand atoms per cluster, provide the high density required for substantial absorption of laser energy. Experimentally, it has been discovered over the last few years that when such clusters are exposed to an intense ultrashort laser pulse, they absorb energy very efficiently. We have applied two-dimensional time-of-flight (TOF) spectrometry to probe the disassembly of atomic clusters like Ar_{40000} and Xe_{150000}, and of molecular clusters, like $(N_2)_n$ [n=50-3000], in strong optical fields. Such clusters yield energetic and very highly charged atomic ions. The ion energy distribution is found to have two components: a low-energy, isotropic component that correlates with a Coulomb explosion mechanism, and a high-energy, anisotropic component that results from a "charge-flipping" acceleration mechanism that yields ion energies *larger* than those expected from purely Coulombic considerations.

The MIT X-Ray Laser Project

David E. Moncton

Argonne National Laboratory, and
Department of Physics, Massachusetts Institute of Technology
E-Mail: dem@aps.anl.gov

Recent advances in accelerator, laser, and undulator technology have created the possibility of constructing a national user facility based on an intense free-electron laser at extreme ultraviolet and x-ray wavelengths. MIT is exploring the construction of such a facility at its Bates Laboratory site, 20 miles north of Cambridge. The science that is foreseen spans many disciplines including atomic and fundamental physics, condensed matter physics and materials sciences, femtochemistry, structural biology, and various fields of engineering. The source we propose, and the experimental methods it will spawn, will generally be qualitatively new and have high impact in many fields of science and technology. The strength of the science and technology base in the northeast region, and in particular at MIT, make this a superb location for such a national user facility.

Three key elements of the facility we envision would make it unique. First, a 4-GeV linear accelerator with superconducting radio frequency cavities would produce such high electron pulse rates that twenty or more beamlines could be extracted to serve a large user community. Second, integrated high-harmonic generation laser technology would seed the electron beam and generate photon beams with high longitudinal coherence and pulse lengths significantly below 100 femtoseconds, perhaps below 1 femtosecond. Third, taking advantage of the ability of linear accelerators to extract beams at different energies, we envision a facility spanning both the traditional extreme ultraviolet and x-ray wavelength range. This approach provides for integration and synergy between the UV and x-ray communities and the laser community, where scientists are anxious to move to wavelengths shorter than conventional table-top technology can provide with high pulse power. A three-year study has begun to develop a construction proposal, optimizing the machine for the remarkable science and education opportunities it will enable, and to proceed with the necessary preparations to be ready for construction in 2007.

History, Present Status and Future Plans of Indian Synchrotron Radiation Sources

R. V. Nandedkar

On behalf of the Indus team,
Center for Advanced Technology, Indore 452013, India

India has a large community of x-ray users and also has a good history of spectroscopy related research using ultraviolet, visible and infrared portion of the electromagnetic spectrum. Raman effect is an example of this. Taking into account the need of this scientific community of having an in-house synchrotron radiation source, the Department of Atomic Energy decided to construct such a facility for the country. After a series of discussions and seminars with the users, it was decided to construct two such sources, one for the soft x-rays and vacuum ultra violet rays and the other for x-rays. These sources are named as Indus-1 and Indus-2 respectively.

The construction of these sources started in the late eighties right from the selection of site at Indore. Indus-1 was commissioned in 1999 and is now operational with 4 beamlines working. Indus-2 is under construction and is expected to be ready soon. In the future it is proposed to install three insertion devices in this ring.

In this talk, a brief historical review of the project, status of both Indus-1 and Indus-2 and their beamlines and the future plans will be discussed.

VUV Molecular Physics and Third (and Fourth) Generation Light Sources: Opportunities And Outlook

Erwin Poliakoff

Department of Chemistry
Louisiana State University, Baton Rouge, LA 70803
E-Mail: epoliak@lsu.edu

Recent photoelectron spectroscopy and dispersed fluorescence measurements on the photoionization of polyatomic molecules demonstrate that nominally forbidden vibrations are excited with surprising intensity, and that their energy dependences elucidate why they are occurring. The unifying theme of these results is that the continuum photoelectron exerts significant influence on which vibrations are excited and the degree of excitation. The data that will be discussed are generated via high resolution photoelectron spectroscopy coupled with high brightness synchrotron radiation. Results are presented on the linear triatomic systems CO_2, CS_2, and N_2O. For these molecules, all vibrational modes are excited, including bending and asymmetric stretching vibrations. Moreover, the energy dependences for the alternative vibrational modes exhibit dramatic differences, which is attributed to the degree and type of localization experienced by the continuum photoelectron in the molecular framework. While the electronic structures of these molecules are very similar, they behave very differently from each other, even over a very broad energy range. Theoretical results by Prof. R. R. Lucchese will be discussed, and the comparison with experiment helps to illuminate our understanding of these phenomena. Preliminary results will be reported on BF_3, as well as extensions to other types of systems.

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Tutorial on Fundamentals of Radiation Physics
Interactions of Photons with Matter

R. H. Pratt

Department of Physics and Astronomy
University of Pittsburgh, Pittsburgh, PA 15260 USA
E-Mail: rpratt@pitt.edu

We review the status of theoretical and experimental work on the basic photon-atom processes, focusing on a single photon interacting with an isolated atom. We consider both the general situation, recent work, current issues, and future opportunities. The processes are (1) photoabsorption, resulting in excitation and single or multiple ionization, (2) photon scattering, both elastic and inelastic, and (3) pair production processes. We consider the interplay of theory and experiment in describing the observables in these processes, and what happens in proceeding from exclusive to more inclusive descriptions. We consider the progression from classical to quantum, and from non-relativistic to relativistic, description. We consider the progression from dipole to full multipole description of radiation. We consider the progression in the description of atomic structures and their interactions, from charge distributions of electrons around point Coulomb nuclei, with bound or continuum electrons in such fields, to correlated structures also with correlated continuum interactions. In photoabsorption recent work has focused on the adequate description of correlations, the role of higher multipole and relativistic effects, high energy behavior, and multiple ionization processes. In photon scattering recent work has focused on the importance of effects beyond independent particle approximation at low energies (correlation and exchange), the observation of infrared rise for soft final photons, the validity of impulse and incoherent scattering factor approximations, and multiple ionization processes.

Ultrafast X-Ray Physics

David Reis, Philip Bucksbaum, and Matthew DeCamp

FOCUS Center and Department of Physics
University of Michigan
E-Mail: dreis@umich.edu

Until recently x-ray techniques have been limited to measurements of static structure and relatively slowly varying dynamics. Dynamics on atomic spatial and temporal scales has now been demonstrated in several pioneering experiments.

We present results on the ultrafast laser-excitation of solids to manipulate synchrotron x-ray pulses. We have recently demonstrated coherent control of x-ray pulses on the tens of picosecond time-scale mediated by coherent acoustic phonon excitation in semiconductors. This research provides insight into transient strain generation and propagation and coupling of carriers to the lattice in the dense-electron hole plasma regime. In addition, control can be extended to femtosecond modulation using optical phonon or electronic excitations culminating in femtosecond time-resolution at synchrotron sources.

Growth Mechanism and Thermal Properties of Thin Organic Films

Milan Sanyal

Surface Physics Division, Saha Institute of Nuclear Physics
1/AF Salt Lake, KOLKATA 700064, India
E-Mail: Milan@lotus.saha.ernet.in

The physical properties of materials confined in nanometer length scale exhibit interesting deviation from the properties of the corresponding bulk materials. Here we shall discuss results of our recent synchrotron x-ray scattering studies on growth mechanism and thermal properties of thin organic films. We have observed evolution of the conventional melting of 3D solids having fixed melting transition temperature from a continuous melting, which is a characteristic of low-dimensional materials, as a function of thickness of metal-organic films deposited using Langmuir Blodgett (LB) technique. We shall also discuss results of energy dispersive x-ray reflectivity measurements carried out at the BESSY-II synchrotron on polystyrene and polyacrylamide films as a function of temperature. We observed reversible negative thermal expansion coefficient below the glass transition temperature of polymers.

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Advanced Photon Source: Science Retrospect and Prospect*

Gopal Shenoy

Advanced Photon Source
Argonne National Laboratory, Argonne, IL 60439
E-Mail: gks@aps.anl.gov

This overview will provide a brief introduction to the development of the synchrotron radiation field and discuss the science drivers that defined the Advanced Photon Source. Successful efforts over the years towards higher spatial, temporal, momentum, and energy resolution, as well as use of x-ray polarization and partial coherence are continuing to produce forefront science at the Advanced Photon Source. These advances have resulted from continued enhancement in the average brightness of x-ray beams, control of polarization, x-ray pulse delivery pattern, constant-intensity operation, and matching x-ray optical schemes. The success will be illustrated through selected examples. The ascending scientific success of the Advanced Photon Source will continue through the development of superior real-time and real-space techniques to study spin and charge dynamics and through further enhancement of average brightness, which will increase the feasibility of many energy- and momentum-resolution experiments that are currently marginal. Before the turn of the decade, we expect ceaseless advances in the synchrotron radiation field with the advent of x-ray free-electron lasers, which will provide fully coherent beams of x-rays with unprecedented peak brightness and femtosecond resolution.

It is the intent of this overview to set the stage for more detailed discussions consistent with the objective of the workshop.

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Photon-Atom Interactions in the X-Ray Energy Region

Nirmal Singh

Department of Physics, Panjab University
Chandigarh-160014, India
E-Mail: nsingh@pu.ac.in

The invited talk will focus on the research work done by the XRF group at Chandigarh covering different aspects of elastic and inelastic scattering of photons by atoms and processes associated with inner-shell photoionisation. The experimental set up involved photon sources consisting of ^{55}Fe, ^{109}Cd and ^{241}Am radioisotopes and an energy dispersive spectrometer with an Si(Li)/HPGe detectors. Elastic and inelastic scattering cross sections have been measured at the 22.1, 59.5 and 88.0 keV photon energies for elements with Z= 1-92 at scattering angle ~120^{o}. Investigations were also done on the KL- and KM-resonant Raman scattering (RRS) cross sections at the 59.536 keV photons for $_{70}$Yb (B_K= 61.332 keV), $_{71}$Lu (B_K= 63.316 keV) and $_{72}$Hf (B_K= 65.345 keV). It is observed that the relative cross sections for the KM to KL_i (i=1,2) RRS deviate significantly from those for the normal fluorescence X-rays. Also, the L_i (i=1,2,3) sub-shell fluorescence yields and the L_1-L_3 Coster-Kronig yield for the elements with $70 \leq Z \leq 92$ were measured using the method of selective photoionization. In addition, alignment of ionized atoms following inner-shell photoionization has been investigated in some high-Z elements by measuring angular dependence of the emitted of L x-rays. Our experiments have ruled out the recently reported large anisotropy for the X-rays from the L_3 subshell (J=3/2).

Application of Synchrotron Radiation Techniques to Nanoscience

Sunil K. Sinha

University of California, San Diego and
Los Alamos National Laboratory
E-Mail: ssinha@physics.ucsd.edu

The development of high-brilliance synchrotron radiation sources have provided powerful new methods for probing the structure and dynamics of nanostructured materials. We shall review some of the recent applications of synchrotron radiation techniques to the study of nanomaterials These include both scattering and real-space imaging methods and the use of coherent X-ray beams for studying nanostructures, the use of resonant magnetic scattering to study magnetic nanostructures, and the use of photon correlation spectroscopy to study their dynamics. Examples will be given of application of such techniques to the study of magnetic dot and hole arrays, structure of confined nanofluids, films exhibiting exchange bias and spin valve effects, spin injection into semiconductors, and carbon nanotubes.

The ALS on Completion of its First Decade

Neville Smith

Lawrence Berkeley National Laboratory
Berkeley, CA 94720
E-Mail: NVSmith@lbl.gov

The Advanced Light Source, a third-generation synchrotron facility optimized for ultraviolet and soft x-rays, started operation in 1993. The current status of the facility will be described, and highlights of recent research in areas such as condensed-matter physics, EUV lithography, nanoscience and femtosecond-pulse generation will be presented. A strategic vision for the ALS into its next decade and the decades beyond will be outlined.

Carbon Nanotubes: Novel Effects of Pressure, Electrochemical Bias and Flow

A. K. Sood

Department of Physics
Indian Institute of Science
Bangalore-560 012 India
E-Mail: asood@physics.iisc.ernet.in

Carbon nanotubes are new forms of carbon with many novel and fascinating properties. This talk will focus on our on-going work on single and multi-walled carbon nanotubes related to the pressure-induced phase transformations and effect of electrochemical bias using Raman spectroscopy and synchrotron x-ray diffraction experiments. We will touch upon our recent studies showing the generation of voltage in carbon nanotubes due to flow of liquids. Raman and x-ray diffraction experiments on single wall nanotubes bundles carried out using diamond anvil cell under hydrostatic and non-hydrostatic conditions reveal a reversible loss of translational coherence of the triangular lattice in the bundles. Recent results will be discussed.

I acknowledge my collaborators-graduate students (Mr. Shankar Ghosh, Dr. P. V. Teredesai and Dr. D. V. S. Muthu), Dr. S.M. Sharma and Mr. S. Karmakar of BARC, Mumbai (for synchrotron x-ray diffraction at high pressures), Prof. N. Kumar and Prof. C. N. R. Rao.

Atomic Physics at the Advanced Photon Source

S. H. Southworth, R. W. Dunford, E. P. Kanter, B. Krässig, and L. Young

Chemistry Division
Argonne National Laboratory, Argonne, IL 60439 USA
E-Mail: southworth@anl.gov

We have used x-ray beams in the energy range ≈5-100 keV at Argonne's Advanced Photon Source to study x-ray/atom interactions and inner-shell decay processes. Electron, ion, and x-ray spectroscopy and coincidence techniques have been used to measure elastic and inelastic x-ray scattering cross sections, double *K*-shell ionization of He by Compton scattering, double *K*-shell photoionization of high-Z atoms, two-photon decay of *K* vacancies, nondipole asymmetries of photoelectron angular distributions, and ion charge-state distributions produced by vacancy cascades following *K*-shell photoionization. Recently, we have initiated studies of x-ray photoionization in the presence of a strong AC field imposed by a focused, short-pulse laser beam. Selected results of our research will be presented with emphasis on atomic processes that are expected to be relevant using fourth-generation x-ray sources.

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