Lectures and Seminars of the CUI course programme in the WiSe2013-2014

CUI Main Lecture

Lecture	Lecturers	Start	Time	Place
Approaches to the simulation of non-equilibrium dynamics	Prof. A. Lichtenstein Prof. P. Schmelcher	17.10.13	Thursdays 08:30-10:00	SemRm 2

Lectures

Lecture	Lecturers	Start	Time	Place
Nichtgleichgewichtsstatistik und Transporttheorie	Prof. M. Thorwart	17.10.13	Mondays and Thursdays 10:15-11:45	Hörsaal AP (Monday) SemRm 4 (Thursday)
Methoden moderner Röntgenphysik – Spektroskopie	Prof. G. Grübel Prof. W. Wurth Dr. M. Martins	15.10.13	Tuesdays 12:45-14:15 Thursdays 08:30-10:00	SemRm 4
Ultrafast Optical Physics I	Prof. M. Drescher	18.10.13	Fridays 08:30-10:00	SemRm 2
Festkörperlaser	Dr. C. Kränkel	21.10.13	Mondays 10:15-11:45	Hörsaal I
Theory of Photon-Matter Interactions	Prof. R. Santra	15.10.13	Tuesdays 08:30-10:00 Fridays 10:15-11:00	SemRm 6
The Basis of Modern Molecular Physics	Prof. J. Küpper Dr. T. Laarmann Dr. S. Trippel Dr. Vendrell-Romagosa	15.10.13	Tuesdays 10:30-12:00 Fridays 10:30-12:00	SemRm I CFEL, Bld. 99, DESY
Struktur-Funktions-Analyse biologischer Makromoleküle*	Prof. C. Betzel Prof. H. Schlüter Prof. R. Willumeit Dr. T. Hackl	17.10.13	Mondays 13:00-13:45 Fridays 11:00-13:00	Mondays SemRm AC1; Fridays Hörsaal D

* Department of Chemistry, Martin Luther King Platz 6.

Seminars

Seminar	Lecturers	Start	Time	Place
Multifunktionale Nanostrukturen	Prof. K. Nielsch Dr. D. Görlitz	17.10.13	Thursdays 14:00-15:30	Mikrostruktur-pausenraum
Quantendynamik von Nanosystemen im Nichtgleichgewicht	Prof. M. Thorwart	15.10.13	Tuesdays 14:00-15:30	SemRm 9/222
Viel-Teilchen Theorie ultrakalter Atome	Prof. L. Mathey	16.10.13	Wednesdays 14:00-15:30	ZOQ SemRm (Bld. 90) Bahrenfeld
Nanostrukturphysik	Dr. G. Meier Dr. K. Buth Dr. T. Matsuyama Prof. U. Merkt	14.10.13	Mondays 14:30-16:00	Bibliothek AP
Festkörperlaser	Prof. G. Huber Dr. C. Kränkel	15.10.13	Tuesdyas 13:30-15:00	SemRm 52 (Bld. 69) Bahrenfeld
Special Topics in Nonlinear Optics and Ultrafast Laser Physics	Prof. F. Kärtner	17.10.13	Thursdays 08:30-10:00	SemRm 2, CFEL (Bld. 99), DESY
Molecular Physics	Prof. Küpper Dr. M. Schnell	17.10.13	Thursdays 10:00-11:30	SemRm I, CFEL (Bld. 99), DESY
Vielteilchensysteme und quantenstatistische Methoden	Prof. M. Thorwart	16.10.13	Wednesdays 14:30-16:00	SemRm 1

Lecture organized by CUI and IMPRS-UFAST:
Lecturer Prof. K. Ishikawa[§]
Laser-matter interaction: from atoms to tissue

Lecture	Date	Time	Place
Laser fundamentals	18.11.2013	Monday 14:00-16:30	ZOQ SemRm (Bld. 90, ground floor)
Atom in an intense laser field	19.11.2013	Tuesday 09:30-12:00	ZOQ SemRm (Bld. 90, ground floor)
High-harmonic generation	19.11.2013	Tuesday 14:00-16:30	ZOQ SemRm (Bld. 90, ground floor)
Femto- and attosecond ionization dynamics	20.11.2013	Wednesday 09:30-12:00	ILP SemRm (Bld. 69, ground floor)
Laser-tissue interaction and its medical applications	20.11.2013	Wednesday 14:00-16:30	ILP SemRm (Bld. 69, ground floor)

[§] If you like to attend, please send first an e-mail to Ms. Anja Bleidorn (Anja.Bleidorn@mpsd.cfel.de).

Lectures organized by IMPRS-UFAST§

Lecture	Lecturers	Start	Time	Place
Basics of Chemistry/Biochemistry	Prof. U. Hahn	05.11.13 06.11.13	15:30-18:00 12:00-14:30	SemRm 19, Dept. Chemistry*
	Prof. R. J. D. Miller	11.11.13 12.11.13 14.11.13 15.11.13	14:00-15:30 14:00-15:30 14:00-15:30 10:30-12:00	SemRm IV (01.111), CFEL, Bld. 99, DESY
Source Technology	Prof. F. X. Kärtner Prof. T. Uphues	18.02.14 20.02.14 25.02.14 27.02.14 03.03.14 06.03.14	09:00-11:00	SemRm IV (01.111), CFEL, Bld. 99, DESY

§ The attendace to these lectures is limited to a specific number (typically 15). Priority is given to members of IMPR-UFAST. If you like to attend, please send first an e-mail to Ms. Anja Bleidorn (Anja.Bleidorn@mpsd.cfel.de).

* Department of Chemistry, Martin Luther King Platz 6.

Lectures by Prof. R. Millane§

Lecture	Date	Time	Place
Single crystal x-ray crystallography and single particle imaging	12.11.2013	Tuesday 14:00-15:00	SemRm III, CFEL, Bld. 99, DESY
Introduction to x-ray fiber diffraction analysis	19.11.2013	Tuesday 14:00-15:00	SemRm IV (01.111), CFEL, Bld. 99, DESY
Introduction to x-ray fiber diffraction analysis	26.11.2013	Tuesday 14:00-15:00	SemRm IV (01.111), CFEL, Bld. 99, DESY

§ If you like to attend, please send first an e-mail to Dr. Antonio Negretti (anegrett@physnet.uni-hambrug.de).

Abbreviations:

SemRm = Seminar room
Bld. = Building
CFEL = Center for Free-Electron Laser Science
IMPRS-UFAST = International Max Planck Research School for Ultrafast Imaging and Structural Dynamics
SFB = Sonderforschungsbereich
GRK = Graduiertenkolleg
ZOQ = Zentrum für Optische Quantentechnologien
ILP = Institut für Laserphysik
AP = Angewandte Physik
DESY = Deutsches Elektronen-Synchrotron
FBC = Fachbereich Chemie

Remark on *Place*:
If the event does not take place at the DESY-Bahrenfeld campus, then it will take place at the department of Physics of the University of Hamburg (Jungiusstraße 9, 20355 Hamburg). See also www.physik.uni-hamburg.de.
SemRm 1 and 2 = Seminar room (1. Floor, right staircase)
SemRm 6 = Seminar room (3. Floor, left staircase)

Abstract: CUI Main Lecture

Approaches to the simulation of non-equilibrium dynamics: We will develop the main ideas and underlying concepts of the nonequilibrium dynamics in classical as well as quantum systems. Illustrations and applications from different areas of physics ranging from cold atoms in optical lattices to the motion of electrons in semiconductor heterostructures will be provided. The main emphasis will be put on a thorough understanding of the corresponding mechanisms and to a simulation of the nonequilibrium transport.
In the first part of the lecture the classical transport in driven spatiotemporal lattices will be studied. The ratchet effects will be introduced and classified according to the breaking of space-time symmetries which are possible for it. Directed currents and transport, their control and dynamical emergence shall be derived from the fundamental laws and on basis of an analysis of the resulting phase space. In a further step we will discuss a second scenario of symmetry breaking which leads to plethora of phenomena discovered recently, such as patterned deposition, spontaneous formation of stationary and traveling density waves as well as dynamical current reversals due to long-range interactions. The lecture concludes with an extended outlook on future physics of spatiotemporally driven lattices and their implementations.
The second part of the lecture is dedicated to the nonequilibrium tunneling dynamics in strongly interacting quantum systems, relevant in particular to ultracold bosonic systems. First we will discuss the characteristics of low-dimensional few- to many-body systems in traps. The intriguing crossover from a weakly interacting mean-field like behaviour to a strongly correlated gas, where the bosons are 'fermionized', will be derived. Based on the here gained knowledge and understanding we will inspect the tunneling dynamics in different regimes and explore its unique properties in the strong interaction regime. The latter includes the crossover from single particle to pair tunneling and novel solely correlation induced processes. The methodology to solve the strongly correlated quantum dynamics will be developed at the example of the family of Multi-Configuration Time-Dependent Hartree Methods.
The course is suited for students being acquainted with quantum mechanics and theoretical mechanics, ie. for master and PhD students. Beyond this, all necessary prerequisites for an understanding will be provided in the course.

Abstracts: Lectures

Nichtgleichgewichtsstatistik und Transporttheorie: The content of the course is the following:

- Keldysh-path integral for bosonic and fermionic systems
- Green functions in the Keldysh-formalism
- Effective Hamiltonian description of dissipative systems
- Kinetical equation
- Applications: charge statistics, dynamic of the magnetization in nanoscale systems, dynamic of biological populations and others

Methoden moderner Röntgenphysik – Spektroskopie (Modern X-Ray Physics – Spectroscopy): The course will present the basics of modern x-ray physics and will concentrate in particular on spectroscopy. This includes a general introduction into x-ray physics as well as applications of soft x-ray spectroscopy to study condensed matter and small quantum system.

- Interaction of soft x-rays with matter

  X-ray absorption, photo effect, Auger effect, x-ray emission
- Accelerator based x-ray sources

  Synchrotron radiation and Free Electron Lasers
- Experimental methods

  Photoelectron spectroscopy, x-ray absorption spectroscopy
- X-ray optics

  Optical materials, EUV lithography, ray tracing
- Applications of soft x-rays

  Small quantum systems, solid-state spectroscopy

This course will give insight in the research field of modern x-ray physics and provide the knowledge to work in this field and to understand the current literature.

Ultrafast Optical Physics I: Ultra-short light pulses are the key to studying highly dynamic processes in nature. They also find an increasing number of applications in technology, information processing and medicine. This introductory course will mediate the special concepts neccessary to understand ultrafast phenomena. The techniques will be discussed to create ultrashort optical pulses and to characterize their temporal properties. This in particular involves nonlinear optical effects. The associated exercise will aid to consolidate the content of the curriculum by solving problems and discussing examples.

Festkörperlaser: Lasers have found numerous applications in science and daily life. Many of these applications from low power green laser pointers to high power material processing devices rely on solid state gain materials such as crystals and glasses in bulk and fiber geometry. This lecture focuses on the fundamentals of theses lasers. It covers the basics of absorption and emission, the interaction between light and matter, optical resonators, Gaussian radiation, pump mechanisms, rate equations and threshold conditions for 3- and 4-level lasers based on rare earth ions, transition metals and semiconductors as well as different operation modes such as Q-switching and mode-locking. Furthermore, insights into the growth of crystals and fibers as well as a short introduction of selected kinds of lasers with their principal characteristics and applications will be given.

Theory of Photon-Matter Interactions:
Textbooks:
- *Molecular Quantum Electrodynamics,* by D. P. Craig and T. Thirunamachandran, Dover
- *Quantum Theory of Light*, by R. Loudon, Oxford University Press
- *Modern Quantum Chemistry*, by A. Szabo and N. S. Ostlund, Dover
- *Quantum Theory of Many-Particle Systems*, by A. L. Fetter and J. D. Walecka, Dover
- *Atomic Structure Theory*, by W. R. Johnson, Springer

Syllabus
1. Canonical formalism
   (a) Transverse and longitudinal fields
   (b) Coulomb gauge
   (c) Lagrangian and Hamiltonian
2. The radiation field
   (a) Quantization of the field
   (b) Fock states
   (c) Coherent states
   (d) Radiative density operator
   (e) Quantum theory of optical coherence
3. Many-electron problem
   (a) Second quantization
   (b) Hartree-Fock method
   (c) Hartree-Slater method
   (d) Configuration interaction
   (e) Many-body perturbation theory
4. Interaction between the photon and electron fields
   (a) Time-dependent perturbation theory
   (b) Few-photon absorption
   (c) Calculation of resonance states using complex absorbing potentials
   (d) Relaxation of excited electronic states (fluorescence, Auger decay, ICD, radiationless decay)
   (e) Rayleigh, Raman, and Compton scattering
   (f) AC Stark effect and Lamb shift
5. Case studies (includes an introduction to nonperturbative techniques)
   (a) Laser-induced alignment of molecules
   (b) Laser dressing of electronic states
   (c) Strong-field physics: tunnel ionization
   (d) Processes at high x-ray intensity

The Basis of Modern Molecular Physics: This module introduces the basic concepts of modern experiments in molecular physics. The students will acquire a detailed understanding of atoms and molecules, their interaction with external fields and other particles, and of experimental concepts in molecular physics. They will develop the skills to envision, plan, simulate, and eventually perform novel experiments to investigate the fundamental and applied aspects of molecular physics in quantum mechanics, chemistry, material science, biology, and so forth. Participants will learn to search for current (primary) literature, to explore a new scientific field, and to independently read and understand articles on previously unknown AMO physics.

Struktur-Funktions-Analyse biologischer Makromoleküle: The students will extend their knowledge about methods and procedures in structural biology and the analysis of interactions between biological macromolecules. In the lecture methods like protein crystallography, nuclear magnetic resonance spectroscopy (NMR), electron microscopy, small angle X-ray scattering and mass spectroscopy will be introduced and the significance of synchrotron radiation and X-ray lasers will be addressed. The course will be hold preferably in German.

Abstracts: Seminars

Multifunktionale Nanostrukturen (Multifunctional Nanostructures): In this seminar talks are given by external guests or group members. The topics are selected from the following 3 categories:

1. Synthesis of nanostructures for magnetic or/and thermoelectric applications (structured thinfilms, nanowires, nanotubes, electrochemical deposition, atomic layer deposition ALD,...),
2. Magnetic properties of nanostructures (switching behaviour of the magnetization, magnetic interactions, magnetic domain walls, magnetoresistance, magnetocaloric behaviour, ...),
3. Thermoelectric properties of nanostructures (conversion efficency, Seebeck coefficient, powerfactor, figure of merit ZT, ...).

Viel-Teilchen Theorie von Festkörpern und ultrakalten Atomen (Many-body theory of ultra-cold atoms and solid state systems): In this research oriented seminar we discuss many-body effects in ultra-cold atoms and solid state systems. Subjects include, for example, Bose-Einstein condensation, superconductivity and superfluidity, low-dimensional systems and fluctuating orders, renormalization group methods and many-body dynamics. Presentation subjects can be chosen from a wide range of fields, such as laser physics, solid state physics, quantum field theory, and atomic physics. The presentations can deal with fundamental questions or applied concepts, such as cooling and detecting methods, or technological aspects of ultra-cold atom systems or solid state systems. Both experimentalists and theorists are very welcome, and a lively discussion is desired.

Nanostruktur: The Seminar is on topics in micro- and nanometer-scale science and technology. Studies range from thin films to micro- and nanostructures and include squares, circles, nanowires, and even more complex micro- and nanoscale geometries. The focus of the seminar is on magnetic nanostructures. Ferromagnetic nanostructures are ideal systems to tailor physical properties of the single object via material parameters, layer sequences, and lithographical processes. Magnetization dynamics on the nanosecond and subnanosecond time scale in ferromagnetic micro- and nanostructures are in the focus of interest in frequency space as well as in real space. E.g., broadband ferromagnetic-resonance measurements obtained by vector-network analyzer spectroscopy are discussed in the presentations of the seminar. Transmission x-ray microscopy with a spatial resolution down to 10 nanometers and a temporal resolution below 100 picoseconds is important to give access to magnetization dynamics on its genuine time- and length scale. Complexity created by periodic arrangement of well-understood building blocks plays not only an important role in biochemistry, photonics, and engineering but is also of increasing importance for magnetism on the nanoscale. Magnetic interactions can be engineered to yield one-, two-, and three-dimensional crystal-like structures that show new intriguing properties that are discussed in the Seminar „Nanostrukturphysik“.

Festkörperlaser: In this seminar, selected guests will report about current topics of solid state laser research. The topics and precise dates of the respective talks will be announced individually via mailing-lists and the ILP and physics department webpages.

Special Topics in Nonlinear Optics and Ultrafast Laser Physics: **Content:**

- Nonlinear Fiber Optics
- Continuum and Super-continuum Generation.
- Dynamics of Fiber Lasers
- Dynamics of Kerr-Lens Modelocked Lasers
- Semiconductor Absorber Modelocked Lasers
- Femtosecond Laser Frequency Combs
- High Energy and High Power Laser Architectures
- High Order Harmonic Generation
- Phase-matching in High Order Harmonic Generation
- Techniques for Isolated Attosecond Pulse Generation
- Synchrotron and FEL Sources
- Phase-sensitive Extreme Nonlinear Optics in Solids and Nanosystems
- Attosecond Time-resolved Spectroscopy

Molecular Physics: This seminar provides a regular lecture series on modern topics in molecular physics. International experts provide introductions and in-depth discussions of state-of-the-art research in molecular and laser physics. Seminars are held in tutorial style, and questions during talks that help the audience to better follow the presentation are highly appreciated. Students will learn to follow research seminars, to extract useful information from seminars and related discussions, and how to articulate questions and comments.
Speakers typically visit CFEL for one or two days and are available for discussions of their and your work.

Abstract: CUI-IMPRS lecture

Laser-matter interaction: from atoms to tissue: With recent progress in laser technology, it is increasingly important to understand laser-matter interaction for atomic and molecular physics research as well as for materials processing and medical applications. This course first focuses on high-intensity femtosecond laser-atom interaction. Topics include laser fundamentals, above-threshold ionization, tunneling ionization, and high-harmonic generation. The course will also treat atomic ionization dynamics by femtosecond (from free-electron lasers) and attosecond (from high-harmonic generation) extreme-ultraviolet pulses. The last topics of the course will include different types of laser-tissue interaction and the medical applications of laser such as photodynamic therapy, percutaneous laser disc decompression, and laser in situ keratomileusis.

Abstracts: Lectures organized by IMPRS-UFAST

Basics of Chemistry/Biochemistry: In this course, Chemistry will mainly be understood as reactions. The course gives an overview about the basics of reaction chemistry and discusses what is already known and what can be measured in the laboratory nowadays (i.e. describing the current frontiers and where the research performed at CFEL can make a difference). In the biochemistry part, the basic principles of nucleic acids (DNA, RNA, their replication etc.) and proteins, their structure and function etc. will be discussed. Also here it will be interesting to work out where the new coherent sources can advance the field.

<u>Key topics:</u>
Mechanism of chemical reactions / Kinetics on “normal” timescales / Photochemistry / Conical intersections, what can be measured with modern fs experiments and how / Basic principles, structure and function of nucleic acids and proteins / Chemical reactions in biochemistry / Relevant timescales

Source technology: The course provides an overview of the working principles of modern light/x-ray/electron sources, including the respective physics background and their current strengths and limitations. The focus will be on techniques and technical basics.

<u>Key topics</u>:
Optics / Laser technology / Pulsed laser technology / Electron sources / Synchrotron-type radiation sources / Accelerator techniques

Measurement of Ultrashort Light Pulses: To measure an event in time requires a shorter one. As a result, the development of techniques for measuring ultrashort laser pulses—the shortest events ever created—has proved quite challenging. Indeed, this fundamental difficulty, coupled with the ephemeral nature of such incredibly short events, has resulted in a rather checkered history of this field, confounded by long periods of misinterpretations and the systemic use of problematic methods, fueled by wishful thinking and wide-spread self-deception. This course will discuss the first method, autocorrelation, and why it yields only a rough and ambiguous estimate of the pulse length, but which was nevertheless very helpful over several decades. It will then describe newer methods that reliably yield the complete pulse intensity and phase. In addition, it will show how to measure laser pulses with as little as zeptojoules of energy (less than one photon!), as well as complex pulses with time-bandwidth products of >1000. It will then describe recent methods for measuring the complete *spatio-temporal* intensity and phase of an arbitrary pulse—even on a single shot. Finally, it will describe very recent, successful efforts to measure the most complex pulses ever generated—also on a single shot!

This course should enable you to:

- Measure the intensity and phase of an ultrashort laser pulse;
- Verify that such a measurement is correct;
- Measure few-femtosecond or extremely complex pulses;
- Measure extremely weak pulses;
- Measure ultrafast polarization variation;
- Determine which technique is right for your application;
- Measure spatio-temporal distortions in pulses; and
- Explain the fundamental mathematics and physics behind these methods.

This course is intended for anyone with an ultrashort laser pulse who would like to measure it. Anyone wishing to perform measurements of solids, liquids, gases, or plasmas would also find these techniques useful. It's also designed for anyone who would just like to see how we can measure the shortest events ever created and, at the same time, learn about some interesting recent research.

Abstract: Lecture by Prof. R. Millane

Professor Millane will present three lectures covering two topics in diffraction imaging as outlined below. The lectures will focus on fundamental principles and methods rather than specific applications, and will be targeted to an audience with a limited knowledge of diffraction imaging.

Lecture topics:

Topic 1: Single crystal x-ray crystallography and single particle imaging

These lectures will focus on an introduction to the relationships between traditional protein x-ray crystallography and the evolving new methods of single particle imaging using x-ray free-electron lasers. The lectures will cover diffraction by crystals versus single particles, the information content of Bragg versus continuous diffraction, phase problems for crystal and single particle diffraction, relationships between phasing methods in the two cases, and some new developments.

Topic 2: Introduction to x-ray fiber diffraction analysis

X-ray fiber diffraction analysis refers to the use of x-ray crystallographic techniques to study polymeric materials that can be prepared as oriented molecular assemblies in fibers, rather than single crystals. The lectures will cover helical symmetry, different kinds of molecular aggregates in fiber specimens, characteristics of diffraction by helical molecules and by fibers, processing of diffraction data, and methods of structure determination.