ESF Meeting 2004
Network on Future Advanced Light Sources (FALS)
Workshop :
"Needs and opportunities for Future Advanced Light Sources"

October 2004, 10th-12th
Propriano, Corsica (France)
http://www-drecam.cea.fr/

BOOK OF ABSTRACTS

INTRODUCTION

The workshop aims at evaluating the needs and fields of application of future short-wavelength light sources by gathering European scientists from different communities. It will broadly cover novel scientific aspects of future advanced light sources and the associated technological challenges. Critical issues such as mechanisms to achieve shorter wavelengths, peak power, pulse shape, pulse jitter, synchronization between primary and secondary pulses ("pump-probe"), transform limited pulses (full longitudinal coherence), EUV and X-ray optics, detectors will be addressed in regards with the type of experiment foreseen : time-resolved, flux-hungry or in the non-linear regime. The meeting should allow potential users to orientate themselves between the different new proposed short-wavelength light sources in Europe, and to focus on proposed applications developing a vision of science for the future. For this purpose, a user guide with the different European sources will be prepared. The programme will comprise a broad overview of the different fields with selected talks by expert from scientific communities that do not meet and interact regularly and who are currently using lasers or synchrotron radiation or X-ray table-top sources.

This workshop takes place in the frame of the European Science Foundation network on Future Advanced Light Sources (FALS), chaired by I. Lindau, for the development of science by bringing together leading researchers to debate alternative light sources such as high order harmonics produced in gases, laser plasma sources, synchrotron radiation and Free Electron Lasers. A first exploratory workshop took place in Zurich (October 23rd-24th, 2000) and was followed by a workshop in Berlin (Dec 8th-9th, 2003) on "Opportunities and challenges for atomic and molecular science at the European FEL and X-FEL sources", chaired by U. Becker and L. Avaldi.

The present workshop will gather a maximum of 70 participants. It will take place in Propriano, Corsica, from October the 10th to October the 12th, 2004. The programme will consist of invited presentations. The workshop is opened to other participants. Registration fees for participants are fixed to 350 € and include bus transportation from Ajaccio airport, local housing and meals. A limited number of student grants will also be available.

http://www.esf.org/forum/ubbcgi/ultimatebb.cgi

Chairs: M. E. Couprie, H. Hertz, E. Seddon.

Local committee:
H. Bachau (CELIA), G. Jamelot (LIXAM), M. Meyer (LURE), L. Nahon (CEA-SOLEIL), A. Rousse (LOA), P. Salières (CEA-SPAM), D. Garzella (SPAM), P. Bonillo (CEA-DRECAM), S. Charleuf (CEA-DRECAM), L. Barbier (CEA-DRECAM).

ABSTRACTS

Session 1: Sources--

SASE, seeding and HGHG schemes for the next generation light sources

Luca Giannessi

ENEA-Frascati, Italy
Luca.Giannessi@frascati.enea.it

The next generation light sources will be based on Free Electron Lasers operating in self amplified spontaneous emission (SASE) regime. In this regime the temporal and spatial coherence of the radiation is provided by slippage and diffraction respectively, and the output radiation is characterized by relatively large shot-to-shot power fluctuations. Solutions aimed at mitigating these effects, based on external seeding the FEL amplifier have been proposed. A review of the possibilities offered by these new schemes including seeding and harmonic generation in cascaded undulator configurations, will be presented

Session 1: Sources--

Synchrotron radiation from third generation storage ring and ERLs

Mikael Eriksson

MAX-lab

Mikael.Eriksson@maxlab.lu.se

The construction, operation and use of third generation light sources are a success story. Some ten of them are in operation today, producing high quality radiation for experiments in many disciplines. New third generation sources are currently being built to cover the increasing need of high quality radiation, one high energy physics ring is turned into a high-performance light source and new sources with very small emittance are being planned.

Energy Recovery Linacs (ERLs) adds the ability of producing very short and intense pulses of radiation and a different emittance defining processes to radiation source theatre.

This lecture will deal with the working principles and synchrotron radiation characteristics of third generation light sources and ERLs. A few examples of third generation sources and ERLs will be presented.

Session 1: Sources--

Harmoni generation produced in gases: From femtosecond to attosecond pulses – Recording atomic transients in time domain

M. Uiberacker[1], E. Goulielmakis[1], R. Kienberger[1], A. Baltuska[1], V. Yakovlev[1], A. Scrinzi[1], Th. Westerwalbesloh[2], U. Kleineberg[2], U. Heinzmann[2], M. Drescher[2], F. Krausz[1,3]

[1] Institut für Photonik, Technische Universität Wien, Gusshausstr. 27, A-1040 Wien, Austria
[2] Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany
[3] Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

matthias.uiberacker@tuwien.ac.at

Today's femtosecond (1 fs = 10^{-15} s) lasers have become important tools for investigating and influencing chemical reactions (e.g. dissociation of molecules) in the time domain. If we want to explore the microcosm even further to be able to resolve the dynamics in the electronic shells of atoms we have to improve time resolution substantially. Bohr's model of the hydrogen atom, where the electron needs about 150 attoseconds (1 as = 10^{-18} s) to orbit around the proton, can be taken to define the characteristic timescale for dynamics inside atoms. The recent observation of single sub-femtosecond extreme ultraviolet (XUV) light pulses has stimulated the extension of techniques of femtochemisty into the attosecond regime.

We demonstrate the generation and measurement of single 250-attosecond XUV pulses suitable for XUV pump–Visible probe (as well as Visible pump–XUV probe) spectroscopy.

The XUV pulses are generated by focusing our intense visible laser pulses, produced by a waveform- (or phase-) stabilized femtosecond laser system, into a gas target to create high energy radiation by the techniques of high harmonic generation. After suitable spectral filtering the single 250-attosecond pulse is sent to the experiment where it excites atoms, which in turn emit electrons. The intense waveform-controlled few cycle laser pulse probes the emission of these and also secondary electrons and can obtain "tomographic pictures" of the time-momentum distribution of the ejected electrons. With the current 750 nm laser probe and the 100 eV XUV pump pulse our apparatus is capable of resolving atomic electron dynamics within the Bohr orbit time.

Session 1: Sources--

Laser driven soft x-ray lasers: Status and prospects

Stéphane Sebban

Laboratoire d'Optique Appliquée, Palaiseau (FRANCE)
sebban@ensta.fr

The development of fast and ultra-fast high power laser systems has opened the path to the development of a large variety of short duration X-ray and XUV sources. Some of these sources, combining a short pulse duration (100 fs to few ps) and a reasonable amount of photons per pulse (from 10^8 to 10^{12}), are now mature for application experiments in numerous fields including solid state physics, biology, atomic physics, hot dense plasma and chemistry.

In this present contribution, an overview of the laser-driven x-ray laser research is presented. We will concentrate on collisional soft x-ray laser sources produced by the interaction of a fast or ultra-fast laser with the matter.

Among the numerous proposed schemes to obtain a population inversion in multicharged ion plasma, the collisional scheme is clearly the most robust. This scheme is generally based on electron impact collisions between the free electrons and ground state bound electrons in a suitable plasma which results in excitation excited level of the ions which will be population inverted with respect to a lower bound level. This scheme requires to get simultaneously the good ionization stage and sufficiently energetic electrons to pump the upper level of the laser transition. A large number of experiment and calculations has been performed and now collisionnal x-ray systems currently reach the saturation regime. Using 2 beams, a long one (ns) which create the ion specie, and a shorter one (sub-ps) who generate the fast electron necessary for the pumping. These sources deliver up to 10^{12} photon per pulse in a duration of less than 2 ps down to 10 nm in a bandwidth of $\Delta\lambda/\lambda=10^{-4}$. These sources are now well characterized and mature for application experiments, but rate are limited by the repetition of the laser drivers.

Another candidate is to use a single ultrashort (few 100 of mJ in 30-50 fs) pulse focused in a gaseous media to create the amplifying media. The laser field is high enough to ionize the plasma and is circularly polarized to generate the fast electrons for the pumping. These sources deliver up to 10^{12} photon per pulse in a duration of 2 ps down to 30 nm in a bandwidth of $\Delta\lambda/\lambda$=few 10^{-5} at a 10 Hz repetition rate.

More recently a promising geometry, consisting in injecting coherent and polarized high order harmonic beam into a plasma amplifier, has been demonstrated. The amplified XUV beam shows good optical quality and sub-ps laser pulse duration is expected. This technique, easily applicable on all existing laser-driven XUV facilities, opens the way to ultra-high intensities studies worldwide.

Session 1: Sources--

Compact laboratory x-ray sources

Ulrich Vogt

Biomedical and X-ray Physics, Royal Institute of Technology, Stockholm, Sweden
and
Institute for X-Optics, University of Applied Sciences Koblenz, RheinAhrCampus, Remagen, Germany
email: vogt@rheinahrcampus.de

Synchrotron radiation is nowadays a brilliant source for a large spectral range including the extreme ultraviolet (EUV), soft and hard x-ray spectral region ranging from about 20 nm to 0.1 nm (≈ 60 eV – 10 KeV). However, there was always an interest in having compact laboratory scale sources for this spectral range since this would enable more users to get access to this kind of radiation. This talk will describe laboratory radiation sources excluding high harmonic radiation and x-ray lasers and therefore sometimes given the term "incoherent" x-ray sources. These sources made remarkable progress in the recent past and must be seen as a complement to synchrotron radiation sources, sometimes even offering features difficult to get at a synchrotron, for example for time resolved experiments.

The talk will be divided into two main parts, the first part containing an overview of the different possibilities that are used to build compact x-ray sources. The two main important principles are radiation based on emission from electron impact sources and radiation from hot plasmas, created by a strong electrical discharge or by a short, intense laser pulse (laser produced plasma). The choice of the proper source will strongly depend on the intended application; there is no universal source solution. Accordingly progress in source development is often driven by the needs of a special application, for example EUV-lithography.

In the second part of the talk it will be shown that compact sources indeed have reached a high development status and enable the laboratory operation of a number of applications. As examples will be presented experiments from the field of x-ray microscopy, x-ray absorption spectroscopy and x-ray reflectrometry using laser produced plasma x-ray sources. Finally future perspectives of laboratory x-ray sources will be outlined.

EUV/Soft X-ray optics – trends and challenges

Torsten Feigl[*]**,** Sergiy Yulin, Nicolas Benoit, Norbert Kaiser

Fraunhofer-Institut für Angewandte Optik und Feinmechanik, Albert-Einstein-Str. 7, 07745 Jena, Germany

feigl@iof.fhg.de phone: +49-(0)3641-807240 fax: +49-(0)3641-807601

Scientists and engineers in fields as diverse as atomic and molecular science, semiconductor industry and space astronomy have a common need to use light ranging from extreme ultraviolet to the soft X-ray region (EUV/Soft X-rays). The demand to enhance optical resolution has pushed the search for technological innovations and improvements. Induced mainly by this aim, optics development in recent years has been focused on components for electromagnetic radiation with increasingly shorter wavelengths λ. The good prospects of EUV/Soft X-rays to be applied in next generation lithography systems (λ = 13.5 nm), microscopy in the "water window" (λ = 2.3 – 4.4 nm), astronomy (λ = 5 – 31 nm), spectroscopy, plasma diagnostics and EUV/Soft X-ray laser research have led to considerable progress in the development of different sources and optics for this spectral range.

However, the ability to use EUV/Soft X-rays (1 … 50 nm) in a constructive way with various optics used in longer wavelength ranges has been limited by the fundamental physics of matter - radiation interaction. There are two reasons for this. First, EUV/Soft X-rays are strongly absorbed by all materials and have a maximum penetration depth less than a few microns. Second, the refractive index of all materials approaches unity, resulting in very small near-normal reflectivity from any single boundary. Therefore, reflectivity enhancement is only possible by using the constructive interference of a large number of partial waves reflected from many boundaries of an artificial multilayer coating. Multilayer coatings for the EUV/Soft-X-ray spectral range can be imagined as an extension of natural crystals towards artificial structures with larger lattice spacing, or as an extension of interference coatings for the visible light towards shorter wavelengths and smaller layer thickness.

The talk summarizes recent progress and the present knowledge in preparation and characterization of multilayer coatings for the EUV/Soft X-ray range with regard to different designs, minimization of structure imperfections, thermal and radiation stability.

Session 2: Optics and detectors---

X-ray optics for imaging and lithography applications

C. David, H.H. Solak, T. Weitkamp, A. Diaz
Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, Switzerland
christian.david@psi.ch

F. Pfeiffer, H. Keymeulen, J.F. van der Veen
Swiss Light Source, Paul Scherrer Institut, Switzerland

The most commonly known type of diffractive x-ray optics are Fresnel Zone plates, which have been successfully used for several decades in x-ray microprobe and imaging techniques at synchrotron beam lines. Spatial resolution values of down to 30nm have been achieved in the soft x-ray region. As the spatial resolving power of a Fresnel zone plate is limited to approximately its outermost zone width, nanofabrication techniques such as high resolution electron beam lithography have to be applied.

The development of x-ray lenses at the Laboratory of Micro- and Nanotechnology are reviewed. A variety of Fresnel zone plates, but also refractive lenses, and wave guides have been developed with various groups at different synchrotron sources. The devices cover a wide range of photon energies up to hard x-rays. An overview of the fabrication techniques, the performance, applications, and - of course - the limitations of the devices is given.

When made with sufficient precision, diffractive optics have the advantage that they are capable of modifying the phase of wave front within a fraction of a wavelength. The second part of the presentation addresses the development and application of other diffractive optics such as gratings and also more complex optical elements. One of these applications is x-ray interference lithography (XIL). At the Swiss Light Source, an undulator branch beam line optimized for operation at Extreme Ultra-Violet Radiation has recently gone into operation. Its end station uses electron beam lithography written diffraction gratings to generate a periodic interference pattern, that can be used e.g. to expose a photo resist. Patterns with periods below 50nm have been produced over reasonably large areas with short exposure times. Applications for this method include patterning of magnetic films, the formation of surfaces for templated protein crystallization, and the grafting of polymer nanostructures. We also developed a method to generate Fresnel zone plates using XIL, which may in future be capable to push the present resolution limit of x-ray microscopy below 10nm.

Session 2: Optics and detectors---

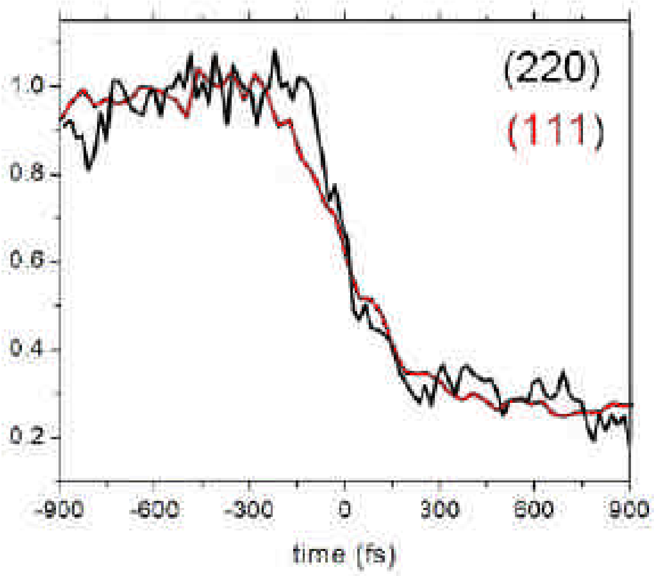
Laser-induced processes in semiconductors probed by X-rays on the femtosecond and picosecond timescale

J. Larsson[a], A. Lindenberg[b] , K. Sokolowski-Tinten[c], K.J. Gaffney[b], C. Calemand, T.N. Hansena, O. Synnergrena, P. Sondhaussa, C. Blomee, J. Sheppardf, M. Wulffg, A. Plechg, G.A. Naylorg, K. Scheidtg, J.S. Warkf and the SPPS Collaboration

aInstitut für Experimentelle Physik, Universität Duisburg-Essen, Campus Essen, 45117 Essen, Germany.bAtomic Physics Division, Department of Physics, Lund University, P.O. Box 118, 22100 Lund, Sweden. cStanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, CA 94025, USA. dBiomedical Center, Dept. of Cell and Mol. Biol., Uppsala Universitet, Husargatan 3, 75124 Uppsala, Sweden. dHASYLAB at DESY, Notkestrasse 85, 22603 Hamburg, Germany fClarendon Laboratory, University of Oxford, Parks Road, Oxford, OX1 3PU, U.K Department of Physics ESRF, BP 220, 38043 Grenoble Cedex 9, France

Jorgen.larsson@fysik.lth.se

We have carried out the first femtosecond X-ray diffraction experiments at an accelerator-based light source. Our aim was not only to elucidate the underlying process behind non-thermal melting, but also to develop measurement methodology at the future high-brightness and short-pulse light sources. In 2008 the Linear Coherent Light Source (LCLS; the X-ray free-electron laser at SLAC) is estimated to be in operation. SPPS [1] (the Sub-Picosecond Pulse Source) is a facility which gives unique research opportunities and allows for development of methodology and technology suitable for LCLS. Electron bunches extracted from the SLAC linac are compressed and sent through an undulator, producing 8-10 keV X-ray pulses with a few times 107 photons/pulse at 10 Hz, and a calculated pulse duration of only 80 fs (FWHM). Here we report the first femtosecond time-resolved X-ray diffraction experiments at SPPS. We have studied nonthermal melting [2, 3] of a covalent semiconductor, namely InSb. Single crystalline bulk InSb-wafers are excited with a 800 nm, 40 fs laser pulse, synchronized to within 1 ps to the SPPS X-ray pulses. In order to obtain the desired ~100 fs time resolution, we have made single shot measurements in a crossed-beam geometry [4, 5]. This geometry which is strongly asymmetric at nearly grazing incidence allowed, the laser pump and X-ray probe depth were nearly matched. Results are shown in the figure below. On the picosecond timescale, the first ultrafast TRXD measurement of coherent folded acoustic phonons in a periodic semiconductor heterostructure has been performed [6] contrast to the previous time-resolved X-ray studies of phonons in bulk materials, within the heterostructure a large number of phonons with different frequencies, but the same **q** are simultaneously excited by laser irradiation of the sample. Thus the time-dependent X-ray reflectivity has a far richer structure than the almost single frequency oscillations observed in bulk materials. The experimental data are in good agreement with simulations, provided that we take into account that the high carrier densities produced by laser irradiation of the sample result in a nonlinear absorption coefficient, leading to the laser energy being deposited nearer to the surface, and thus a steep strain profile within the structure.



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Time resolved solution chemistry

A. Plech[1], V. Kotaidis[1], R. Vuilleumier[2], F. Mirloup[2], M. Lorenc[3] and M. Wulff[3]

(1) Fachbereich Physik, Universität Konstanz, Universitätsstraße 10, D-78457 Konstanz, Germany;
(2) Laboratoire de Physique Théorique des Liquides, Université Pierre et Marie Curie, 4, Place Jussieu, F-75005 Paris, France
(3) European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble, France
anton.plech@uni-konstanz.de

Optical studies of photo-excitation in solutions are a powerful tool to study the kinetics of chemical bond formation and relaxations of molecules in a liquid environment. With the advent of powerful synchrotrons as source for high brilliance x-rays it has become possible to resolve the structural kinetics of photo-excitation on a picosecond time scale [1-4].

We will discuss relevant techniques which adress structure determination in disordered condensed matter as well as the experimental requirements and limitations of the technique [4-6]. The x-ray scattering data contains information about the structure of the solute molecules as well as the coordination to the embedding solvent molecules. From that starting point model-free structure solution can be achieved. Through the global information content of short wavelength scattering techniques not only the molecular kinetics can be resolved in time, but also the hydrodynamics of the interacting medium, such as the solvent is accessible. This helps for a better understanding of energy exchange in selectively excited composite systems [7].

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Session 3: Biology ---

Biological X-ray microscopy: Current status and future developments at FEL sources

Gerd Schneider

BESSY m.b.H., Albert-Einstein-Str. 15, 12489 Berlin, Germany
Schneider@bessy.de

The x-ray microscope installed at the 3rd generation storage ring BESSY II is dedicated for applications in life, environmental and materials sciences. It covers the photon energy range between 250 - 750 eV. Currently, the spatial resolution is about 25 nm. To protect biological cells from radiation damage caused by X-rays, imaging of the samples has to be performed at cryogenic temperatures, which makes it possible to take multiple images of a single cell as required for tomography [1]. Due to the small numerical aperture of zone plates, X-ray objectives have a depth of focus on the order of several microns. By treating the X-ray microscopic images as projections of the sample absorption, computed tomography can be performed [2,4]. Since cryogenic biological samples are resistant to radiation damage, it is possible to reconstruct frozen-hydrated cells imaged with a full-field X-ray microscope. This approach is used to obtain 3-D information about the location of specific proteins in cells. To localize proteins in cells, immunolabelling with strongly X-ray absorbing nanoparticles was performed [3]. To detect protein distributions inside of cells, X-ray microscopy tomography of immunolabelled frozen-hydrated cells was performed. In the talk, the current status and future aspects of biological x-ray microscopy at FEL sources will be discussed.

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Opportunities for the study of biological systems using Advanced Light Sources.

Peter Weightman

Physics Department and Surface Science Research Centre, University of Liverpool, Oxford Street, Liverpool, L69, 3BX, UK
peterw@liv.ac.uk

Future Advanced Light Sources have considerable potential for advancing research on important biological problems. This lecture will consider the potential for research on live tissue, cell membranes and DNA-DNA and DNA-protein interactions which exploits the Terahertz and UV-Visible regions of the electromagnetic spectrum through imaging and spectroscopy.

The comments on the potential for research in biology using terahertz radiation will be rather speculative. A more substantial account will be given of the techniques of Reflection Anisotropy Spectroscopy (RAS) and Reflection Anisotropy Microscopy (RAM). RAS has been shown to be able to monitor the orientation and interaction in real time of biological molecules adsorbed at metal-liquid interfaces. It achieves surface sensitivity by measuring the change in polarisation on reflection of normal incidence light from the surface of a cubic crystal.

This talk will present recent results of studies of the RAS of DNA bases and DNA sequences adsorbed at the Au(110)/electrolyte interface. Results will also be presented for the single stranded DNA sequence of the 18 base EUB338 probe and of the 16S rRNA gene found in all bacteria

A brief description will be given of how the sensitivity, spectral range and in particular the timescale of RAS will be radically improved by the proposed UK Fourth Generation Light Source (4GLS).

Session 4: Atomic and Molecular Physics, Plasma Physics --------------------

Time resolved dynamics in polyatomic molecules with VUV pulses

Valérie Blanchet

LCAR-IRSAMC, CNRS-UMR5589, 31062 Toulouse
val@irsamc.ups-tlse.fr

The level of development of both sources and characterisation[1] of the VUV radiation produced by harmonic generation have reached the point where applications are possible in low-density gas phase time-resolved spectroscopy. Despite recent efforts,[2] the tunability, the photon flux (~10^9 photons/pulse) and the stability of these sources are such that the time-resolved experiments that can be carried out are difficult and are mainly on molecular systems with a huge dipole moment and in a unseeded beam.[3,4] For instance, to real do time-resolved coincidence experiments (quite essential in molecular physics), the photon flux has to reach at least ~10^{12} photons/pulse.[5,6] This kind of experiment is one of these that might be more easily achievable with a high brilliance femtosecond source such as the arc-en-ciel source.

The molecular ionization continuum could provide an interesting template for the study of time-resolved molecular dynamics: the ion electronic and the electron partial wave structure are sensitive to electronic population dynamics, whilst ionic vibrational and rotational structure are sensitive to nuclear dynamics (resolved only in the small polyatomic molecules).[7] We have studied the dynamics in a highly excited states of acetylene populated by an femtosecond VUV laser pulse and photoionized by a UV laser pulse.[4] We show that even when the bandwidth of the exciting pulse covers several electronic states, it is possible to measure short decay lifetimes through time-resolved photoelectron spectroscopy. This is performed by using a frequency-modulated (chirped) excitation pulse and requires a full characterization of the temporal profile of the pump and probe pulses.[8] A VUV femtosecond pulse would naturally be useful as a probe to photoionize directly the photofragments. Then the kinetic energy distribution and vector correlations of the fragments could be recorded as well as the photoelectron angular distributions (PADs) measured in the molecular frame of the dissociating molecule.[5,9] The changes observed in the PADs during the dissociation time directly reflect the time-dependent separation and reorientation of the fragments. We will give two examples for which a time-resolved photofragmentation (VUV probe pulse) is needed to experimentally underpin the dynamics : vibronic relaxation of Na_3F[10] and dissociation of $(NO)_2$.[11] Another straightforward application of a VUV probe pulse is to reach the excited states of the ion. Indeed by playing on the ionization dynamics, the relaxation dynamic in the excited state may be revealed. Depending on the time, we will illustrate this point on the relaxation dynamics of Decatetraene.[12]

We describe these experiments emphasizing the typical characteristics that are the cross-correlation time, the spectral range of the pump and probe pulses, the photon flux as well as the repetition rate. The wavelength tunability is not only necessary for the pump but as well for the probe pulse, especially in the case of PAD detection as recently demonstrated.[13] Coincidence experiments are particularly interesting to investigate photofragments correlation[14] as well as the cluster dynamics.[6,15,16] The few femtosecond time-resolved coincidence experiments that have been done, involve multiphoton transitions at the pump or either the probe steps. To satisfy the need of a photon flux in the UV range (>10^{12} photons/p), the pump and the probe pulse are simply the second (~400 nm)[9], the third (~266nm)[14,16] or even the forth harmonics (~200 nm)[15] of the fundamental wavelength of the laser chain. The

VUV source of arc-en-ciel, combined with a UV laser pulse will greatly improve the coincidence experiment by delivering a high photon flux with tunability at high repetition rate.

Time-resolved experiments are particularly interesting once combined with dynamical calculations. Their comparisons provide new insights into the non-adiabatic processes that underpin our understanding of photochemistry. Nevertheless dynamical calculations are rapidly limited once that the excited state of interest reaches very high electronic energy. Among the recent time-resolved experiments, only a few have been confronted with the calculations, mainly because of a lack of precise potential hypersurfaces. On the other hand, the dynamics of the ground electronic state, for which wavepacket dynamics might be available, is interesting for very general reaction like unimolecular predissociation or isomerisation. The most efficient way to create a wavepacket in the ground electronic state is to use the pump-dump excitation: the pump populates an excited electronic state (UV range), whilst the dump pulse by stimulating emission from this higher electronic state creates a highly vibrational wavepacket in the ground electronic state. If the excited electronic state is dissociative the pump pulse needs to be an ultrashort pulse, whilst if it is not, there is no constraint on its duration. This is a simple extension of stimulated emission pumping[17] using femtosecond pulse instead of a frequency resolved laser. The vibrational wavepacket, corresponding to a "stretched molecule" has to reside in an energy near the reaction barrier to underpin the vibrational redistribution that occurs during the isomerisation or the dissociation. At any time delay with the dump pulse, a VUV probe pulse projects the vibrational wavepaket onto the ion ground state or photoionizes the fragments both at the limit of ionisation. Very recently, this femtosecond pump-dump-probe has been applied successfully on an anion system for which the ionization energy lies in the UV range.[18] This pump-dump-probe experiment should provide a wealth of information ranging from intramolecular vibrational redistribution in highly excited molecules to the vibrational influences on electron transfer; from isomerisation to unimolecular dissociation, just to name a few.

List of collaborators : Lund laser center, Lund, Suède : J. Andersson, I. Hjelte, A. L'Huillier, J. Mauritsson, J. Norin, S. Sorensen**.,** LCAR, Toulouse, France : B. Girard, P. Labastie, J.M. L'Hermite, A. Lepadellec, S. Zamith., LPPM, Orsay, France : S. Boyé, D. Gauyacq. Steacie Institute, Ottawa, Canada : A. Stolow.

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Session 4: Atomic and Molecular Physics, Plasma Physics ----------------------

Exploring high atomic and molecular excitation with intense coherent short-wavelength radiation.

P. Lambropoulos

Department of Physics, Univ. of Crete and IESL-FORTH, Heraklion, Crete, Greece
labro@iesl.forth.gr

About forty years ago, the first laser-induced two-photon absorption in an atomic vapor was observed in Cesium. With the subsequent developments in laser technology, the field of multi-photon processes and strong field phenomena evolved through a series of stages, the most recent one being dominated by ultrashort pulses whose absolute phase may also be controlled. Assuming that in the immediate or near future we will have sources of some intensity and subpicosecond pulse duration in the XUV and shorter wavelength range, which aspects of novel atomic and molecular physics would become available for exploration? What can we learn and expect from the experience of the previous forty years? What are the differences from and similarities with strong field interactions in the infrared and optical range?

I discuss the operational meaning of the various intensity regimes in this new wavelength range. Issues of perturbative versus non-perturbative behaviour as well as time-dependent versus transition probability per unit time need to be discussed in a quantitative framework. Would few- or multi-photon processes be of interest and what would we learn? Since photons in the energy range of, say 40 eV and above would interact predominantly with electrons below the valence shells, we need to ask what information such processes would reveal. One aspect that immediately suggests itself is the few-photon excitation of multiply excited electronic states, including those of the Auger type. If the intensities available will allow, say two- to four-photon processes, then indeed hitherto largely unexplored manifolds of atomic excitations will become accessible. The way such manifolds couple multiple excitations to multiple continua would become accessible to experimental investigation for the first time. The demands on intensity, photon-energy range and pulse duration need to be carefully estimated. If the relative phase of beams with different but commeasured frequencies could be controlled, then additional aspects pertaining to coherent control of transitions and products of photo-breakup could be profitably explored, as has been done in the optical and near UV range.

The combination and synchronization of short-wavelength and ultrashort optical laser pulses has already been shown theoretically to promise information on the coupling of highly excited and highly correlated states. It also appears possible to exploit such a combination towards exploring the pulse duration and shape of the XUV pulse. Quantitative ideas along these lines will also be discussed.

Interaction of intense VUV radiation with rare gas atoms and clusters

H. Wabnitz[1*], A.R. B. de Castro[1], P. Guertler[2], T. Laarman[1], W.Laasch[1], J. Schulz[1], P. Breger[1] and T. Moeller[1]

Hamburger Synchrotronstrahlungslabor HASYLAB at Deutsches Elektronen Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany
* present adress : *Commissariat à l'Energie Atomique, DRECAM/SPAM, Centre d'Etudes de Saclay, 91191Gif-sur-Yvette, France*
wabnitz@drecam.cea.fr

The interaction of intense laser radiation with atoms has been a subject of ever growing interest for more than two decades. The basic ionization mechanisms, such as multi-photon ionization (MPI), tunnel ionization and above barrier ionization have been studied in great detail both experimentally and theoretically since the 1980's [1].

In the infrared and visible spectral range the strong field interaction with atoms is dominated by field ionization processes. On the other hand, at short wavelengths in the vacuum ultraviolet (VUV), soft, and hard X-ray regime it is expected that the atoms will be ionized by multi photon ionization. However, important questions such as the wavelength and power density dependence of multi photon processes and the scaling laws for cross sections at short wavelengths (VUV $\rightarrow$ X-ray) remain open.

Until now, experiments were hindered by the lack of sufficiently intense short wavelength light sources. This situation is presently changing. New and very intense sources like powerful high harmonic generation (HHG) sources and Free-Electron Lasers (FEL) are planned and under construction. In line with the development of new light sources numerous theoretical studies have been performed and predicted various non-linear processes in atoms, for example [2, 3]. Depending on the wavelength, non-linear processes become important at rather high power densities of 10^{14}-10^{18} W/cm^2.

The high intensity obtained recently at the VUV-FEL at DESY [4] allows getting first results at VUV wavelengths. This contribution will give a review of the studies investigating rare gas atoms and rare gas clusters [5-7]. The findings can serve as a starting point for detailed comparison between experimental and theoretical results.

Furthermore, ideas for complementary experiments using HHG sources will be presented.

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Plasma Generation and Probing Plasmas with XUV Sources

Eugene T Kennedy

School of Physical Sciences/NCPST, Dublin City University, Dublin 9, Ireland.

eugene.kennedy@dcu.ie

Historically, progress in the experimental study of the interaction of short wavelength photons with matter has been facilitated by successive improvements in instrumentation and particularly light sources. New developments of Free Electron Lasers operating at short wavelengths continue this trend and will have major implications for future research possibilities in the VUV to X-ray spectral regions.

The interaction of ionizing radiation with atoms and ions is a key fundamental process and is challenging both experimentally and theoretically. At short wavelengths, individual photons have sufficient energy to excite either inner-shell electrons or more than one electron at a time. Experiments provide important data for the interpretation of atomic and ionic processes in laboratory and astrophysical plasmas and for critical comparison with the predictions of the most advanced theoretical calculations. The latter must properly include many-body collective effects if they are to correctly predict the photon-atom or photon-ion interactions in the short wavelength energy regions.

Photoexcitation/photoionisation experiments on ions are particularly difficult due to the requirement of combining sufficiently intense ion beams with appropriately bright short wavelength light sources. Many of the results to date have been obtained using laser-produced plasmas as VUV/XUV short wavelength continuum sources to probe synchronized laser plasma plumes, which produce the absorbing atom or ion species. Laser plasma based table-top experiments are flexible and have produced a wide range of interesting data (particularly on ions) in their own right and have also provided useful preliminary data for later more detailed experiments at storage ring facilities. Examples from studies of the interaction of ionizing radiation with atoms and ions ranging from few-electron atomic and ionic systems to the many-electron high atomic number actinides are reviewed and illustrate the advantages and limitations of the Dual Laser Plasma technique.

The emission characteristics of laser-generated plasma sources depend on the laser pulse energy, time duration and target material and they have found varied other applications at short wavelengths, some of which will be briefly described. The talk will conclude with a future perspective, which anticipates the new Free Electron Laser developments that will provide uniquely intense radiation beams and introduce a new era in the study of ionizing photon - matter interactions.

Round table on techniques (specificities, sources requirements, domains of applications, future developments). Chair : E. Seddon

Session 5: Material, surface science and chemistry----------------------------

Probing electronic relaxation in solids with Ultrashort VUV pulses.

S. Guizard, J. Gaudin, G. Geoffroy, G. Petite

Laboratoire des Solides Irradiés, Ecole Polytechnique,
91128 Palaiseau, France.
guizard@celia.u-bordeaux1.fr

VUV light and X-rays have always been important tools in solid state physics. Different experimental techniques, based on the detection of particles emitted at the surface (electrons, ions..) or luminescence photons, as well as direct absorption measurements are widely spread to characterise bulk and surfaces of all kind af materials. Important progress in the generation of ultrashort pulses in these short wavelength domains have recently been achieved and are now becoming available to carry out time resolved experiments. In particular, during the last three years, several groups in the world have acquired intense femtosecond laser systems and developed sources of high order harmonics which are entirely devoted to solid state physics experiments. The first experiments performed in the free electron laser in Hamburg, which provide unprecedented intensities in the VUV range, is also opening access to new field of physics where high excitation densities give rise to unobserved behaviours. I will present results recently obtained and discuss which improvements of the sources would be the most valuable to investigate the dynamics of the relaxation processes that follow electronic excitation in solids.

Session 5: Material, surface science and chemistry-----------------------------

Ultrafast phase transitions probed by X-rays

D. Boschetto and A. Rousse

Femtosecond X-ray (PXF) group, Laboratoire d'Optique Appliquée,

ENSTA-Ecole Polytechnique, Chemin de la Huniere, Palaiseau

http://loa.ensta.fr/pxf/

davide.boschetto@ensta.fr

The understanding of any physical process requires the knowledge of his elementary and precursor phenomena. In the special case of a structural transition, the key point is to understand the contribution of the elementary atomic motions responsible of the phase change. This information can only be caught by a technique providing time and space resolution at the atomic level. Because the time-scale of the elementary atomic motion is around 100 fs (1fs = 10^{-15} s) and the relative inter-atomic distance of the order of 1 Å, the most suitable probing tools are femtosecond X-ray pulses. X-ray diffraction, absorption and scattering must then be used on this time-scale to study samples. Today, very few x-ray sources are available for that purpose. Among them, laser-produced plasma x-ray radiation has played a major role the last years since the demonstration of femtosecond x-ray diffraction [1].

The aim of this presentation is to discuss the first applications of this technique: the study of non-thermal melting in semi-conductors [2] and coherent optical phonon [3].

The non-thermal melting is a phase transition induced by a very intense laser pulse that takes place on a time-scale of about 300 fs, much faster than the time required for electron-lattice thermalization. On the other hand, longitudinal optical phonons are believed to play an important role as a precursor process of this structural transition. These atomic vibrations correspond to the elementary displacements inside the elementary cell of the crystal. Their measurement and characterisation represents an important step for the understanding of this ultrafast phenomenon.

We will then describe the new ultrafast x-ray tools as well as novel applications foreseen in the future with the development of the next generation of ultrafast x-ray sources.

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Spectromicroscopy: recent achievements and new projects

Maya Kiskinova

Sincrotrone Trieste, Area Science Park, Basovizza, 34012-Trieste, Italy
kiskinova@elettra.trieste.it

Recent progress in synchrotron radiation spectro-microscopy and imaging has contributed significantly to advancing the frontiers of surface and material science. The synchrotron laboratory ELETTRA has one of the most extensive programs in the field of x-ray spectromicroscopy in Europe with three photoemission microscopes using different approaches to get sub-micrometer spatial resolution. Selected results obtained at ELETTRA will be used to illustrate the recent achievements in identification of spatial variations in the composition and electronic properties of model and fabricated morphologically complex surfaces and interfaces, nanotubes, discrimination of local chemical events during surface reactions, investigations of mass transport phenomena due to thermal diffusion, electromigration or surface reactions, examination of domains in magnetic nanostructures etc.

The outlook will emphasize on the EU-funded X-ray microscope under commissioning, which will allow new class of experiments by combining the potential of full-field imaging transmission microscopy for morphological and dynamic studies with the spectroscopic potential of the scanning x-ray microscopy. This new instrument will expand spectromicroscopy applications at Elettra to earth and environment sciences, biology, medicine and many other domains of material and applied science.

Session 5: Material, surface science and chemistry-----------------------------

Magnetic properties of materials

Hervé Cruguel

Lure. Bât. 209 D, Univ. Paris-Sud, BP 34, 91898 Orsay cedex, France.

Herve.cruguel@lure.u-psud.fr

Magnetic properties of materials and their theoretical frame will first be introduced. Then, the key points of light sources which make these properties available to scientist will be examined, in particular for synchrotron radiation and free electron laser. More specifically, properties such as polarisation, high flux, spatial and temporal resolution, energy range and energy resolution will be discussed. Some example of the different techniques used to get this information will be given in order to illustrate the large diversity of this field (from millimetre to nanometre structure; from second to picosecond time scale). Examples such as LMDAD on cluster and thin film, PEEM, reversal dynamic and precession will be presented. Future prospects will finally be opened.

EUV Lithography

Willi Neff[1], Klaus Bergmann[1], Joseph Pankert[2]

[1] Fraunhofer-Institute for Laser Technology; Steinbachstrasse 15; 52074 Aachen; Germany
[2] Philips Extreme UV GmbH; Steinbachstrasse 15; 52074 Aachen; Germany

willi.neff@ilt.fraunhofer.de

Optical lithography is the manufacturing technology used to print circuits onto computer chips. The necessity to steadily increase the capability of these chips forces the semiconductor manufacturers to pack more and more transistors with ever smaller features onto a chip. Currently UV light with 193 nm wavelength is used for the exposure of the photo resist on the silicon chips. The limits of this technology will be reached within the next few years. Thus, so-called "Next-Generation Lithographies" will be required. EUV lithography (EUVL) that uses extreme ultraviolet light around 13.5 nm wavelength is proposed to become the successor to optical lithography.

Light source and collector optics are critical components on the way to realize EUV lithography. The requirements on source and collector are derived from a throughput model for the processing of up to 120 wafers per hour in a commercial EUV scanner. Material (debris) emitted from components of the source strongly influences the reflectivity of the collector being located in close vicinity. A variety of different source concepts based on laser-produced or gas-discharge plasma are under development world-wide. Reliable EUV metrology methods are necessary to characterize all the essential features of the source-collector module.

Requirements as well as scientific and technological challenges are discussed. Results of the source development program of Philips Extreme UV are presented.

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Medical Imaging and Radiotherapy with Synchrotron Radiation. A closer look at the U647 programs: PAT-PLAT, Iodine-enhanced Synchrotron Stereotactic Radiotherapy and quantitative imaging of perfusion parameters in brain tumors

AM Charvet, JF Adam, MC Biston, C Boudou, A Joubert, W Renier, J Rousseau,
B Bertrand, JF Le Bas, H Elleaume, N Foray, J Balosso, F Estève,
Unité INSERM U647/ESRF
S Corde, S Fiedler, G Le Duc, S Bohic, G Berruyer,
T Brochard, C Nemoz, M Renier, A Bravin, ESRF
charvet@esrf.fr

A review of the main axes of development of medical applications of SR will be given. The main imaging and quantitative analysis techniques are: dual energy subtraction, quantitative CT, diffraction enhanced and phase-contrast imaging; small-angle diffraction. These imaging techniques have been applied to coronary angiography, brain and breast tumor characterization, bone densitometry and lung ventilation. In the field of tumor radiotherapy, micro-beam radiotherapy (MRT), and high Z-element enhanced kilovoltage radiotherapy are being investigated as candidates for clinical research protocols.

Status of the INSERM U647 programs: Our research team U647 is primarily interested in brain tumors, their radiotherapy and X-ray imaging, and carries out its synchrotron related work on the Medical Beamline ID17 of the ESRF, in collaboration with the ESRF staff. Two modalities of radiotherapy have been investigated in pre-clinical studies on rats, as well as on cells or DNA: photo-activation with platinum (PAT-PLAT) and iodine-enhanced synchrotron stereotactic radiotherapy (ISSR). In both modalities an exogenous high Z element is introduced in the area of the tumor, to take advantage of the higher interaction cross-section of X-rays and atoms in the photo-electric domain. The guiding principle for the PAT-PLAT technique was to introduce the high Z element, namely platinum, in the DNA of the cancerous cells. It was hoped that following direct absorption of the X-ray photons by the platinum atoms via the photo-electric effect on core levels, enough low energy Auger electrons would be produced in each platinum atom to locally create irreparable double strand breaks of the DNA molecule in each cancerous cell of the tumor. The guiding idea behind ISSR was to introduce high Z-elements (iodinated contrast agent) in the microscopic blood vessels feeding an evolving tumor. The locally increased absorbed X-ray dose would damage the blood vessels, thereby stopping tumor evolution. Synchrotron radiation from a high energy storage ring is a good X-ray source for these techniques since it provides enough photons for an intense monochromatic X-ray source in the 50 to 80 keV range. Pre-clinical studies have been carried out on rats for both modalities at the ESRF, and show a significant increase in survival of the rats [1,2]. Cell survival and DNA repair have been studied for both modalities to better understand the mechanisms involved.

The success of Iodine-enhanced Synchrotron Stereotactic Radiotherapy depends on appropriate contrast agent distribution in the tumor volume. For that and for the general study of tumor evolution we are also carrying out quantitative measurements of cerebral blood volume, blood flow and contrast agent distribution.

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QUESTIONNAIRE

We aim at preparing a European VUV sources booklet for users. For this purpose, a questionnaire was prepared.

- Please check the questionnaire
- Please prepare a list of projects, projects leaders and their e-mails, who should fill the questionnaire. Please send this information to H. Bachau.
- Help can be asked to the speakers of session 1.

SOURCES CHARACTERISTICS

TYPE OF SOURCE:	
RANGE OF WAVELENTH:	***e*V**
POLARIZATION:	**lin H lin V Circular**
TUNABILITY:	**YES NO**
REPETITION RATE:	**Hz**
PULSE DURATION:	**fs**
PEAK INTENSITY:	**W/cm^2**
ENERGY PER PULSE:	**mJ**
PEAK POWER:	**W**
AVERAGE POWER:	**W**
BANDWIDTH (FWHM)[%]:	**%**
COHERENCE TIME:	**fs**
NUMBER OF PHOTONS PER PULSE:	
AVERAGE FLUX OF PHOTONS:	**s^{-1}/0.1% bandwidth**
PEAK BRILLANCE:*	
AVERAGE BRILLANCE:*	
OBJECTIVES	
REMARKS	

* in unit of photons/(s $mrad^2$ mm^2 0.1% bandwidth)