Ultra-Bright Light Sources Topical Conference
Room 2001 - Session UB-WeM

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Moderator: C. Wöll, Ruhr-Universitat Bochum, Germany

8:00am **UB-WeM1 Spectro-Microscopy with Undulator Radiation: Towards the Resolution Limits***, **E. Umbach**, T. Schmidt,* University of Wuerzburg, Germany*; H. Marchetto,* Fritz-Haber-Institute MPG, Germany*; U. Groh,* University of Wuerzburg, Germany*; R. Fink,* University of Erlangen, Germany **INVITED**

It is a dream of surface science to combine methods such as LEED, XPS, ARUPS, PhD, NEXAFS, and XAES with high spatial resolution and with microscopic techniques. Numerous successful microscopes called LEEM or X-PEEM are commercially available today. The heart of these instruments is a simple low-energy electron microscope consisting of objective and projective lenses and a 2-dim detector. However, due to aberrations these instruments are limited in their spatial and energy resolution. A collaboration of several groups has designed and built a new type of spectro-microscope that combines a "normal" LEEM/PEEM instrument with aberration corrections (chromatic AND spherical) and energy resolution using an imaging energy filter. The instrument is installed at BESSY II and uses photons and elec-trons as sources. A spatial resolution of 0.5 nm at an energy resolution of <100 meV is theoretically achievable at a hundred times higher transmission compared to conventional instruments. This instrument called SMART is now in the final phase of testing and commissioning. Concept, technical realization, and present achievements will be reported. The SMART allows to combine nearly simultaneously various electron micros-copy techniques (LEEM, PEEM, X-PEEM, MEM) with various high-resolution electron spectroscopy and electron diffraction techniques from small sample spots (nano-XPS, -ARUPS, -XAS, -LEED). First experiments on the growth mecha-nisms and dynamics of organic thin films, their dependence on substrate and sub-strate morphology, their molecular orientation, and on the internal structure of mi-crocrystallites show the potential of the instrument and will be presented in the talk.

8:40am **UB-WeM3 Soft X-Ray Spectromicroscopy at the NSLS***, **C. Jacobsen**,* Stony Brook University **INVITED**

Soft X ray spectroscopy can be used to provide information on the concentration of various organic functional groups. By taking a series of images over a closely-spaced range of photon energies around an x-ray absorption edge, one obtains spectrum-per-pixel data much as is done in spectrum imaging in electron energy loss spectroscopy. At Stony Brook, we have developed a series of scanning transmission x-ray microscope systems which operate in the 280-800 eV energy range at the National Synchrotron Light Source. These microscopes use Fresnel zone plates as focusing optics; recent optics have 30 nm finest zone width and 160 micron diameter for good working distance when used for studies at the carbon edge (290 eV). When using this system for studies in biological and environmental science specimens, one obtains very rich but complex data which are not possible to analyze by traditional approaches (exhaustive electronic state modeling and spectrum fitting) used for studies of single molecular types. Instead, we have developed pattern recognition approaches which allow one to analyze the data in terms of the predominant spectroscopic themes. Recent applications in biological and environmental science will be described.

9:20am **UB-WeM5 X-ray Tomography: Imaging Biological Cells at Better than 50 nm Resolution***, **C. Larabell**,* University of California at San Francisco and Lawrence Berkeley National Laboratory*; M.A. Le Gros,* Lawrence Berkeley National Laboratory **INVITED**

X-ray tomography is an emerging new imaging technique that can examine whole, hydrated specimens with a spatial resolution approaching 15 nm. X-ray imaging at photon energies below the K- absorption edge of oxygen, referred to as the water window, exploits the strong natural contrast for organic material embedded in a mostly water matrix. With a transmission X-ray microscope using Fresnel zone plate optics, specimens up to 10 microns thick can be examined. Because of the low NA of X-ray lenses (NA=0.05), combined with the effect of polychromatic illumination and a wavelength dependant focal length, the effective depth of field is large (6-10 microns). The experiments presented here were performed at the Advanced Light Source using a full field transmission X-ray microscope, which employs a bend magnet X-ray source and zone plate condenser and objective lenses. The condenser zone plate acts as a monochromator and the X-ray images are recorded directly on a cooled, back-thinned 1024x1024 pixel CCD camera. Live cells were rapidly frozen by a blast of liquid nitrogen-cooled helium gas, and maintained at –140 degrees C by a steady flow of cold helium. We have used this imaging approach to obtain 3D reconstructions of cells in their native state at better than 50 nm isotropic resolution. These images reveal remarkable details of the nuclear and cytoplasmic architecture of fully hydrated whole cells. With X-ray imaging, the internal structures are not masked by ice and the resulting images are inherently of high contrast. In addition the proteins, lipids and nucleic acids are detected by the amount of carbon and nitrogen they contain, generating quantifiable data based on their absorption coefficient. Data collection is extremely fast, with a complete data set for tomographic reconstruction requiring less than 3 minutes. Consequently, X-ray tomography is an exciting new high-throughput approach for obtaining 3-D, quantifiable information from whole, hydrated cells

10:40am **UB-WeM9 Diffraction Microscopy***, **J. Kirz**,* Stony Brook University and Lawrence Berkeley Lab **INVITED**

A coherently illuminated isolated specimen creates a speckle pattern in the far field. If the intensity of this diffraction pattern is recorded with sufficient detail, the image of the specimen can be reconstructed using an iterative algorithm. The principles of this "lensless" imaging technique will be presented, along with a description of the instrumentation used, and the technical challenges involved. The ultimate limitating factor in resolution is radiation damage to the specimen. While this technique is now being used by several groups, we will emphasize the work done by the Stony Brook/Cornell group working at the Advanced Light Source.

11:20am **UB-WeM11 Science at the Free-Electron Lasers at DESY in Hamburg: Status and Perspectives***, **W. Wurth**,* University of Hamburg, Germany **INVITED**

Free-Electron Lasers in the extreme ultraviolet and in the X-ray regime offer ultrashort photon pulses with extremely high peak brilliance. These properties open exiting new possibilities for research in laser-matter interactions, ultrafast science, spectroscopy, and structural analysis with applications in physics, chemistry, materials science, and life sciences. The novel sources will allow to probe matter on atomic length and time scales with unprecedented detail. Fascinating science is envisioned in the fields of femtosecond dynamics of non-equilibrium states and ultrafast processes in molecules, clusters and condensed matter systems as well as in life sciences. This will be complemented by novel imaging techniques based on the unique coherence properties of the new sources. In my talk I will report on first scientific results obtained in the XUV-regime with the Free-Electron Laser in Hamburg (FLASH) in operation since 2005. In addition, I will review the status and the perspectives of the European X-ray Free-Electron Laser facility (XFEL) to be built at DESY in Hamburg.

12:00pm **UB-WeM13 In-Situ Electronic Structure Study of Chemical Reactions with Photon-In/Photon-Out Soft-X-Ray Spectroscopy***, **J.-H. Guo**,* Lawrence Berkeley National Laboratory

The electronic structure ultimately determines the properties of matter. Photon-in/photon-out soft-x-ray spectroscopy has been the subject to a revived interest owing to the new generation synchrotron facilities and high performance beamline and instruments. Soft-x-ray absorption spectroscopy (XAS) probes the local unoccupied electronic structure, soft-x-ray emission spectroscopy (XES) probes the local occupied electronic structure, and resonant inelastic soft-x-ray scattering (RIXS) probes the intrinsic low-energy excitations, such as charge transfer, proton energy transfer etc. Photon-in/photon-out soft X-ray spectroscopy is essentially bulk sensitive, since the attenuation length of photons in this energy range is typically hundreds of nanometers in solid matter. The penetration depth offers a few experimental opportunities not present in electron based spectroscopies. Here we take advantage of the large photon attenuation length to perform the first X-ray emission study of liquid water and solutions. The liquid cell has a window to attain compatibility with UHV conditions of the spectrometer and beamline, The synchrotron radiation enters the liquid cell through a 100 nm thick silicon nitride window and the emitted X-rays exit through the same window. This allows in particular liquid/solid interfaces to be studied. A number of examples, including some recent experimental findings, then illustrate the potential of XAS and XES applications in materials sciences.

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2:00pm **UB-WeA1 Science at the BESSY Soft X-Ray FEL in Berlin Adlershof*, W. Eberhardt,*** BESSY GmbH, Germany **INVITED**

BESSY is operating Europe's largest third generation synchrotron radiation user facility for the VUV and Soft X-Ray range. For this presentation special emphasis will be placed upon introducing the BESSY FEL project. BESSY is planning to build a Soft X-Ray FEL facility covering the photon energy range from 24 eV to 1 keV at the site next to the existing BESSY II storage ring. This new facility will offer laser like photon beams with fully coherent, high power (mJ) pulses of < 20 fs duration, enabling a whole set of novel experiments dedicated to understand dynamical processes in matter or for the investigations of very dilute systems. These pulses will be generated in a HGHG scheme (High Gain Harmonic Generation) which offers controlled, reproducible pulses as determined by the external seed UV (430-230 nm) laser pulse. Additionally this scheme allows for an inherent synchronization for pump-probe investigations. The HGHG-FEL covers the traditional BESSY II photon energy range, which is especially suited for electronic structure investigations of atoms, molecules, clusters, and solids. With the anticipated temporal resolution of < 20 fs charge transfer processes and time resolved 'femtochemistry' studies as well as magnetization dynamics in magnetic materials establish some of the major areas of scientific interest in this new facility. Furthermore, in exploiting the coherence of the photon pulses in microscopy applications of soft-matter and biological samples it is possible to acquire an image using a single laser pulse. Thus stroboscopic time resolved images of dynamical processes in living cells become possible. In general, the science planned at this facility is complementary to the science envisioned for the planned TESLA X-FEL facility at DESY and the Linac Coherent Light Source (LCLS) at Stanford.

2:40pm **UB-WeA3 The Next Generation Light Source at Jefferson Lab*, G.P. Williams,*** *FEL Team,* Jefferson Lab **INVITED**

Jefferson Lab operates a fourth generation accelerator-based light source. The facility is based on an Energy Recovered Linac (ERL),@footnote 1@ which has a significant advantage in brightness over a conventional electron storage ring (synchrotron) source. Both terms contributing to the brightness are enhanced. The power is enhanced by multiparticle coherent effects,@footnote 2@ while the source size is smaller because the horizontal emittance is approximately equal to the vertical emittance (round beams). This type of source has additional advantages in that the bunch lengths are in the 100's of femtosecond range, allowing ultrafast phenomena to be studied in the time domain. The JLab facility incorporates 3 sources: (1). A 10 kW av. power 1-14 micron tunable Infrared Free Electron Laser (IRFEL) with energies of 120 microJoules per pulse: (2). A 1 kW av. power 250 nm to 1 micron UVFEL with up to 25 microJoules per pulse: and (3). A 0.1 to 5 THz source@footnote 3@ with 1 microJoule per pulse. All 3 sources can operate at pulse repetition frequencies up to 75 MHz and pulse lengths in the range 250 - 2000 femtoseconds. We will present details of the source, and will make frequent comparisons with storage ring sources and x-ray FELs. We will also discuss and show examples of key scientific applications of this unique light source. These cover the fields of medicine, biology, physics, chemistry and materials science with experiments ranging from dynamics to disease treatment. The applications also include studies of non-linear effects and 2 photon pump-probe dynamics. In addition to this source, Jefferson Lab operates a 6GeV accelerator, which is capable of producing sub-picosecond x-rays with a brightness comparable to dipole radiation at a storage ring. This will also be presented. @FootnoteText@@footnote 1@G.R. Neil et al, Phys. Rev. Let. 84, 662 (2000). @footnote 2@C. J. Hirschmugl, M. Sagurton and G. P. Williams, Physical Review A44, 1316, (1991). @footnote 3@G.L. Carr, et al, Nature 420 153 (2002).

3:20pm **UB-WeA5 THz Technology and Its Applications to the Study of Hydration Layers and Thin Films*, M. Havenith,*** Universität Bochum, Germany **INVITED**

By the development of new, powerful radiation sources the so-called “THz gap” between MW and IR spectroscopy has been closed. This has allowed tackling new applications in various fields. First an overview over the progress over the development of new radiation sources in last years will be given. Then I will focus on applications using a high power laser p-Ge THz spectrometer. By measuring absolute absorption coefficients in the THz region we were able to determine the hydration dynamics of solvated sugars and proteins. Moreover, the setup of a THz cavity enhanced attenuated reflection spectrometer will be discussed. First applications include the investigation of surfaces and thin films.

4:00pm **UB-WeA7 High Harmonics of Ultrashort Laser Pulses as Coherent Soft X-Ray Source for Attosecond Time Resolved Photoemission Spectroscopy*, U. Heinzmann,*** Universität Bielefeld, Germany **INVITED**

The combination of the comb of high harmonics of a phase-stabilized ultrashort laser pulse focussed into a rare gas atomic beam@footnote 1@ with an optimized multilayer mirror system as soft x-ray monochromator@footnote 2@ yields isolated soft x-ray pulses of 200 attoseconds duration.@footnote 3@ Thus photoelectron and Auger electron emission processes have been studied time resolved with a fs and even sub-fs time resolution, which is needed to observe the dynamics of atomic and molecular decay processes.@footnote 4,5@ The report reviews the experimental techniques of production and analysis of the ultrashort pulses, presents recently performed pump-probe photoionization and photodissociation processes and discusses its application to condensed matter studies. @FootnoteText@ @footnote 1@ R. Kienberger et al. Nature 427, 817 (2004)@footnote 2@ A. Wonisch et al. Applied Optics 45, No 17 (2006)@footnote 3@ E. Goulielmakis et al. Science 305, 1267 (2004)@footnote 4@ M. Drescher et al. Nature 419, 803 (2002)@footnote 5@ P. Siffalovic et al. J. Biotechn. 112, 139 (2004).

Author Index

Bold page numbers indicate presenter