Laserlab
Europe

Laserlab Europe

Visions on Future Laser-based X-ray Science and Technology

19-20 November 2018

ICFO

Program Monday, November 19th

9:00 - 9:10 h	Welcome
9:10 - 9:40 h	Imaging ultrafast electronic and nuclear dynamics molecules **Rolles, D. / Kansas State**
9:40 - 10:20 h	Ultrafast imaging of atomic and electronic motio using x-rays **Natan, A. / SLAC**
10:20 - 10:40 h	COFFEE BREAK - ICFO NEST Hall
10:40 - 11:10 h	Perspectives for ultrafast X-ray spectroscopy of chemica systems **Chergui, M. / EPFL**
11:10 - 11:40 h	Structural Dynamics in Complex Chemical and Biochemic Systems **Techert, S. / Göttingen, DESY**
11:40 - 12:10 h	Ultrafast dynamics of solids: Interfaces and correlated materials **Wolf, M. / FHI Berlin**
12:10 - 12:40 h	Non-equilibrium nanoscale control of charge, spin & lattice motion in magnetic materials **Dürr, H. / Uppsala**
12:40 - 12:50 h	Group Photo
12:50 - 13:45 h	LUNCH - ICFO NEST Hall
13:45 - 14:15 h	Laser plasma sources for application in material and biomedical engineering, plasma physics and technology, and radiobiology **Fiedorowicz, H. / MUT**
14:15 - 14:45 h	X-ray based plasma diagnostics **Williams, G. ; Fajardo, M. / Lisbon**
14:45 - 15:00 h	COFFEE BREAK - ICFO NEST Hall
15:00 - 15:30 h	Quantum imaging with incoherently scattered x-rays **von Zanthier, J. / Erlangen**
15:30 - 15:50 h	EUV and SXR photon handling **Poletto, L. / Padova**
15:50 - 16:10 h	High-resolution X-ray detection with pnCCD detectors **Hartmann, R. ; Strüder, L. / pnSensor GmbH**
16:10 - 16:30 h	Soft X-ray Metrology for Semiconductor Manufacturing **Brussaard, S. / ASML**
16:30 - 17:30 h	**Round table**
17:30 - 18:30 h	Optional lab tour - Please sign up
19:00 h	Dinner at Ca n'Estella. Departure by bus in front of ICFO

Program Tuesday, November 20th

9:00 - 9:30 h	Attosecond pulse shaping **Sansone, G. / Freiburg**
9:30 - 10:00 h	Opportunities with seeded FEL **Penco, G. / FERMI**
10:00 - 10:20 h	Femtosecond x-ray experiments at EUXFEL **Bressler, C. / XFEL GmbH**
10:20 - 10:40 h	COFFEE BREAK - ICFO NEST Hall
10:40 - 11:10 h	Laser-driven HHG sources **Johnsson, P. / Lund**
11:10 - 11:30 h	X-ray spectroscopy and nanoscale imaging in the lab with laser produced plasma sources and tailor made X-ray optics **Stiel, H. ; Kanngiesser, B. / Berlin**
11:30 - 12:00 h	Considering the laser driven X-ray sources to develop bio-medical applications **Wolf, M. / FHI Berlin**
12:00 - 12:30 h	Laser-driven SXR lasers **Dürr, H. / Uppsala**
12:30 - 13:30 h	LUNCH - ICFO NEST Hall
13:30 - 13:50 h	Application of laser plasma EUV and soft X-ray sources in nanoimaging, pulsed radiography and tomography and absorption spectroscopy **Fiedorowicz, H. / MUT**
13:50 - 14:20 h	Ultra-short pulse radiation sources based on laser wakefield accelerators **Jaroszynski, D. / Strathclyde**
14:20 - 14:40 h	COFFEE BREAK - ICFO NEST Hall
14:40 - 15:00 h	Quantum optical spectroscopy **Tzallas, P. / FORTH-IESL and ELI-ALPS**
15:00 - 15:20 h	Phase-contrast imaging for biomedicine **Stutman, D. / ELI-NP**
15:20 - 15:40 h	Compact, high-yield incoherent and coherent X-ray sources by Traveling- Wave Thomson-Scattering **Steiniger, K. / HZDR**
15:40 - 17:00 h	**Round table**
17:00 - 17:10 h	Closing remarks.

BOOK OF ABSTRACTS

Imaging Ultrafast Electronic and Nuclear Dynamics in Molecules

Daniel Rolles

J.R Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, KS

Short and intense X-ray pulses produced by high harmonic sources and free-electron lasers allow probing ultrafast electronic and nuclear dynamics in molecules with element and site-specificity. Combined with electron and ion momentum imaging, this enables studies of intramolecular charge transfer and of other ultrafast electronic processes during light-induced reactions.

References:
B. Erk et al., *Imaging Charge Transfer in Iodomethane upon X-Ray Photoabsorption*, Science 345, 288-291 (2014).
A. Rudenko et al., *Femtosecond response of polyatomic molecules to ultra-intense hard X-rays*, Nature 546, 129-132 (2017).
F. Brauße et al., *Time-resolved inner-shell photoelectron spectroscopy: From a bound molecule to an isolated atom*, Phys. Rev. A 97, 043429 (2018).

Ultrafast imaging of atomic and electronic motions using x-rays

Natan, A

Stanford PULSE Institute, SLAC National Accelerator Laboratory, 2575 Sand Hill Rd Menlo Park, CA, 94025 USA

Electronic and nuclear motions are key ingredients of all chemical reactions. Making molecular movies of such motions in their natural time and length scales is a challenging and significant research field currently emerging using ultrafast X-ray pulses [1]. We will discuss the state of the art in imaging dynamics of simple molecules using X-rays and the opportunities and challenges that future light sources and nonlinear methods hold [2,3].

1 Glownia, J. M., et al. "Self-referenced coherent diffraction X-ray movie of Ångstrom-and femtosecond-scale atomic motion." Physical review letters 117.15 (2016): 153003.
2 Li, Siqi, et al. "Characterizing isolated attosecond pulses with angular streaking." Optics express 26.4 (2018): 4531-4547.
3 Rouxel, Jérémy R., et al. "X-Ray Sum Frequency Diffraction for Direct Imaging of Ultrafast Electron Dynamics." Physical Review Letters 120.24 (2018): 243902.

Perspectives for ultrafast X-ray spectroscopy of chemical systems

Majed Chergui

Ecole Polytechnique Fédérale de Lausanne, Laboratoire de Spectroscopie Ultrarapide and Lausanne Centre for Ultrafast Science, 1015 Lausanne, Switzerland

In this talk, I will present some recent achievements in ultrafast spectroscopic studies of (bio)chemical systems and of materials, in order to stress and highlight some of the open issues where modern sources of X-ray pulses can make a significant contribution.

Structural Dynamics in Complex Chemical and Biochemical Systems

Techert, S.

Structural Dynamics of (Bio)Chemical Systems, Deutsches Elektronen-Synchrotron DESY,
Notkestr. 85, 22607 Hamburg
Fakultät für Physik, Georg-August-Universität, Friedrich Hund Platz 1, 37077 Göttingen

In the present talk we will give an overview of our strategy utilizing the pulsed characteristics of X-ray sources, in particular synchrotrons and free electron lasers, to gain structural dynamics information of micro- and macromolecules on their time scales of reactivity which ranges from femtoseconds to milliseconds. Two detailed examples will be given, where ultrafast optical spectroscopy and ultrafast structural dynamics studies based on high flux and pulsed X-ray methods (synchrotron and Free Electron Laser sources) have been utilized as complementary tools for studying the real time structure-function relationships of opto-electronic devices such as photo-switches, photo-switchable ferroelectrics or novel types of solar cells.

References:

1. S. Bari, R. Boll, S. Techert, et al. Chapter 15: High flux X-ray sources and Free Electron Lasers for Studying Ultrafast Time Structure Imprints in Complex Chemical and Biochemical Reactions, in: X-ray Free Electron Lasers, eds. U. Bergmann, V. Yachandra, J. Yano, Royal Chemical Society, Oxford Press (2017) and references therein.

Ultrafast dynamics of solids: Interfaces and correlated materials

Martin Wolf

Fritz Haber Institute of the Max Planck Society

The emergent physical properties of solids and interfaces arise from the complex interplay of fundamental interactions between the electron, spin, orbital and lattice degrees of freedom. Ultrafast spectroscopy can identify these interactions and quantify couplings and energy flow between different subsystems. Here I will provide my perspective on the current status and future prospectsusing multiple techniques.

Non-equilibrium nanoscale control of charge, spin & lattice motion in magnetic materials

Hermann A. Dürr

Department of Physics and Astronomy, Uppsala University, Sweden

The idea to probe, change and control functional materials properties with the help of light has long intrigued researchers in materials science. I will show for several examples the unique potential of using femtosecond pulses from x-ray free electron lasers to probe in real time the ultrafast dynamics in nanoscale systems. Understanding and engineering the evolving electron, spin and lattice motion on the time- and lengthscales associated with the relevant magnetic interactions promises new ways for storing and processing of information.

Laser plasma soft X-ray and EUV sources for application in metrology, processing materials, plasma physics and radiobiology

Henryk Fiedorowicz, Andrzej Bartnik, Przemysław Wachulak

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00-908 Warsaw, Poland

Laser plasma sources of soft X-rays and extreme ultraviolet (EUV) have been developed using a double-stream gas puff target irradiated with nanosecond laser pulses from Nd:YAG lasers [1]. Applications of the sources in metrology of EUV mirrors [2] and filters, micromachining of polymers and modification of polymer surfaces for biocompatibility control [3], EUV photoionized cold plasma studies [4], and DNA damage with soft X-ray nanosecond pulses at high dose of radiation [5] are presented.

References:

1. H. Fiedorowicz et al. Appl. Phys. B 70 (2000) p. 305
2. R. Rakowski et al. Opt. Appl. 36 (2006) p. 593
3. I.U. Ahad et al. J. Biom. Mat. Res. A 102 (2014) p. 3298
4. A. Bartnik et al. Phys. Plasmas 23 (2016) art. no. 043512
5. D. Adjei et al. Rad. Phys. Chem. 120 (2016) p. 17

X-ray based plasma diagnostics

Gareth Williams

GoLP, IPFN, Instituto Superior Técnico, Lisbon, Portugal

Matter in extreme conditions (MEC) comprises a range of astrophysical and terrestrial states, such as those found in collapsing stars, and during intense laser heating of solids. Challenges in the theoretical treatments, and lack of extensive supporting data have hindered progress. The last decade has witnessed a plethora of new insights into these states from a range of new x-ray sources [1-3]. The current state and future prospects of using novel x-ray sources for MEC science will be discussed.

[1] Nagler et al., *Turning solid aluminium transparent by intense soft X-ray photoionization*
Nature Physics (2009)
[2] Vinko et al., *Creation and diagnosis of a solid-density plasma with an X-ray free-electron laser.*
Nature (2012)
[3] Mahieu et al., *Probing warm dense matter using femtosecond X-ray absorption spectroscopy with a laser-produced betatron source*
Nature Communications (2018)

Quantum imaging with incoherently scattered x-rays

Joachim von Zanthier

Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg,
91058 Erlangen, Germany

We show that methods from quantum imaging, i.e., exploiting higher order intensity correlations, can be used to image the 3D arrangement of sources that scatter incoherent X-ray radiation [1-3]. We discuss a number of properties of the incoherent diffraction imaging (IDI) method that are conceptually superior to those of conventional coherent X-ray structure determination [2].

[1] A. Classen et al., Phys. Rev. Lett. 117, 253601 (2016).
[2] A. Classen et al., Phys. Rev. Lett. 119, 053401 (2017).
[3] R. Schneider et al., Nature Phys. 14, 126 (2018).

Extreme-ultraviolet and soft X-ray photon handling

Luca Poletto

CNR-Institute for Photonics and Nanotechnologies, Padova, Italy

The main topics related to photon handling of extreme-ultraviolet and soft X-rays photons for table-top ultrafast beamlines with femtosecond or sub-femtosecond resolution for the generation and use of high-order laser harmonics are discussed. The presentation is focused on three main issues: 1) beam monochromatization; 2) beam conditioning; 3) beam focusing.

High-resolution X-ray detection with pnCCD detectors

Robert Hartmann

PNSensor GmbH, Otto-Hahn-Ring 6, 81739 Munich, Germany

In the fields ranging from physics and chemistry to material and life sciences X-ray techniques are able to deliver meaningful answer to fundamental questions. pnCCD detectors exhibit a high X-ray quantum efficiency, fast and low-noise readout and the ability for spectroscopic imaging [1,2], which makes them well suited for instrumentation at modern X-ray facilities [3].

References:
[1] L. Strüder et al., Nucl. Instr. And Math. A 614, (2010) 483-496
[2] W. Leitenberger et al., Journal of Synchrotron Radiation 15 (2008), 449-457
[3] M. Seibert et al., Nature 470 (7332), (2011) 78-81

Soft X-ray Metrology for Semiconductor Manufacturing

Seth Brussaard

ASML

ASML is the world's largest manufacturer of lithography systems and all leading chipmakers use ASML's technology to print their most complex structures. Accurate metrology during production has become essential. Increasing complexity and shrink move the devices beyond the limits of visible light metrology. (Soft) X-rays can extend the metrology capabilities to meet the demands of the semiconductor industry.

Attosecond pulse shaping

Giuseppe Sansone

Albert-Ludwigs-University Freiburg, Stefan-Meier-Strasse 19
79104 Freiburg Germany

We will present a new approach for the characterization of the phase difference between harmonics of a fundamental frequency ω, generated by seeded Free Electron Laser. The technique allows to overcome the lack of synchronization between the extreme ultraviolet harmonics and an auxiliary laser pulse. We will present results obtained at the FERMI showing the characterization and shaping of attosecond waveforms.

Opportunities with Seeded FEL

Giuseppe Penco

Elettra-Sincrotrone Trieste

The advent of seeded FELs constitutes an unprecedented breakthrough, overcoming the limited longitudinal coherence of the self-amplified spontaneous emission FEL and providing intense fully coherent X-ray photons. This step-forward paved the way to a number of coherent control experiments, multi-color schemes, attoseconds x-ray and phase-locked pulses.

References:
Nat. Photonics 6, 699 (2012);
Nat. Photonics 10, 176 (2016);
Phys Rev. Lett. 116, 024801 (2016)

Femtosecond X-Ray Experiments at European XFEL

Christian Bressler

European XFEL

Pico- and femtosecond x-ray experiments deliver new insight into evolving dynamic processes, including reactive transition metal compounds. The utilized x-ray tools have been combined at the Femtosecond X-Ray Experiments (FXE) Instrument at European XFEL. We will present the current FXE status at European XFEL [1] together with some early results.

[1] Photon Beam Transport and Scientific Instruments at the European XFEL
T. Tschentscher, C. Bressler, J. Grünert, A. Madsen, A. P. Mancuso, M. Meyer,A. Scherz, H. Sinn, U. Zastrau, Appl. Sci. 7, 592 (2017)

Laser-Driven High-Order Harmonic Generation Sources

Per Johnsson

Department of Physics, Lund University, Sweden

High-order harmonic generation (HHG) sources driven by ultrashort laser pulses have, during the last decades, become indispensable tools for basic research in atomic, molecular and optical physics, with first promising applications also in e.g. liquids and nanosystems. This presentation will give an overview of the current trends in HHG source development, and elaborate on some future directions.

X-ray spectroscopy and nanoscale imaging in the lab using laser produced plasma sources and tailor made X-ray optics

Holger Stiel1 and Birgit Kanngießer2

Berlin Laboratory for innovative X-ray technologies (BLiX)
1 Max-Born Institut, 12489 Berlin, Max-Born-Str. 2A, Germany
2 Institut für Optik und Atomare Physik, TU Berlin, 10623 Berlin, Hardenbergstr. 36, Germany

The transfer of methods such as X-ray spectroscopy or microscopy from synchrotron to the lab requires both powerful laboratory X-ray sources and efficient optical systems. As examples for this transfer we present a water window soft X-ray microscope [1] and a soft X-ray absorption spectrometer [2] based on laser plasma sources and adapted optics, developed at BLiX. Furthermore, we will discuss the advantages of HAPG optics [3] for hard X-ray spectroscopy in the lab.

References

1. Legall H., Blobel G., Stiel H., Sandner W., et al. Compact x-ray microscope for the water window based on a high brightness laser plasma source. Opt. Express 20, 18362-18369, 2012.
2. Mantouvalou I., Witte K., Martyanov W., Jonas A., et al. Single shot near edge x-ray absorption fine structure spectroscopy in the laboratory. Applied Physics Letters 108, 201106, 2016.
3. Stiel H., Schnürer M., Legall H., Malzer W., et al. Prospects of ultrafast x-ray absorption investigations using laboratory based sources. SPIE 8849, 8, 2013.

Considering the laser driven X-ray sources to develop bio-medical applications

Philippe Zeitoun

Laboratoire d'Optique Appliquée – Palaiseau – France

Biological or medical applications have for many decades taken benefit of X-ray sources, mainly tubes and synchrotrons and recently free-electron lasers. With the strong improvement in reliability and performances of laser-driven X-ray sources, they are mature to be fully considered for complementing the actual X-ray sources for bio-medical applications. Two kinds of applications will be considered for the current discussion: imaging and radiotherapy both from the single cell to human. Present and future prospect of this research field will be presented and discussed.

Laser driven soft x-ray lasers

Stéphane Sebban

Laboratoire d'Optique Appliquée – Palaiseau – France

Emerging applications of coherent soft x-ray sources, notably in biology, require high energy and ultrashort pulse duration in the femtosecond-scale to probe the ultra-fast dynamics of matter in the nanometer scale. Laser driven plasma-based soft x-ray lasers turn out to be good candidates since they can emit a large number of photon (up to 10^{15} per pulse) within a narrow linewidth and exhibit high-quality optical properties once seeded with high-harmonic sources. Present and future prospect of this research field will be presented and discussed.

Application of laser plasma EUV and soft X-ray sources in nanoimaging, pulsed radiography and tomography, and absorption spectroscopy

Przemysław Wachulak, Andrzej Bartnik, Henryk Fiedorowicz

Institute of Optoelectronics, Military University of Technology, Warsaw, Poland

Applications of laser plasma light sources in EUV and soft X-ray nanoimaging [1], pulsed EUV radiography and tomography [2] and near-edge soft X-ray absorption fine structure (NEXAFS) spectroscopy [3] are presented. The sources are based on a double-stream gas puff target irradiated with nanosecond pulses from a compact Nd:YAG laser.

References:

1. P. Wachulak et al. Appl. Phys. B 118 (2015) p. 573; P. Wachulak et al. Appl. Sci. (Switzerland) 7 (2017) art. no.548; P. Wachulak et al. Sci. Rep. 8 (2018), art. no. 8494
2. P. Wachulak et al. Laser Part. Beams 31 (2014) p. 219; P. Wachulak et al. Opt. Lett. 39 (2014) p. 532
3. P. Wachulak et al. Opt. Expr.26 (2018) p. 8260; P. Wachulak et al. Materials 11 (2018) art. no. 1303; P. Wachulak et al. Spectrochim. Act. B 145 (2018) p. 107

Ultra-short pulse radiation sources based on laser wakefield accelerators

Jaroszynski, D.

University of Strathclyde

We show how laser radiation can be transformed into incoherent and coherent radiation using laser-driven plasma waves. We show that the electron beam and radiation from the laser wakefield accelerator could be useful tools for time resolved imaging and probing of matter subject to stimuli. As an example we present experiments showing that 26 fs XUV pulses can be produced directly from a LWFA driven undulator and discuss ways of producing sub-fs XUV pulses in the water window.

Quantum optical spectroscopy

Paraskevas Tzallas

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2 ELI-ALPS, ELI-Hu Kft., Dugonics tér 13, H-6720 Szeged, Hungary

I will present the synthesis of strong laser-field physics and quantum-optics. Specifically, I will describe how the strong-field laser-matter interaction can lead to the generation of non-classical light-states which carry the information of the interaction [1-3]. Utilizing a novel detection method named "quantum spectrometer", these light states have been used to recover the high-harmonic spectrum, and reveal information which is inaccessible by conventional approaches.

References

[1] I. A. Gonoskov, et al., Sci. Rep. 6, 32821 (2016).
[2] N. Tsatrafyllis, et al., Nat. Commun. 8, 15170 (2017).
[3] N. Tsatrafyllis et al., (Submitted)

Phase-contrast imaging for biomedicine

Stutman Dan

Extreme Light Infrastructure – Nuclear Physics, Bucharest-Magurele, Romania
Johns Hopkins University, Department of Physics, Baltimore, Maryland USA

Phase-contrast X-ray imaging can dramatically improve soft tissue contrast [1]. A biomedical imaging program utilizing PW lasers is being planned at ELI-NP, including development of ultrabright X-ray sources, of phase-contrast methods optimal for laser sources, and studies of breast cancer diagnostic. An X-ray optics laboratory will support this research. Biomedical applications of X-ray phase-contrast imaging will be presented.

[1] Stutman D, Beck TJ, Carrino JA, Bingham CO. Talbot phase-contrast X-ray imaging for the small joints of the hand Physics in medicine and biology. 2011;56(17):5697-5720

Compact, high-yield incoherent and coherent X-ray sources by Traveling-Wave Thomson-Scattering

Klaus Steiniger

Helmholtz-Zentrum Dresden-Rossendorf

In Traveling-Wave Thomson-Scattering pulse-front tilted, petawatt class laser pulses are scattered off relativistic electrons to realize compact optical free-electron lasers or brilliant incoherent X-ray sources with state-of-the-art electron accelerators and high- power laser systems. Example setups of TWTS OFELs providing ultraviolet radiation are presented together with an optical setup to compensate laser dispersion.

References:

[1] A. D. Debus, et al. "Traveling-wave Thomson scattering and optical undulators for high-yield EUV and X-ray sources". Applied Physics B 100(1), 61 (2010). ISSN 0946- 2171. doi:10.1007/s00340-010-3990-1.

[2] K. Steiniger, et al. "Optical free-electron lasers with Traveling-Wave Thomson- Scattering". Journal of Physics B: Atomic, Molecular and Optical Physics 47(23), 234011 (2014). ISSN 0953-4075. doi: 10.1088/0953-4075/47/23/234011.

[3] K. Steiniger, et al. "Building an Optical Free-Electron Laser in the Traveling-Wave Thomson-Scattering Geometry". Submitted to Frontiers in Physics, section Optics and Photonics (2018).