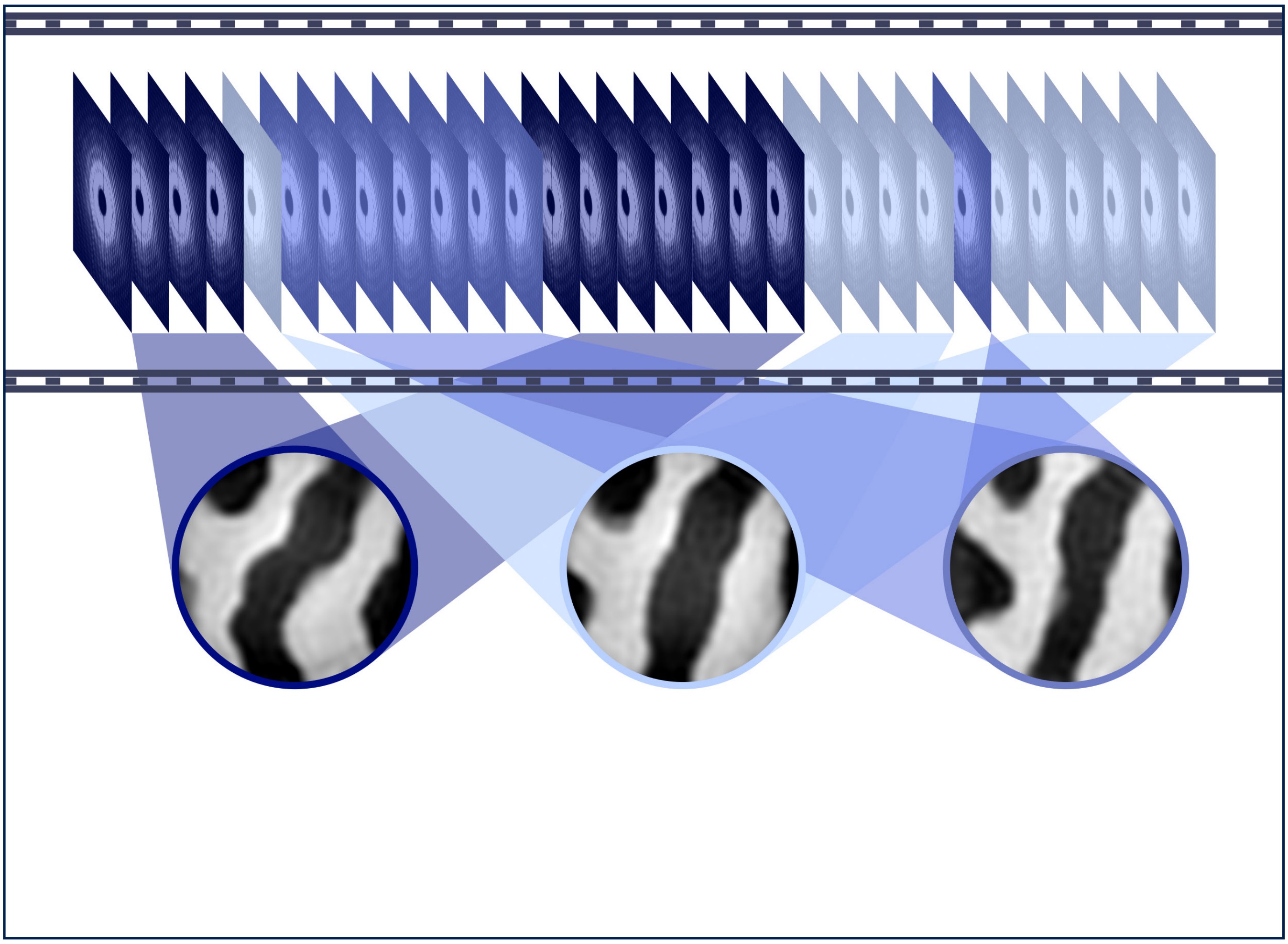
Max-Born-Institut
für Nichtlineare Optik
und Kurzzeitspektroskopie
im Forschungsverbund Berlin e.V.

Annual Report 2023



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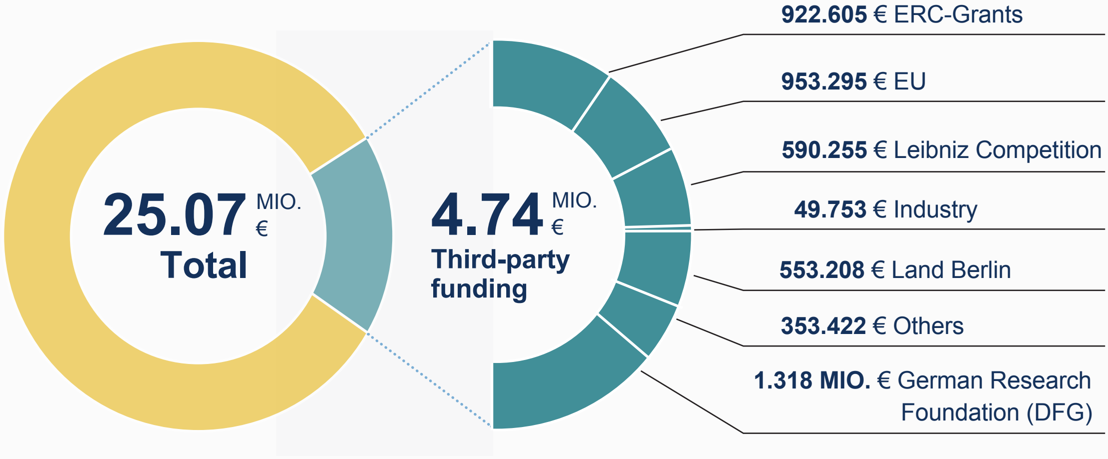
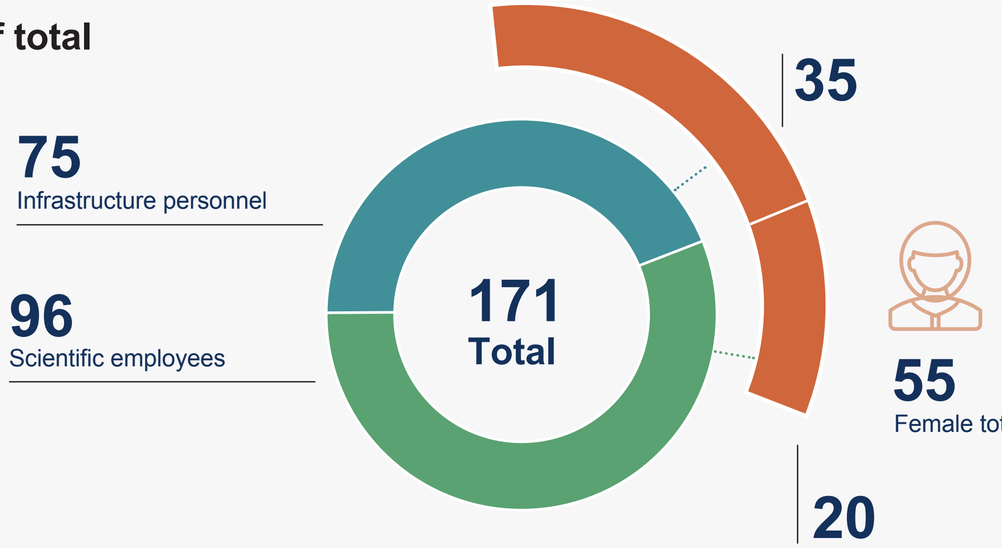
2023 in Figures

Budget

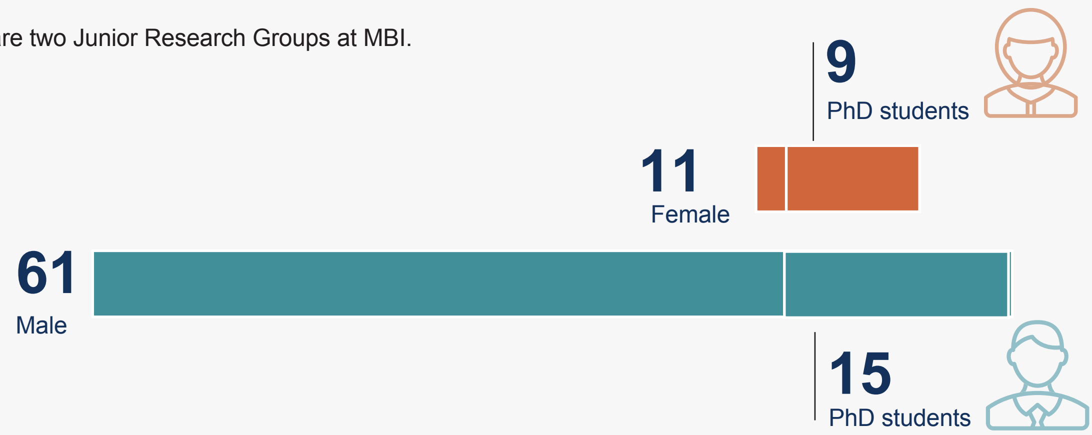


Staff total

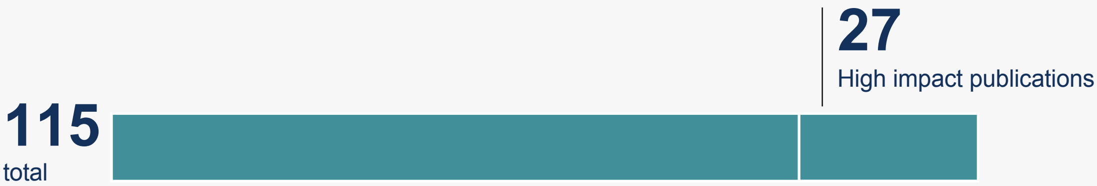


Scientific staff

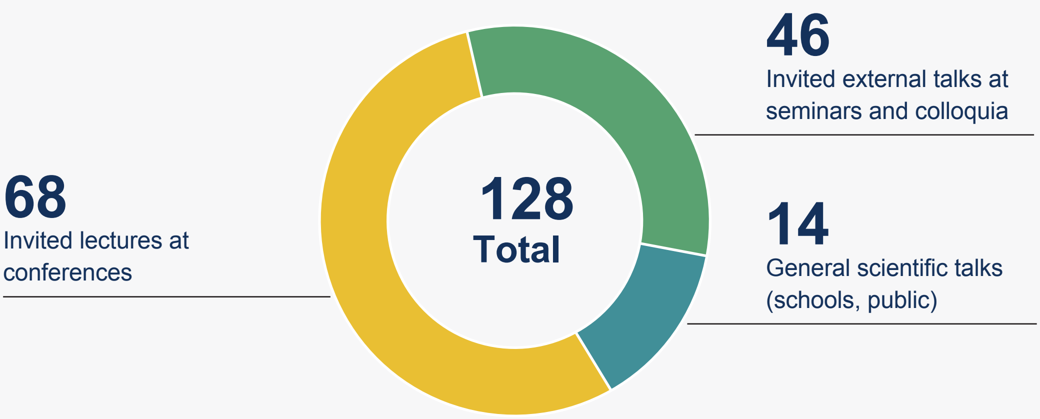
There are two Junior Research Groups at MBI.



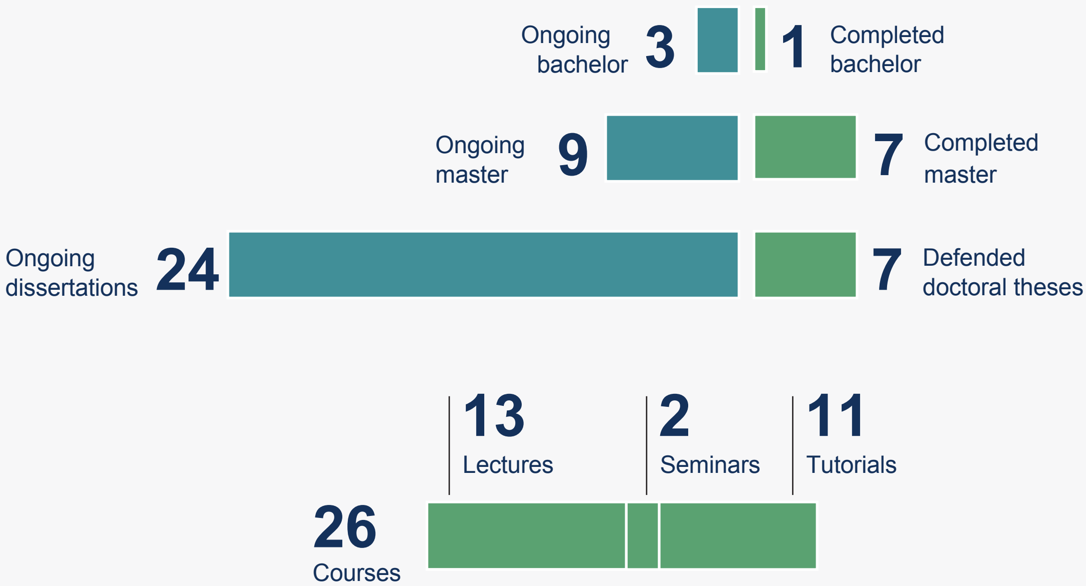
Publications



Scientific communication



Education and Teaching



Annual Report 2023

Max-Born-Institut
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Photos: © Berit Kraushaar (pp. 42, 44, 46)

Preface

Scientific Highlights

Short Description of Research Projects

Interviews

Cooperation partners

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Preface

This Annual Report provides an overview of the research and activities at the Max-Born-Institute (MBI) in 2023. You will find that the format has significantly changed from previous years. The presentation of selected scientific highlights is complemented by reports from the individual scientific projects at MBI, which are now much more selective and concise. At the same time, we have started to include elements that reflect the “life at the institute”, featuring noteworthy events during the year and putting a spotlight on MBI staff.

In addition to a birds-eye view on scientific highlights and key figures for the institute, you can still find the complete record of publications and invited talks in the appendix, together with information on academic teaching and training, guest lectures, activities in scientific organizations, and third-party funding. Further information is available on our website.

Partly, the year 2023 was still characterized by the aftereffects of the Covid pandemic in previous years. While the MBI was largely able to successfully manage the years 2020-2022 of the pandemic itself, in 2023 it became apparent that the temporary institute and laboratory closures were not without consequences. This was to be expected, as the generation of scientific knowledge at MBI generally requires the acquisition of experimental data. Restricted access to laboratories at MBI and elsewhere resulted in a lower publication output in subsequent years, after the data “on the shelf” has been analyzed and published. All in all, 115 articles have been published in peer-reviewed journals and books, including a substantial number of papers in high-impact journals. After the Covid years and many canceled conferences, the number of invited talks by MBI scientists at international conferences has returned to its usual level of over 100. The FEMTO 15 conference was organized by Thomas Elsaesser and Marc Vrakking. The conference was hosted by MBI together with the FU Berlin.

Two appointment processes on the professor level were completed in 2023. The appointment of Nathalie Picqué jointly with Humboldt-Universität zu Berlin was completed towards the end of the year, allowing her to start the scientific reorientation of Division C, now called “Precision Physics”. The conversion of the laboratories for the new tasks is underway; in parallel the recruitment to fill vacant positions is underway and the area is gradually being developed.

Following her success in the Leibniz Professorship Program, an appointment process was carried out together with Freie Universität Berlin, which ultimately resulted in the appointment of Sangeeta Sharma to a professorship in Theoretical Solid State Physics. At the same time, a new Department B4 “Theory of Dynamics in Quantum Materials” was created at the MBI under the leadership of Prof. Sharma.

In 2023, MBI scientists received several honors. Among these, Olga Smirnova received the Mildred Dresselhaus Award and a Guest Professorship at the University of Hamburg. For her PhD thesis, Lisa-Marie Kern received the 2023 Carl Ramsauer Award of the Physikalische Gesellschaft zu Berlin. We congratulate Olga and Lisa-Marie on these well-deserved recognitions.

In closing, we would like to thank all members of the MBI community for their strong efforts in 2023, and we thank the funding bodies for their consistent support of the institute.

Stefan Eisebitt Nathalie Picqué Marc Vrakking

Research Structure of the Max-Born-Institut

1 – Lasers and Light-Matter-Interaction

1.1
Fundamentals of Extreme Photonics

1.2
Ultrafast Laser Physics and Nonlinear Optics

2 – Ultrafast and Nonlinear Phenomena: Atoms, Molecules, and Clusters

2.1
Time-resolved XUV-science

2.2
Strong-field Few-body Physics

3 – Ultrafast and Nonlinear Phenomena: Condensed Phase

3.1
Dynamics of Condensed Phase Molecular Systems

3.2
Solids and Nanostructures: Electrons, Spins, and Phonons

3.3
Transient Structures and Imaging with X-rays

4 – Laser Infrastructure and Knowledge Transfer

4.1
Implementation of Lasers and Measuring Techniques

4.2
Application Laboratories and Technology Transfer

4.3
Nanoscale Samples and Optics

Organizational Structure of the Max-Born-Institut

Board of Trustees of the Forschungsverbund Berlin e.V.
Chair: J. Koch-Unterseher (Senat Chancellery Berlin)

FVB Managing Director
N. Münnich
(Forschungsverbund Berlin)

Board of Directors
S. Eisebitt (TU Berlin)
N. Picqué (HU Berlin)
M. Vrakking (FU Berlin, Managing Director)

Scientific Advisory Board
Chair: M. Chergui
(EPFL, Switzerland)

Executive Assistant
A. Grimm

Division A: M. Vrakking

Attosecond Physics

- A1: Strong-field Processes at Extreme Wavelengths (A. Rouzée)
- A2: Ultrafast XUV-Physics (O. Kornilov)
- A3: Ultrafast Lasers and Nonlinear Optics (T. Nagy)
- Junior Group: Attosecond XUV nonlinear optics (B. Schuette)

Division B: S. Eisebitt

Transient Electronic Structure and Nanoscience

- B1: Electron and Spin Dynamics (C. von Korff Schmising)
- B2: Imaging and Coherent X-rays (B. Pfau)
- B3: Laser Development (M. Schnuerer)
- Junior Group: Complex spin structures in time and space (D. Schick)

Division C: N. Picqué

Precision Physics

- C1: Femtosecond Spectroscopy of Molecular Systems (E. Nibbering)
- C2: Solid State Light Sources (G. Steinmeyer)
- C3: Femtosecond Spectroscopy of Solids (M. Woerner)

Theory Department: M. Y. Ivanov

- Attosecond Theory (M. Y. Ivanov)
- Strong Field Theory (O. Smirnova)
- Theoretical Optics & Photonics (K. Busch, HU Berlin)
- Condensed Matter Theory (S. Sharma)

Administration (A. Grimm) **IT** (T. Kruel) **Maintenance** (A. Herzog)
Library (J. Rehse) **Mechanical Design and Workshop** (T. Müller)

Members of the Scientific Advisory Board

Prof. Dr. Dieter Bauer (from 01 Apr 2023)
Universität Rostock, Institut für Physik, Germany

Prof. Dr. Francesca Celagari (from 01 Apr 2023)
DESY - Institut für Experimentalphysik & Universität Hamburg, Germany

Prof. Dr. Giulio Cerullo
Politecnico de Milano, Dipartimento di Fisica, Italy

Prof. Dr. Majed Chergui (Chair)
École Polytechnique Fédérale de Lausanne (EPFL), Institute of Chemical Sciences and Engineering, Switzerland

Prof. Dr. Hermann Dürr (from 01 Apr 2023)
Uppsala Universitet - Department of Physics and Astronomy, FREIA, Sweden

Prof. Tony Heinz (until 31 Mar 2023)
Stanford University, Department of Applied Physics, USA

Prof. Dr. Jon Marangos (until 31 Mar 2023)
Imperial College London, Department of Physics, UK

Prof. Dr. Christoph Quitmann
Lund University, Max IV Laboratory, Sweden

Prof. Dr. Ursula Roethlisberger (until 31 Mar 2023)
École Polytechnique Fédérale de Lausanne (EPFL), Institute of Chemical Sciences and Engineering, Switzerland

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Ludwig-Maximilians-Universität München (LMU), Department Chemie, Germany

Prof. Dr. Jan Michael Rost (until 31 Mar 2023)
Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

Prof. Albert Stolow (from 01 Apr 2023)
University of Ottawa - Departments of Chemistry & Physics, Canada

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Prof. Dr. Andreas Knorr
Technische Universität Berlin, Institut für Optik und Atomare Physik, Germany

Prof. Dr. Christoph Koch (until 31 Mar 2023)
Humboldt-Universtität zu Berlin, Institut für Physik, Germany

Prof. Dr. Martin Weinelt
Freie Universität Berlin, Fachbereich Physik, Germany

Representatives of the Federal Republic and the State of Berlin

Jan Neitzke
Bundesministerium für Bildung und Forschung, Ref. 711, Bonn, Germany

Aylin Gümüs
Senatskanzlei, Wirtschaft und Forschung, Ref. VI D, Berlin, Germany

Leibniz Association

MBI is a member of the Leibniz Association

Scientific Highlights

A new chapter for all-attosecond spectroscopy

Bernd Schütte

The first generation of attosecond pulses (1 attosecond corresponds to 10^{-18} seconds) at the turn of this century has enabled unprecedented insights into the world of electrons. For their pioneering work first leading to the demonstration of attosecond pulses in 2001, Anne L'Huillier, Pierre Agostini and Ferenc Krausz were awarded with the Nobel Prize in Physics 2023. Current attosecond techniques, however, come with an important drawback: To be able to record a movie in a pump-probe experiment, an attosecond pulse typically has to be combined with a femtosecond pulse (1 femtosecond corresponds to 10^{-15} seconds) whose optical cycles (a few femtoseconds long) is used as a clock with attosecond resolution. This constitutes a limitation for the investigation of electron dynamics on attosecond timescales.

Ever since the first demonstration of attosecond pulses, it has been the dream of many scientists to perform experiments in which a first attosecond pump pulse initiates electron dynamics in an atom, a molecule, or a solid-state sample, and where a second attosecond probe pulse interrogates the system at different time delays. This goal turned out to be very challenging, because it requires intense attosecond pulses. The underlying process of high-harmonic generation (HHG) is very inefficient though. As a result, only a very few proof-of-principle demonstrations of attosecond-pump attosecond-probe spectroscopy (APAPS) have been reported, which made use of large setups and specialized laser systems operating at low repetition rates (10-120 Hertz).

At the MBI we have recently demonstrated a different approach, allowing us to perform APAPS experiments using a much more compact setup. For this purpose, we used a turn-key driving laser at a kilohertz repetition rate. This resulted in a substantially more stable operation, which is a key requirement for the successful implementation of APAPS.

These stable and intense attosecond pulses were used in an APAPS experiment, in which argon atoms were ionized by an attosecond pump pulse, resulting in the generation of singly-charged Ar^{+} ions. The formation of these ions was probed by an attosecond probe pulse, leading to further ionization and the formation of doubly-charged Ar^{2+} ions. The results are shown in Fig. 1, where an increase of the Ar^{2+} ion yield on a very fast timescale is observed. This shows that the involved pump and probe pulses indeed have attosecond pulse durations, which can also be seen in the inset of Fig. 1.

The modest infrared driving pulse energies used in this study open the way for performing APAPS experiments at even higher repetition rates up to the megahertz level. The required laser systems to drive these experiments are already available or under development. As a result, the novel concept may enable unprecedented insights into the world of electrons on extremely short timescales, which are not accessible by current attosecond techniques.

Publication

M. Kretschmar *et al.*, "Compact realization of attosecond-pump attosecond-probe spectroscopy", Sci. Adv. 10, DOI: 10.1126/sciadv.adk9605 (2024).

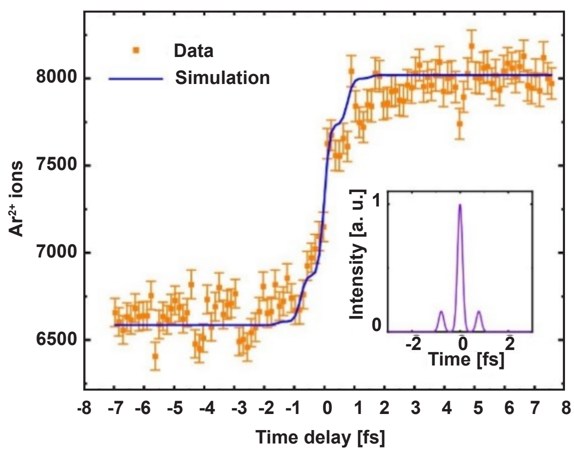


Fig. 1: Two-color APAPS. The generation of Ar^{+}, as initiated by a broadband attosecond pump pulse with a photon energy around 20 eV, is probed by a second pulse with a central photon energy of 33.5 eV. This is above the second ionization potential of Ar, thereby producing Ar^{2+}. The increase of the Ar^{2+} ion yield around zero delay is explained by the more efficient generation of Ar^{2+} when the probe pulse follows the pump pulse. The inset shows a fit of the attosecond pulse structure.

Light shaping of valley states

Sangeeta Sharma, John Kay Dewhurst, Samuel Shallcross

The manipulation of electrons in crystals by light is governed by two fundamental processes, each with a distinct temporal realm. Direct quantum transitions enable excitation from the ground state to higher energies at ultrafast attosecond to femtosecond times, however the "return journey" is slow: it must involve scattering from the lattice and the generation of heat, processes that occur on picosecond to nanosecond times. A general ultrafast "quantum switch", in which charge is coherently excited and de-excited at femtosecond times between, for example, the valley valence and conduction band edges of a 2d semi-conductor, appears therefore not to be possible.

In a recent work Sharma and Shallcross posed the question of whether this holds in the case of currents: is a "quantum current switch" driven only by the coherent processes of light-matter interaction possible? It turns out that the vector nature of current allows just such a switch [1]. As a vector field in momentum space, charge can be successively excited changing the shape of the vector field and allowing it to sum (to create the macroscopic current) to any number, including zero. This, as shown in Fig. 1, allows the perfect lossless switching of current between valleys by successive ultrafast laser pulses: charge in the conduction band always increases, but the current switches between valleys as the vector field changes shape in momentum space in response to the light pulse.

Publication

(for full title see appendix 1)

[1] S. Sharma, J. K. Dewhurst, and S. Shallcross Nano Letters 2023 23 (24), 11533-11539 DOI: 10.1021/acs.nanolett.3c03245

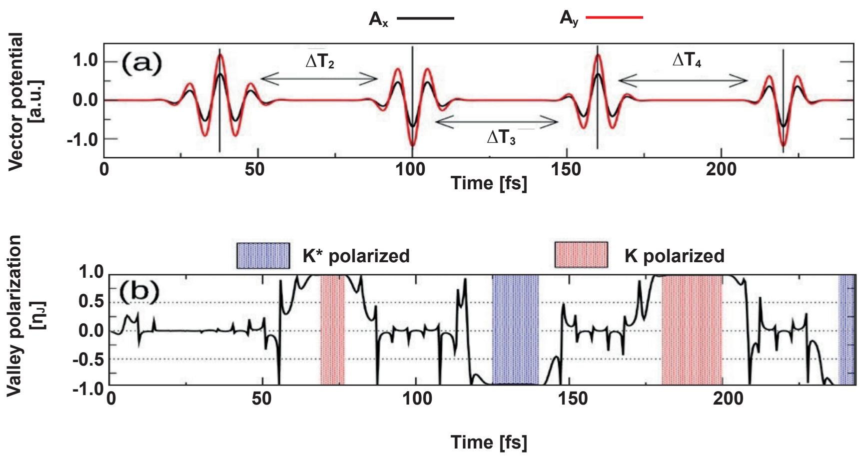


Fig. 1: A perfect and lossless light controlled valley switch in graphene. A successive sequence of few cycle light pulses, vector potential shown in panel (a), generate a series of perfect switching events between a 100 % valley polarized current, panel (b), in which the current alternates between flowing only at the K valley and only at the K valley. After each switching event the current retains the 100 % valley polarization.*

In just a few clicks. Dual-comb spectroscopy in the dark

Bingxin Xu, Jaijun Chen, Theodor W. Hänsch, Nathalie Picqué

Two-sentence abstract: Dual-comb spectroscopy is implemented in low-light conditions at optical powers of a few tens of picowatts. Quantum-limited sensitivity is demonstrated for comb-line-resolved spectra of Doppler-broadened transitions in the ultraviolet region.

A frequency comb is a spectrum of evenly spaced, phase-coherent laser lines, that acts like a frequency ruler. Such optical combs are now widely used to count the oscillations of a laser wave and serve as the clockwork in optical atomic clocks. As an application beyond the original purpose, dual-comb spectroscopy has emerged as a powerful technique for precise spectroscopy over broad spectral bandwidths [1]. It has mainly been used for infrared linear absorption of small molecules in the gas phase. It is based on measuring the time-dependent interference between two frequency combs with slightly different line spacings and it does not suffer from the geometric limitations associated with traditional spectrometers, thus offering great potential for high precision and accuracy [2].

However, dual-comb spectroscopy typically requires intense laser beams, making it less suitable for scenarios where low light levels are critical. We have now shown experimentally that dual-comb spectroscopy can be effectively used in starved-light conditions, at power levels more than a million times weaker than those typically used. The interference signals can be observed in the statistics of the clicks of a photon-counting detector, even when the power is so low, that, on average, only one click is registered over the time of 100 laser pulses (Fig.1a). Under such circumstances it is extremely unlikely that two photons, one from each laser, are simultaneously present in the detection path. The experiment cannot be explained intuitively by assuming that a photon exists before detection [3].

Our results are showcased using two distinct experimental setups with different types of frequency-comb generators, with a signal-to-noise ratio at the fundamental limit [4]. Our achievement highlights the optimal use of available light for experiments, and opens up prospects in challenging scenarios where low light levels are essential. One of our experiments was performed in the near-ultraviolet region, where spectra with resolved-comb lines could be obtained for the first time, as a step towards shorter wavelengths. Indeed, a particularly compelling future application is precise vacuum- and extreme-ultraviolet molecular spectroscopy over broad spectral spans. Currently, broadband extreme-UV spectroscopy is limited in resolution and accuracy, and relies on unique instrumentation at specialized facilities. Dual-comb spectroscopy at short wavelengths is particularly challenging and our work provides a promising answer to the pressing problem of dealing with the low power of ultraviolet frequency comb generators produced by non-linear frequency conversion of near-infrared sources. Our results extend the full capabilities of dual-comb spectroscopy to low-light conditions, unlocking novel applications in precision spectroscopy, biomedical sensing, and environmental atmospheric sounding.

Publications

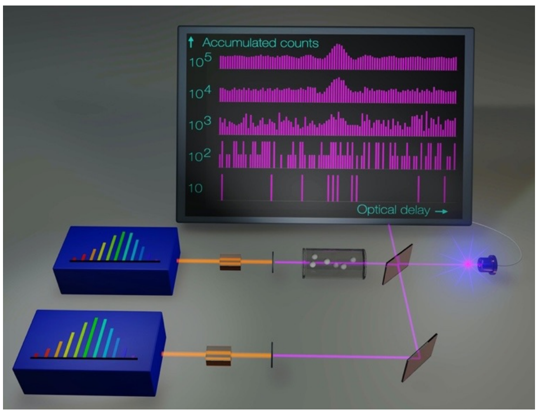
[1] N. Picqué, et al. Nature Photonics **13** (2019) 146-157

[2] N. Picqué, et al. Photoniques **113** (2022) 38-42

[3] N. Picqué, et al. Proc. Natl. Acad. Sci. U.S.A. **117** (2020) 26688-26691

[4] B. Xu, et al. Nature **627** (2024) 289-294

a)



b)

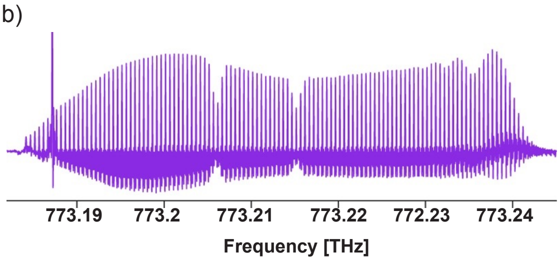


Fig. 1: (a) An ultraviolet photon-counting dual-comb spectrometer. (b) Photon-counting near-ultraviolet dual-comb spectrum of weak transitions in $_{133}$Cs at an optical power of 90 pW.

A New Method to Image Nanometer-Scale Fluctuations in Materials

Bastian Pfau

The microscopic realm of the world is constantly in motion and marked by unceasing alteration. Even in seemingly unchanging solid materials, these fluctuations can give rise to unusual properties, such as high-temperature superconductivity. Fluctuations are particularly pronounced during phase transitions and nonequilibrium situations, but can also be present in equilibrium such as the thermally activated continuous reorganization of magnetic domains in a ferromagnet.

Studying these microscopic processes in detail, however, is generally a difficult task, and capturing the spatio-temporal dynamics in a movie is even more challenging. This is because the fluctuations happen quickly and often take place at the nanometer scale. Even the most advanced high-resolution X-ray and electron microscopes are unable to capture the rapid, stochastic motion. The problem is fundamentally rooted in a dilemma between spatial and temporal resolution. In a real experiment, the number of photons incident on a sample per volume and time is limited - due to source and instrument constraints, and also owing to sample perturbation, contrast bleaching, and ultimately sample destruction. Therefore, averaging over an extended period of time is key for the majority of high-resolution imaging experiments leading to a loss of temporal resolution and to motion-blurred images.

The newly developed method of Coherent Correlation Imaging (CCI) overcomes this dilemma. CCI is a high-resolution, full-field imaging technique that realizes multi-shot, time-resolved imaging of stochastic processes. The key idea is taking multiple snapshots of the sample in quick succession while reducing the illumination enough to keep the sample intact. While it is impossible to retrieve a distinct high-resolution image from a single snapshot alone, the snapshots still contain sufficient information to classify them, i.e., one can detect if the system is in a state which has occurred before. By averaging selectively over snapshots classified to belong to the same state, a high contrast and high spatial resolution image can be generated. Temporal resolution down to the acquisition time of a single snapshot arises independently from an exceptionally low misclassification rate.

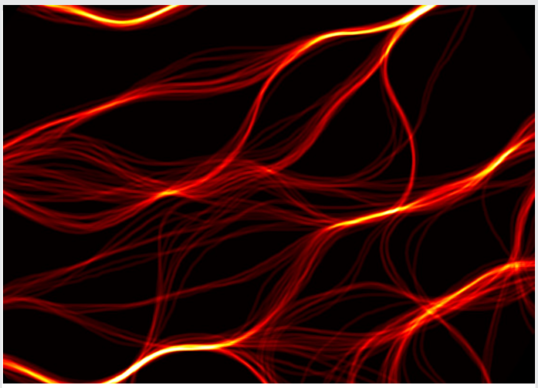


Fig. 1: Map of the borders between the magnetic domains shifting back and forth in time. The whole map is only about 700 nanometers in width.

The new method to image fluctuations was demonstrated by imaging microscopic domain patterns that occur in thin ferromagnetic layers. The magnetization in these domains points either upward or downward. Imaging the stochastic motion of nanometer size domains has been deemed impossible, so far. Using CCI, a sample consisting of such a magnetic layer was investigated at the National Synchrotron Light Source II on Long Island near New York City. It was found that the patterns remained unchanged at room temperature. But at a slightly elevated temperature of 37°C, the domains began to move back and forth erratically, displacing each other. This "dance of the domains" was observed for several hours. A map created from the movie, as shown in the figure, highlights the preferred location of the boundaries between the domains. This map and the movie of the domain-wall movements led to a better understanding of the magnetic interactions in the material, promoting future applications in spintronics applications.

CCI is based on the interference of the scattered radiation and thus massively expands the potential of coherent X-ray sources such as free-electron lasers and high harmonic generation laboratory sources to study spatio-temporal fluctuations in matter. We expect it to pave the way to addressing fundamental questions such as the contribution of pinning and topology in phase transitions or the role of spin and charge order fluctuations in high-temperature superconductivity. Our current work is geared towards applying the scheme in conjunction with a synchronized pump pulse by a laser, allowing to boost the temporal resolution and study nonequilibrium dynamics.

Publication

[1] *Coherent correlation imaging for resolving fluctuating states of matter*; Christopher Klose, Felix Büttner, Wen Hu, Claudio Mazzoli, Kai Litzius, Riccardo Battistelli, Ivan Lemesh, Jason M. Bartell, Mantao Huang, Christian M. Günther, Michael Schneider, Andi Barbour, Stuart B. Wilkins, Geoffrey S. D. Beach, Stefan Eisebitt and Bastian Pfau; Nature **614**, (2023), 256

Short Description of Research Projects

1.1 Fundamentals of Extreme Photonics

David Ayuso, Wilhelm Becker, Viktor Bender, Graham G. Brown, Kurt Busch, Stefanos Carlstroem, Eelena A. Christou, Philip C. Flores, Deepika Gill, Rico Heilemann, Joachim Herrmann, Anton Husakou, Mikhail Ivanov, Álvaro Jiménez-Galán, Nikolai D. Klimkin, Alexander G. Löhr, Astrid B. Lund, Pablo M. Maier, Nicola Mayer, Marjansadat Mirahmadi, Felipe Morales, Serguei Patchkovskii, Maria Richter, Álvaro Rodriguez Echarri, Aycke Roos, Samuel Shallcross, Sangeeta Sharma, Olga Smirnova, Sergey Solovev, Justas Terentjevas, Sili Yi, Wenhua Zhao, V. Zimmermann

Project Mission

- Theoretical description, understanding and control of nonlinear light-matter interaction in atoms, molecules, photonic and nano-structures and solids
- Theory of nonlinear optical spectroscopies of charge, energy, and spin flow on asec to fsec time scales
- Guide, inspire and assist experiments at the MBI & elsewhere

Key Directions

Attosecond and few-Femtosecond Dynamics in Atoms, Molecules, and Solids

- Multi-electron and coupled electron-nuclear dynamics in atoms and molecules
- High harmonic spectroscopy of electron dynamics in molecules & solids
- Field-driven dynamics in quantum materials

Light Propagation in Complex Media, Light-matter Manipulation in Photonic structures and Nano-structured media

- Quantum photonics applications in quantum information processing
- Optical simulation of quantum materials
- Extreme nonlinearities at few-photon, few-atom level
- Coupled Maxwell-Schrödinger solvers
- All-optical high-resolution sampling of ultrashort pulses

Ultrafast Magnetism

- Ab-initio description of electron and spin dynamics in solids
- Control of ultrafast spin dynamics with light in atoms, plasmas and solids

Emerging directions

- Quantum Optics with HHG
- Contributing Groups
- T1: Attosecond Dynamics (M. Y. Ivanov)
- T2: Strong Field Theory (O. Smirnova)
- T3: HU-MBI Group on Quantum Electrodynamics in Structured Space (K. Busch)
- B4: Theory for Dynamics in Quantum Materials (S. Sharma)
- The research is organized in three interconnected Research Thrusts.

Research Thrust I: Real-time Description of Ultrafast Electron and Structural Dynamics

- Coupled electron nuclear dynamics in polyatomic molecules in the gas and condensed/liquid phase (T1, B4)
- Few-body dynamics, electron-electron and electron-nuclear correlations in extreme conditions: single-cycle pulses, intense fields, XUV/Xray fields (T1, T2)
- Coupling of spin and charge dynamics to lattice dynamics (B4)
- Main challenge: multiple time scales: asec to psec

Methodology and Code Development:

- First-principle simulations of few-particle systems in extreme conditions (T1, T2)
- Multi-scale/multi-resolution analysis of strong-field and asec processes (T1)

MBI integration and synergies:

- Mid-IR, few-cycle, CEP-controlled strong field spectroscopy, Attosecond spectroscopy

Research Thrust II: Shape, Control, and Imaging of Matter with Tailored Light

- Field-driven (sub-cycle) dynamics with tailored light: from atoms and molecules to in solid state materials & photonic structures (T1, T2, B4)
- Ultrafast magnetism at few fsec time scale (B4)
- Optical simulations of quantum materials: topological photonics (T3)
- Attosecond spectroscopy of new phases and phase transitions (T1, T2)
- Ultrafast, ultra-sensitive chiral nonlinear spectroscopy and control (T2, T1)
- Main challenge: Multiscale modelling, infinite lattice vs finite spatial domains

Methodology and Code Development

- Optical simulation of quantum dynamics
- ELK code for light-driven solids
- Wannier-90+ semiconductor Bloch equations
- R-matrix+HHG codes for molecules

MBI integration and synergies:

- Applications to attosecond and strong-field physics experiments (Research Area 2)
- Applications to ultrafast magnetism (Research Area 3)

Research Thrust III: Light Propagation in Complex Media and Photonic Structures

- Extreme nonlinear optics ab-initio (T1, T2): Solution of coupled Maxwell – time-dependent Schrödinger equations in complex media
- Light propagation in photonic structures, including extreme nonlinearities at the few-atom, few- photon level (T3)
- Main challenge: Interfacing microscopic and macroscopic response in the highly non-linear regime (T1, T2, T3, B4)

Methodology and Code Development

- Time-domain finite-element solver for the Maxwell equations using Galerkin techniques
- Coupled Maxwell-Schrödinger solvers for few atoms inside waveguides
- TDSE solvers for atoms in strong laser fields coupled to Maxwell (UPPE): Light amplification in dense, rapidly ionizing gas targets

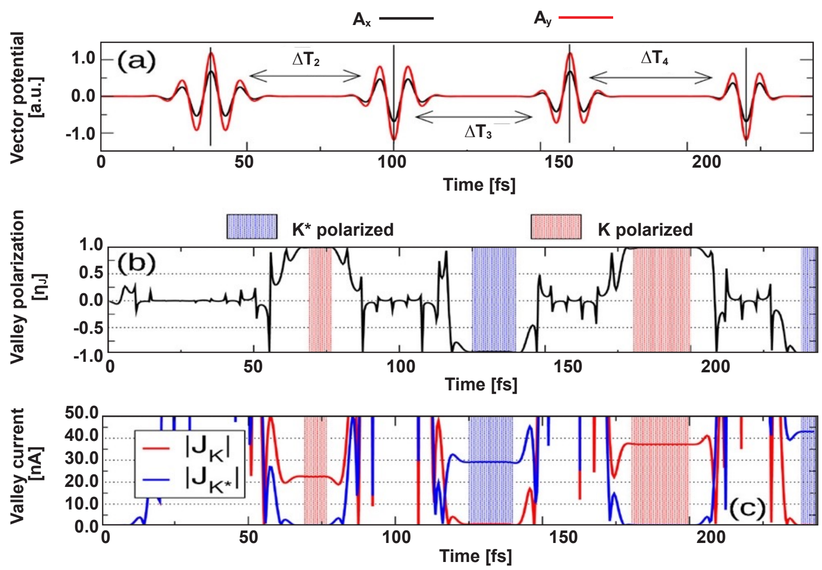


Fig. 1: Highlight RT I: Femtosecond valley switch. (a) Laser vector potential for a train of four laser pulses of identical frequency 0.4 eV, durations 16.8, 13.5, 11.6, and, 10.1 fs, and a carrier envelope phase alternating between +90° and −90°. (b) The corresponding real time valley polarization of the current, revealing both polarization transients during the pulse, but between pulses a stable valley polarization alternating between full polarization at the K and K valleys as indicated by the shaded areas. (c) Magnitude of the valley currents; Nano Lett. 2023, 23, 24, 11533-11539*

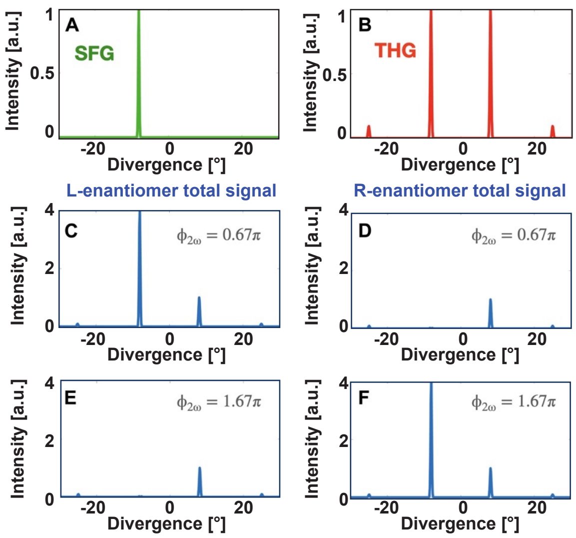


Fig. 2: Highlight RT II: Enantiosensitive SFG in propylene oxide. (A, B) Intensity at frequency 3ω in the far field associated with chiral SFG (A) and achiral THG (B). (C-F) Total intensity emitted from L (C) and (E) and R (D) and (F) propylene oxide, resulting from adding the chiral SFG (A) and achiral THG (B) contributions, for $\phi_{2\omega}$ = 0.67π(C) and (D) and $\phi_{2\omega}$ = 1.67π(E) and (F). Sci. Adv.9, eadj1429 (2023)

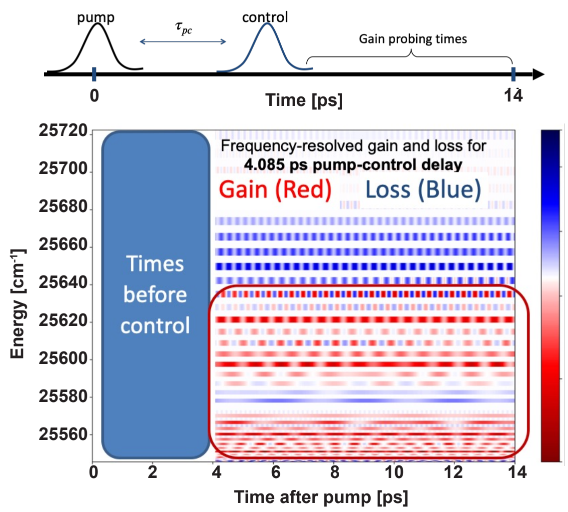


Fig. 3: Highlight RT III: Quantum control of lasing in open air by a sequence of two optimally delayed pulses. Red color signifies gain, blue -loss. The calculation involves coupled electronic, vibrational and rotational dynamics in N_2 molecule and its ion.

- Coupling of spin charge lattice dynamics to Maxwell's equations

MBI integration and synergies:
- Mid-IR driven HHG beamlines
- Light propagation in nano-structured photonic objects
- Applications to new optical sensors

SHORT OUTLOOK
- Our latest results open new research avenues, including the development of
- schemes for increased sensitivity in chiral sensing, including application of photonic
- structures to control propagation of multi-color light fields,
- the use of tailored light-matter interaction to generate tailored quantum states of light
- with massive number of photons, and the development of new ways to control spin textures and spin flow in matter
- on ultrafast time scales

HIGHLIGHTS 2023

- PHz control of valley polarization in 2D materials (RT I, Fig.1)
- Enantio-sensitive sum-frequency generation (RT II, Fig. 2)
- Lasing in the air: a quantitative solution to a multiscale challenge (RT III, Fig. 3)

1.2 Cutting-edge Light Sources

José Cardoso de Andrade, Weidong Chen, Rostyslav Danylo, Federico Furch, Uwe Griebner, Martin Kretschmar, Mark Mero, Martin Mörbeck-Bock, Valentin Petrov, Li Wang, Tobias Witting, Tamas Nagy, Günter Steinmeyer

Research on light-matter interaction often requires light sources in previously inaccessible parameter regions. The project 1.2 gathers MBI's research activities in nonlinear optics and laser physics focusing on the development of custom-designed novel light sources. Driven by applications, our focus lies on superior pulse energy, short pulse duration, or high average power and repetition rate. We intend to cover a broad range of the electromagnetic spectrum from THz to the soft X-rays with few-cycle pulses. In the infrared (IR) we can mostly achieve this goal with lasers and parametric sources. One example is the development of a large-scale, mid-IR optical parametric amplifier operating at 5 µm, which emits 80 fs pulses with 3 mJ energy at a 1 kHz repetition rate. This source has served for hard x-ray generation for project 3.3 and currently undergoes commercialization. We explore new optical materials and use them in novel mode-locking schemes or parametric amplifiers to cover hard-to-reach spectral ranges. At shorter wavelengths or when primary sources cannot directly support few-cycle pulses, we apply post-compression, e.g., in hollow-core fibers (HCF) or in multi-pass cells. Here, we developed a high-energy stretched flexible HCF beamline to compress Ti:sapphire pulses at 1 kHz to sub-4 fs duration with 6 mJ energy, yielding 1.5-cycle pulses at above-TW peak power for immediate application in project 2.1. Beyond these activities, the carrier-envelope phase (CEP) of few-cycle pulses has become a parameter of growing importance at MBI. Pertinent stabilization schemes and their limitations therefore constitute a third branch of activities in the project.

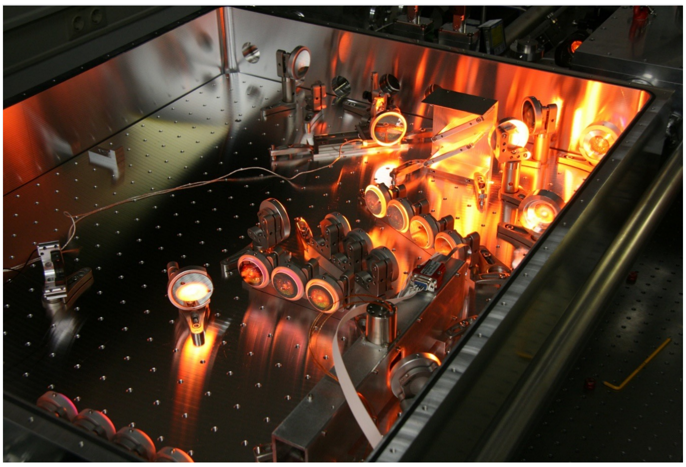


Fig. 1: Chirped mirrors of a high-energy, few-cycle hollow fiber compressor.

To this end, we investigated the CEP noise of a cw seeded parametric amplifier using single-shot dispersive temporal interferometry at the full 50 MHz repetition rate

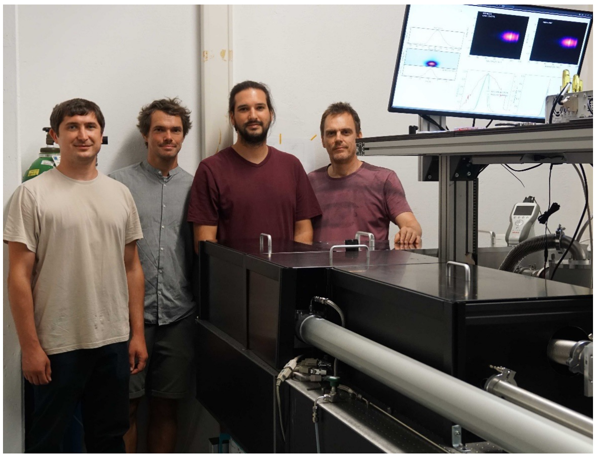


Fig. 2: Rostyslav Danylo, Martin Kretschmar, José Andrade and Tamas Nagy with the VUV light source.

of the femtosecond pump laser. Without the cw seed this scheme acts like an optical parametric generator, emitting vacuum-seeded univariate [-π,π] phase noise. Even at the lowest measurable seed levels, phase noise reduces to the mrad range and reaches a remarkably low value of 82 mrad at the highest available seed power of 8 mW. This noise level can be theoretically estimated from the Schawlow-Townes noise of the master oscillator of the femtosecond pump laser system, yielding an estimate for the vacuum noise of 100 µW, i.e., about two orders of magnitude smaller than the maximum available seed power. As pulse energies in the fiber-based master oscillator are rather weak, usage of an all-solid-state femtosecond laser promises further reduction of residual phase noise by another order of magnitude. As parametric amplifier schemes are versatile in terms of wavelength coverage, these schemes appear highly appealing for generating frequency combs in the near and mid-infrared.

In another effort we explored the possibility of generating µJ-level, few-fs-long light pulses in the vacuum ultraviolet (VUV; 100-200 nm) spectral region. Such pulses are highly demanded for studying valence electron dynamics in many chemically or biologically relevant molecules. We induce resonant dispersive-wave emission during soliton self-compression of 10 fs near-infrared pulses in a helium-filled capillary exhibiting negative dispersion. A part of the soliton energy resonantly converts to ultraviolet wavelengths that are phase-matched with the fundamental soliton. By varying the gas pressure, we can tune the wavelength of the ultrashort pulses between 160 and 200 nm. However, handling and characterization of VUV pulses are very challenging due to excessive dispersion of virtually all

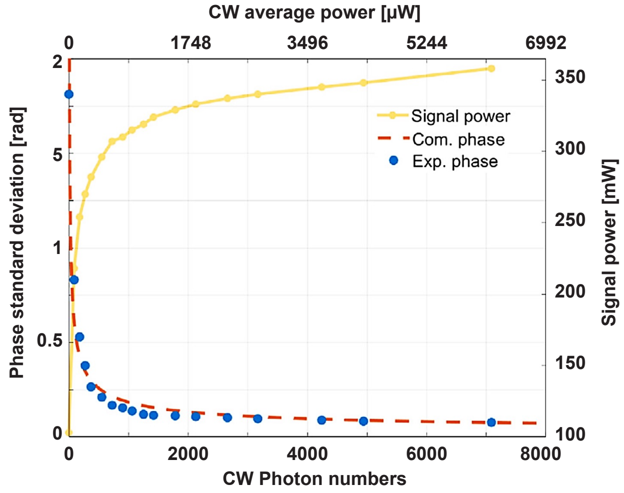


Fig. 3: Measured CEP phase noise of a cw seeded parametric comb source (blue dots) in comparison with computed phase fluctuations derived from the Schawlow-Townes noise of the femtosecond pump laser.

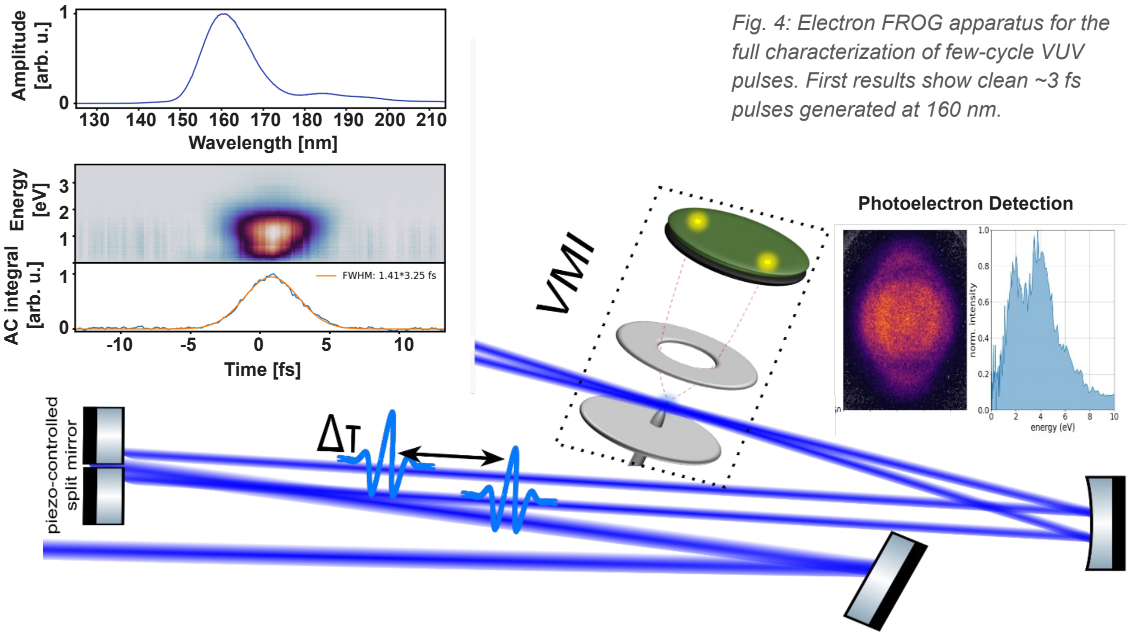


Fig. 4: Electron FROG apparatus for the full characterization of few-cycle VUV pulses. First results show clean ~3 fs pulses generated at 160 nm.

optically transparent materials. Therefore, we attached a vacuum beamline directly to the output of the hollow waveguide, avoiding distortion of the VUV pulses during propagation. We fully characterized the pulses with frequency-resolved optical gating (FROG) utilizing two-photon ionization of noble gases. Our arrangement is based on a velocity-map imaging spectrometer and records the kinetic energy spectrum of the photoelectrons as a function of a delay between two pulse replicas reflected off a split-and-delay mirror pair (Fig. 4). The VUV pulse shape is then reconstructed from the recorded spectrograms by an iterative phase-retrieval algorithm.

With these results we succeeded in generation and complete in-situ characterization of few-fs VUV pulses, paving the way towards pump-probe experiments in the VUV at unprecedented temporal resolution. With this new light source, we will study a series of organic molecules exhibiting fast dynamics that were impossible to resolve in previous studies.

SHORT OUTLOOK

One of our most important plan is to bring the multi-10 mJ ps pulses at 2 µm to the few-cycle regime by applying extended post compression. Combining that source with a matched high-harmonic scheme we wish to boost the available soft X-ray pulse energy by an order of magnitude, considerably extending the current possibilities of time-resolved absorption spectroscopy in the water window.

HIGHLIGHTS 2023

- Sub-50 fs pulses at 2 µm from mode-locked Tm lasers
- Townes solitons for nonlinear compression of few-cycle multi-mJ pulses at 5 µm in bulk ZnSe
- cw-seeded optical parametric amplifiers with sub-100 mrad CEP jitter
- 22 mJ/1 kHz Ho:YLF regenerative amplifier emitting at 2 µm
- Sub-4 fs pulses tunable across the VUV

2.1 Beyond femtosecond timescale dynamics: Watching and steering electronic motions in quantum systems

Kasra Amini, Rostyslav Danylo, Lorenz Drescher, Federico Furch, Miguel O. S. Guzman, Anton Husakov, Misha Ivanov, Álvaro Jiménez Galàn, Oleg Kornilov, Martin Kretschmar, Mark Mero, Felipe Morales Moreno, Tamas Nagy, Serguei Patchkovskii, Maria Richter, Fernando Rodriguez Diaz, Arnaud Rouzée, Andrey Ryabov, Claus-Peter Schulz, Bernd Schütte, Arnab Sen, Olga Smirnova, Eli Sobolev, Evaldas Svirplyz, John Thomas, Mikhail Volkov, Marc J. J. Vrakking, Tobias Witting, Zhuang-Yan Zhang, Mikalai Zhavarankau

The development of sources of ultrashort pulses of short-wavelength radiation by means of the high-order harmonic generation (HHG) process has opened up a new paradigm for the investigation of light-matter interactions. With pulse durations reaching the attosecond timescale and wavelengths extending into the X-ray spectral range, these novel light sources have provided a new playground for the real-time observation of the motion and interaction of electrons at the atomic length scale, including their coupling with slower nuclear dynamics, in systems as diverse as atoms, small molecules, 2D materials and solids. Over the last two decades, teams at the Max Born Institute have been at the frontier of the attosecond science field, developing unique sources of attosecond and femtosecond XUV and soft X-ray pulses. Our project focuses on the laser-driven generation, steering, and imaging of electronic dynamics in atoms and molecules on ultrafast timescales ranging from femtoseconds to attoseconds using the unique attosecond source capabilities available at our institute. In particular, a strong emphasis is given to the investigation of elementary electronic processes in small quantum systems including the ultrafast rearrangement of the electronic cloud following valence and core-shell ionization of a (multi-electron) atom or molecule, ionization-driven charge migration, charge transfer phenomena and spin dynamics mediated by nuclear motion in extended molecular systems and quantum entanglement in photoionization experiments.

Fig. 1: Martin Kretschmar and Rostyslav Danylo with their setup for the generation of TW level, few-cycle laser pulses based on hollow-core fiber compression used for high-order harmonic generation.

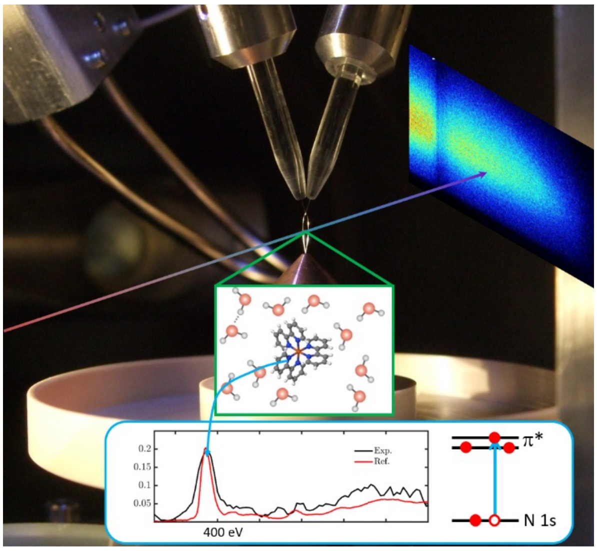


Fig. 2: N K-edge soft X-ray absorption spectroscopy in a liquid flat-jet.

In a first experiment performed in a joint collaboration between projects 2.1 and 3.1, we investigated the ultrafast electronic relaxation dynamics of the prototypical coordination complex Fe^{II}(2,2'-bipyridine)$_3^{2+}$ in aqueous solution upon ultraviolet excitation of the singlet metal-to-ligand charge transfer (^{1}MLCT) state. We used femtosecond soft X-ray absorption spectroscopy as probing method, using a table-top extreme HHG setup providing broadband soft X-ray pulses beyond the N K-edge (400 eV), and novel flatjet technology for sample delivery (Fig. 2). The charge transfer dynamics was directly mapped onto the change of absorption at the N K-edge with a sub-60 fs time resolution. In our combined experimental and theoretical investigation, we unambiguously identify for the first time spectral signatures of the short-lived MLCT and metal centred (MC) states before the long-lived ^{5}T quintet state is reached (Fig. 3c).

One of the holy grails in attosecond science is the development of a well-synchronized pair of isolated attosecond pulses for attosecond pump-attosecond probe experiments. In this scheme, one attosecond pump pulse is used to trigger a coherent electronic wavepacket excitation into an atomic or molecular target that is then probed using a second, time-delayed, isolated attosecond laser pulse. Due to the low efficiency of the HHG

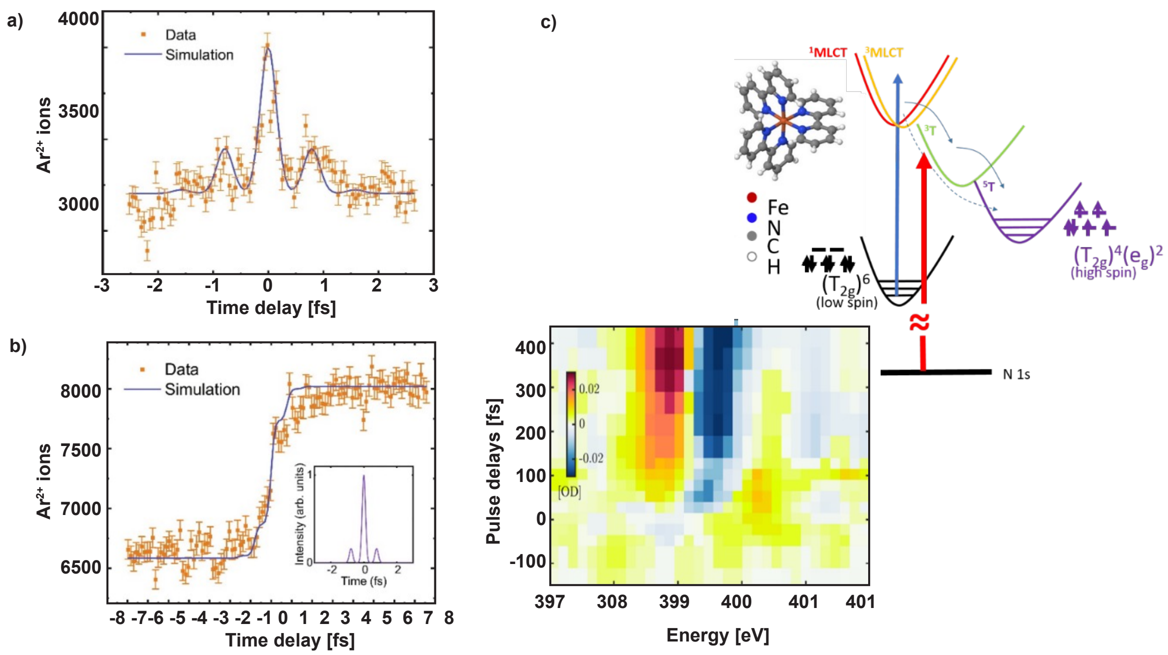


Fig. 3: a) Autocorrelation measurement of two identical XUV pulses measured by recording the two-photon double ionization yield in Ar. b) Time-dependent Ar^{2+} ion yield measured as a function of the delay between a broadband XUV pump pulse and a second XUV probe pulse with photon energies above the second ionization potential of Ar. In c), we show the potential energy landscape of $Fe^{II}(2,2'\text{-bipyridine})_3^{2+}$ together with the measured N K-edge transient absorption spectrum recorded using a table-table soft X-ray source after 400 nm pump laser excitation.

process, most experiments have so far been limited to the investigation of laser-driven electron dynamics in a combined XUV-NIR pump-probe configuration, in which the electron dynamics is mainly driven by the NIR dressing laser field. A team led by Bernd Schütte at the Max Born Institute has successfully broken this last frontier by implementing novel schemes for the efficient generation of a pair of intense isolated attosecond pulses (Fig. 3a). In a recent effort, the source was used to investigate and temporally resolve the two-photon double ionization dynamics of Argon (Fig. 3b) using a two-color pump-probe experiment with attosecond pulses. The source will be used in the near future to directly watch coherent electronic motion in atoms and molecules.

SHORT OUTLOOK

Our recent investigations open new opportunities to explore ultrafast electron dynamics in matter with an exquisite temporal resolution from simple atomic systems in the gas phase to extended molecular systems in solution. In particular, our unique ability to perform attosecond pump-probe experiments with table-top laser systems opens the door towards the systematic investigation of quantum electronic coherences and entanglement in atoms and molecules. Furthermore, ultrafast nitrogen K-edge spectroscopy of charge flow dynamics in metal-ligand complexes as demonstrated recently paves the way towards new avenues in time-resolved soft X-ray spectroscopy of gas- and solution-phase photochemistry.

HIGHLIGHTS 2023

- Femtosecond soft X-ray absorption spectroscopy of gas-phase molecules and metal complexes in solution
- Intense attosecond pulse generation for all Attosecond pump-probe experiments
- Ultrafast electronic relaxation pathways of molecules probed by TRPES at FELs
- Ultrafast keV electron diffraction @ 30 kHz repetition rate, first molecular movie of *trans-cis* isomerization in azobenzene
- Leibniz SAW collaborative excellence project: Mapping FMOs in Ultrafast Charge Migration (join activities between projects 2.1 and 3.1)

2.2 Towards XUV strong-field physics

Evaldas Svirplys, Eli Sobolev, John Thomas, Mikhail Volkov, Oleg Kornilov, Marc Vrakking, Bernd Schütte

The generation of strong infrared laser fields has led to many discoveries in atomic, molecular and condensed-phase physics on ultrashort timescales. Furthermore, strong laser fields have enabled the development of attosecond science. A next frontier is to explore strong-field physics induced by intense attosecond pulses in the extreme-ultraviolet (XUV) region of the electromagnetic spectrum. Here the challenge arises from the fact that the intensities of attosecond pulses are typically low.

To overcome this challenge, we have developed a new setup for the generation of intense attosecond pulses. In a first step, a cascaded post-compression setup was developed to generate powerful infrared pulses which oscillate for only about one optical cycle. These infrared pulses are then used to generate attosecond pulses using a setup extending over 18 meters. To obtain attosecond pulses with high intensities, curved mirrors with a short focal length are used that allow focusing of the attosecond pulses to small spot sizes down to the nanometer region.

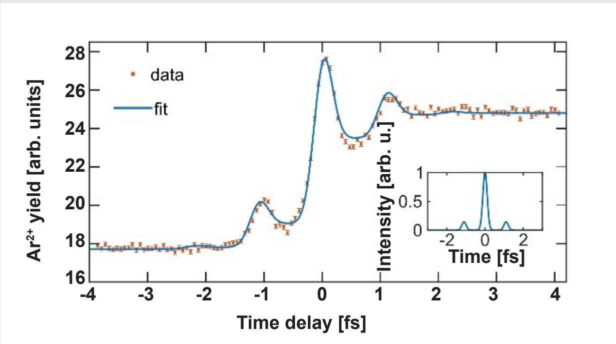


Fig. 1: Attosecond-pump attosecond-probe experiment showing signatures of simultaneous two-photon absorption (characterized by the oscillatory behavior) and sequential two-photon absorption (characterized by the increase of the Ar^{2+} ion yield at positive delays).

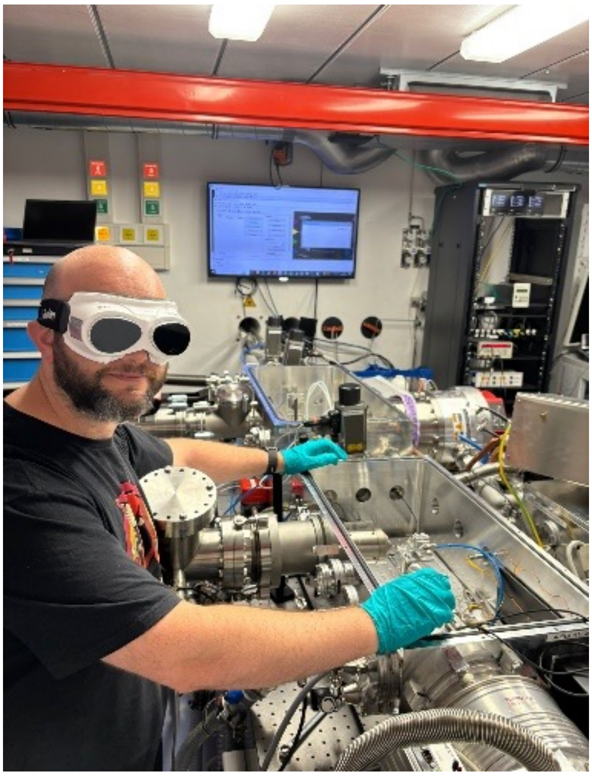


Fig. 2: Eli Sobolev at his setup for the generation of intense attosecond pulses.

We demonstrated the generation of intense attosecond pulses by performing attosecond-pump attosecond-probe spectroscopy experiments, in which a first XUV photon was absorbed by the attosecond pump pulse and a second photon was absorbed by the attosecond probe pulse. As shown in Fig. 1, two different effects can be observed: Oscillations of the Ar^{2+} ion yield are visible around zero time delay, which are a signature of simultaneous two-photon absorption. This process is more efficient when the individual attosecond pulses overlap in time. Furthermore, the Ar^{2+} ion yield is increased at positive time delays, which is a signature of sequential two-photon ionization. The attosecond probe pulse has a higher photon energy and can therefore more efficiently generate Ar^{2+} ions when it arrives after the pump pulse. These results not only demonstrate the generation of attosecond pulses with high intensities, but they also represent a substantial improvement in the data quality that can be obtained in attosecond-pump attosecond-probe experiments.

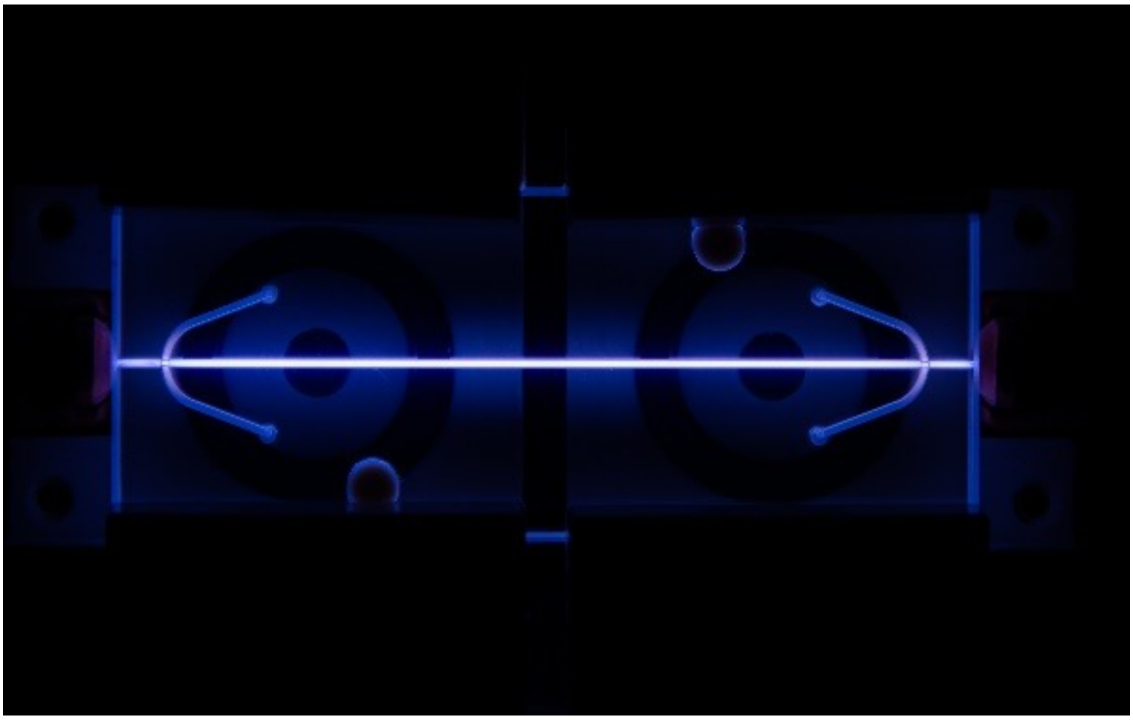


Fig. 3: Plasma from hydrogen molecules generated in a capillary discharge source.

While attosecond pulses are usually focused using curved mirrors, there are a number of disadvantages associated with these mirrors. These include low reflectivities, fast degradation of these mirrors when exposed to XUV light as well as complex alignment procedures that are necessary. At the same time, conventional lenses cannot be used to focus attosecond pulses: On one hand, the XUV photons would be absorbed, and on the other hand, the pulses would be stretched in time. To overcome these challenges, we are developing a plasma lens to focus attosecond pulses. To generate the plasma, a dense target of hydrogen molecules is ionized using a capillary discharge source. A photograph of the plasma is presented in Fig. 3.

After the ignition of the plasma it takes a few hundred nanoseconds until the electron density distribution across the XUV beam profile becomes parabolic, leading to the formation of a concave lens. Since the refractive index of free electrons is below unity, this concave lens is ideally suited to focus attosecond pulses. In contrast to conventional lenses, the plasma lens can be used to focus broadband XUV pulses. Moreover, dispersion of the attosecond pulses in the plasma is small, meaning that the attosecond pulse structure is preserved after the lens. Our first results are very promising, showing a clear focusing effect and a high XUV transmission at the same time. An important advantage of the attosecond plasma lens is that thin metal filters, which are usually used to block the infrared driving pulses after the generation of attosecond pulses, are not needed, since the focusing characteristics of infrared pulses are entirely different. This results in a very high transmission of the generated XUV pulses, which is highly beneficial for applications.

SHORT OUTLOOK

In a next step, strong-field effects in atoms and molecules exposed to intense attosecond pulses will be studied. This may include the investigation of Stark shifts, lineshape modifications and Rabi oscillations. The understanding of these processes may be important when performing attosecond-pump attosecond-probe spectroscopy in atomic, molecular and condensed-phase targets. Furthermore, we will temporally characterize the pulse structure of the attosecond pulses which are obtained in the focus of the attosecond plasma lens.

HIGHLIGHTS 2023

- Generation of ultrastable intense attosecond pulses
- Development of an attosecond plasma lens
- Generation of elliptically polarized XUV pulses
- Investigation of Ar dimers in strong fields

3.1 Dynamics of Condensed Phase Molecular Systems

Erik T. J. Nibbering, Oleg Kornilov (project coordinators), and Marius-Andrei Codescu, Thomas Elsaesser, Evgeny Gorelov, Peng Han, Carlo Kleine, Alina Khodko, Arkadi Kundik, Maté Kurucz, Achintya Kundu, Debkumar Rana, P. Singh, Marc-Oliver Winghart, Jia Zhang

This project aims at a real-time observation of ultrafast molecular processes in the condensed phase, addressing the dynamics of elementary excitations, photoinduced chemical reactions and ultrafast changes of the electronic and/or chemical structure of molecular systems. The project makes use of a broad range of experimental techniques including all-optical pump-probe spectroscopy in a range from the soft-X-ray to far-infrared, infrared photon-echo and multidimensional vibrational spectroscopies, and photoelectron spectroscopy using ultrashort VUV, XUV, and soft-X-ray pulses. To pursue the aims of the project both dedicated experimental setups at the MBI are developed and used and experiments at large scale facilities are pursued (beamtimes at synchrotrons, and free electron lasers).

Topic 1 Dynamics and interactions in hydrated biomimetic and biomolecular systems
(ERC-2018-ADG-BIOVIB, ERC-2018-STG-NONABVD)

Electric forces acting on molecules in liquids at ambient temperature fluctuate at terahertz (THz) frequencies with a direct impact on their electronic properties and optical spectra. We introduce the transient THz Stark effect to modify the electronic absorption spectra of dye molecules and, thus, elucidate and determine the underlying molecular interactions and dynamics. Picosecond electric fields of megavolts/cm induce a nonequilibrium response of the prototypical dye Betaine-30 (B-30) in polar solution that is probed via transient absorption changes. The field-induced broadening of the absorption band follows the THz intensity in time, with a minor impact of solvent dynamics. The response of the ground- and excited-state dipoles of B-30 allows for a quantification of electric forces in the polar environment and demonstrates, supported by molecular dynamics simulations, the prominent role of spectral diffusion in determining the line shape of the electronic absorption spectrum.

Topic 2 Water-mediated proton transport dynamics between acids and bases
(DFG NI 492/13-1; ERC-2017-ADG-XRayProton)

Protons in low-barrier superstrong hydrogen bonds are typically delocalized between two electronegative atoms. Conventional methods to characterize such superstrong hydrogen bonds are vibrational spectroscopy and diffraction techniques. We introduce soft X-ray spectroscopy to uncover the electronic fingerprints for proton sharing in the protonated imidazole dimer, a prototypical building block enabling effective proton transport in biology and high-temperature fuel cells. Using nitrogen core excitations as a sensitive probe for the protonation status, we identify the X-ray signature of a shared proton in the solvated imidazole dimer in a combined experimental and theoretical approach. The degree of proton sharing is examined as a function of structural variations that modify the shape of the low-barrier potential in the superstrong hydrogen bond. We conclude by showing how the sensitivity to the quantum distribution of proton motion in the double-well potential is reflected in the spectral signature of the shared proton.

Topic 3: Electron transport dynamics in donor-acceptor molecular systems
(ERC-2017-ADG-XRayProton, SMART-X)

This is a joint effort with project 2.1, progress has been achieved on solution phase femtosecond UV-pump soft-X-ray probe spectroscopy on the ultrafast charge transfer dynamics in the prototypical metal-ligand complex $Fe^{I}I(bpy)_3^{2+}$ in aqueous solution. For details see the summary of project 2.1.

Topic 4 Electronic excited state dynamics in molecular model systems
(DFG KO 4920/1-1)

XUV photoelectron spectroscopy (XPS) is a powerful method for investigating the electronic structures of molecules. However, the correct interpretation of results in the condensed phase requires theoretical models that account for solvation. We present experimental aqueous-phase XPS of organic biomimetic molecular switches, NAIP and p-HDIOP These switches are structurally similar, but have opposite charges and thus present a stringent benchmark for solvation models which need to reproduce the observed ΔeBE = 1.1 eV difference in electron binding energy compared to the 8 eV difference predicted in the gas phase. We present calculations using implicit and explicit solvent models. The latter employs the average solvent electrostatic configuration and free energy gradient (ASEC-FEG) approach. Counterions, explicitly accounted for in ASEC-FEG, contribute to the stabilization of molecular states and reduction of ΔeBE upon solvation. We further carry out tandem investigation by trXPS and transient absorption (collaboration with Strasbourg) of relaxation dynamics of aminoazobenzene Metanil Yellow. Relaxation dynamics reveal a long-lived state, which presents itself differently in the two complementary methods. Theoretical computations suggest involvement of a long-lived TICT state, which was not observed before.

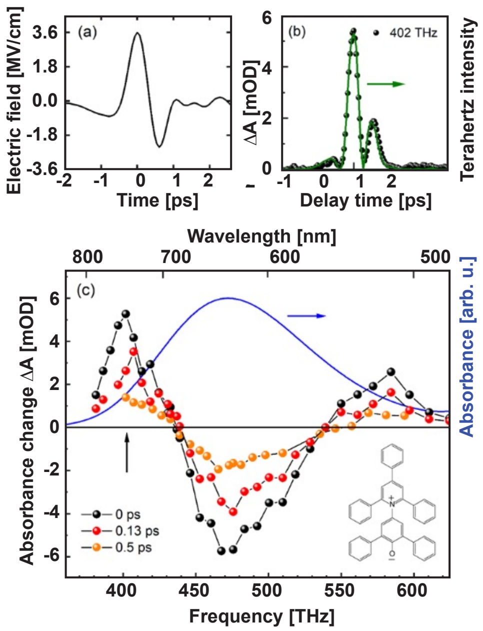


Fig. 1: Terahertz Stark effect: (a) Time dependent THz electric field. (b) Time dependent THz intensity (solid line), The symbols give the absorption change of the dye solution at a frequency of 402 THz (wavelength 746 nm, black arrow in panel (c)) as a function of time delay between the maximum of the THz electric field and the probe pulse. (c) Stationary absorption spectrum of betaine 30 in DMSO (blue solid line, no THz field) and transient absorption spectra for different delay times (symbols). The shape of the transient spectra reflects a spectral broadening with an absorption decrease in the center and absorption increases on the wings of the stationary spectrum. Inset: molecular structure of betaine 30 is shown as an inset.

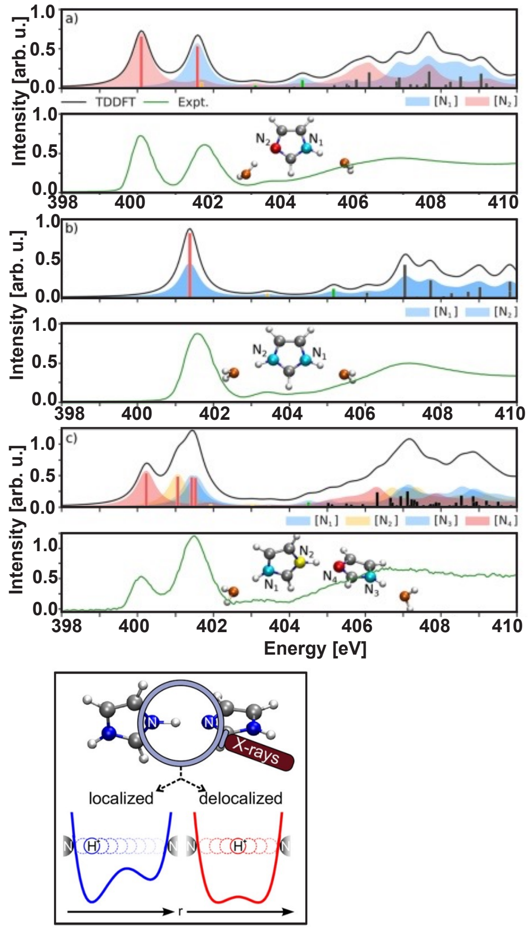


Fig. 2: Protonated imidazole dimer, a prime example of a shared proton in a low barrier double well potential molecular system, has been studied with nitrogen K-edge spectroscopy. In particular the nitrogen 1 s core →π LUMOs transitions are sensitive to proton sharing interactions.

SHORT OUTLOOK

Electronic and vibrational structural dynamics using a combined approach of ultrafast IR and soft-X-ray spectroscopy.

HIGHLIGHTS 2023

- The Terahertz Stark Effect - A dynamic probe of electric interactions in polar liquids
- Ultrafast proton transfer pathways mediated by amphoteric imidazole
- Electronic fingerprint of the protonated imidazole dimer probed by X-ray absorption spectroscopy
- Photoelectron spectroscopy of oppositely charged molecular switches in the aqueous phase

3.2 Solids and Nanostructures: Electrons, Spins, and Phonons

Clemens von Korff Schmising, Sangeeta Sharma and Michael Woerner (project coordinators), and Viktor Bender, Martin Borchert, Kurt Busch, José R. Cardoso de Andrade, Àlvaro Echarri, Stefan Eisebitt, Peter Elliot, Thomas Elsaesser, Ahmed Ghalgaoui, Martin Hennecke, Somnath Jana, Peter Jürgens, Alexandre Mermillod-Blondin, Tino Noll, Bastian Pfau, Laura Rammelt, Klaus Reimann, Johanna Richter, Matthias Runge, Daniel Schick, Samuel Shallcross, Themistoklis Sidiropoulos, Nisha Singh, Puloma Singh, Felix Steinbach, Nele Stetzuhn, Evaldas Svirplys, John Thomas, Jens W. Tomm, Roman V. Volkov, Kelvin Yao, Wenhua Zhao

In correlated condensed matter systems, the interaction of electrons, phonons, and spins leads to a wide range of novel phenomena of both fundamental and practical interest. In an interdisciplinary approach, we select carefully designed material systems and perform experiments with ultra-high time resolution and in a very broad spectral range from terahertz (THz) to soft x-ray frequencies. Key topics are light-induced, ultrafast processes in magnetic materials, which we investigate by element-specific spectroscopy exploiting resonant magneto-optical effects. We also study the dynamical quantum properties of phonons in crystals including coherence and relaxation processes in high-field charge transport using multidimensional THz spectroscopy. We take advantage of the strong connection to project 3.3 "Transient Structures and Imaging with X-rays", where we extend our investigations to explore the "structure-function relationship" of related materials using X-ray diffraction and scattering as well as coherent imaging techniques.

Applied research is carried out in the area of spectroscopic analysis of optoelectronic materials as well as by studies of light-matter interactions in materials processing. The wide range of state-of-the-art experimental techniques is complemented by research in theoretical optics and photonics, as well as theoretical solid-state theory using time-dependent density functional theory. This provides a direct link to experimental activities in the field of light propagation and light-matter interaction in solids and nanostructures.

In the following, we report on selected highlights of two topics.

Nonlinear terahertz (THz) spectroscopy: In 2023 the THz team (Fig. 1: Matthias Runge) has mapped for the first time the linear and nonlinear optical polaron response using ultrafast two-dimensional spectroscopy in the THz frequency range [RRW23]. In such experiments, multi-photon ionization of isopropanol molecules by a femtosecond generates free electrons and the resulting changes of the dielectric properties of the liquid are probed and/or manipulated by a sequence of time-delayed THz pulses (Fig. 2a). During electron relaxation to the localized ground state, collective polaron oscillations are impulsively launched, modulating the dielectric function of the liquid and thus the electric field of a single THz pulse transmitted through the excited sample. These oscillations are perturbed by the interaction with a second THz pulse, resulting in a marked change of the oscillation phase and frequency during the perturbation (Fig. 2 b). The electric field of the perturbing THz pulse induces a nonresonant nonlinear polarization that acts on the polaron and changes the collective oscillations of the electron and solvent cloud. The polaron oscillations are associated with modulations of the radial space charge, i.e. longitudinal size oscillations of a spherical molecular cloud around each electron. Theoretical calculations within a continuum model reproduce the observed phase modulations.

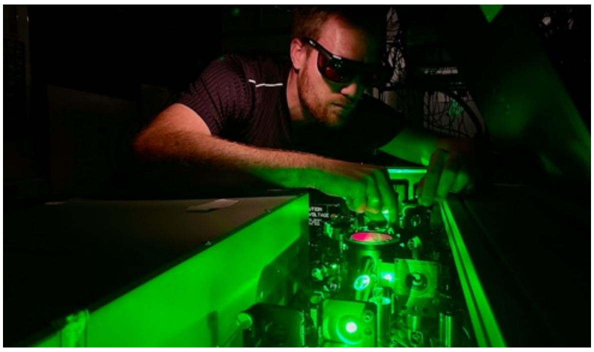


Fig. 1: Matthias Runge adjusts the laser amplifier, which is an essential part of the two-dimensional terahertz spectrometer.

Magnetism and transient electronic structure: We are interested in finding efficient and ultrafast ways to manipulate magnetization, and are currently focusing on two mechanisms, direct interaction with light pulses or indirect interaction by light-driven spin current pulses.

We followed the first approach by laser exciting a magnetic system consisting of ferromagnetic 3*d* transition metals and a 5*d* heavy metal. Such systems are interesting because they allow the study of the interplay between *intrinsic* 3*d* and *induced* 5*d* ferromagnetism, and give rise to tunable magnetic properties, i.e. they combine both fundamental and applied research perspectives. We employed element-specific, core-to-valence-band transitions in the extreme ultraviolet spectral range using high harmonic radiation to study the ultrafast response of a prototypical CoFeB/Pt bilayer. By disentangling the dynamics of Co, Fe and Pt, we found a much smaller demagnetization time constant as well as a much larger demagnetization amplitude of the induced moment of Pt compared to the intrinsic moment of Co and Fe (Fig. 3). Our results suggest enhanced spin-flip probabilities due to the high spin-orbit coupling localized at the heavy metal Pt, and support the hypothesis that a laser-generated, incoherent magnon population within the ferromagnetic film leads to an overproportional reduction of the induced magnetic moment of Pt. [KJY23]

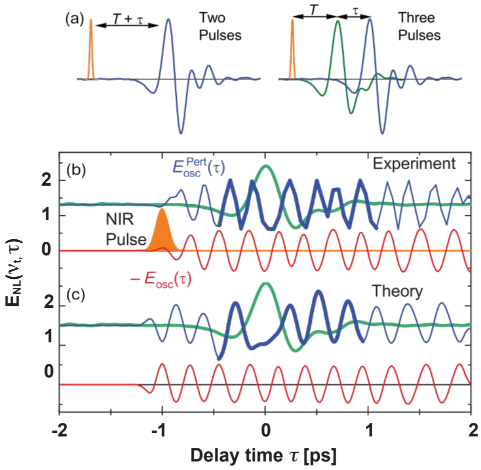


Fig. 2: a) Pulse sequences of the ultrashort excitation pulse and consecutive THz pulses. b) Measured and c) calculated polaron oscillations of solvated electrons in the alcohol isopropanol at T = 1 ps. Red: unperturbed oscillations, blue polaron oscillations perturbed by a second THz pulse (green).

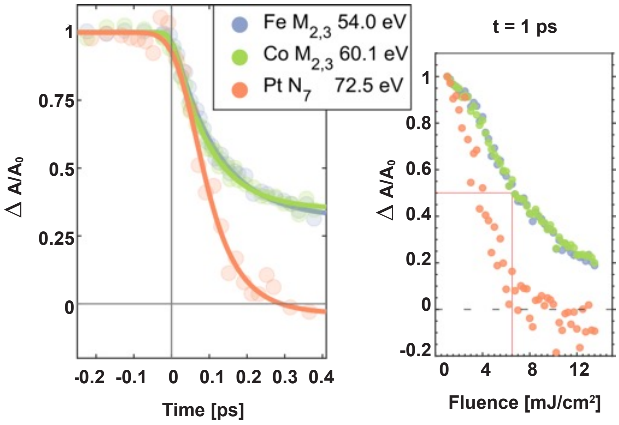


Fig. 3: Magnetic asymmetry A of a CoFeB/Pt bilayer as a function of both time and fluence. The induced magnetization of Pt is quenched faster and more efficiently.

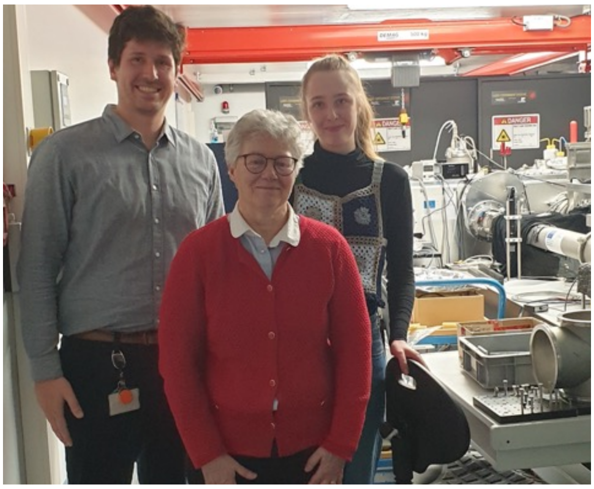


Fig. 4: Physics 2023 Nobel Laureate Anne L'Huillier visits our HHG "Nanomovie" laboratory to meet with Leibniz Junior Group leader Daniel Schick and PhD student Jasmin Jarecki.

In a theoretical work, we have addressed the second mechanism by exploring ways to efficiently generate spin currents. For the broad class of two-dimensional materials, we investigated how to control the spin and valley indices, which are the key quantum labels and form the foundational elements of the fields of spintronics and valleytronics. We were able to show that femtosecond laser light combining a circularly polarized pulse of optical frequency and a linearly polarized pulse of terahertz (THz) frequency, a so-called "hencomb" pulse, can generate precisely tailored spin currents for the dichalcogenide WSe_2 and valley currents for bilayer graphene. The frequency of the circular light component and the polarization vector of the THz light component are shown to be the key control parameters of these pulses. These results thus open a path towards light control of spin/valley current states at ultrafast times. [SES23]

SHORT OUTLOOK

The “hencomb” pulse concept, developed and applied this year to WSe_2 [SES23] and graphene [SGS23], opens a clear perspective to control spin currents and spin order at ultrafast times, and in consonance with this aim, investigations this year of few femtosecond valley polarization by linear light [SDS23] invite future work on the ultrafast limit of light pulses and the potential emergence of unique physical processes in this regime. In order to experimentally study the response of a magnetic system to the injection of such ultrashort spin current pulses, we will work on the optimization of sample design and excitation, as well as on the development of new geometries to access the element- or layer-dependent response in XUV spectroscopy.

HIGHLIGHTS 2023

- Manipulating collective motions of electrons and solvent molecules in a polar liquid
- Ultrafast carrier dynamics and symmetry reduction in bismuth by nonperturbative optical excitation in the terahertz range.
- Ultrafast response of induced and intrinsic magnetic moments revealed by element-specific spectroscopy in the XUV spectral range.
- Laser light hybrids control giant currents at ultrafast times
- Establishment of design rules and discovery of ps kinetics of "hot" carriers for InGaN diode lasers
- Resolving the nonthermal phase transition in Niobium dioxide by time-resolved harmonic spectroscopy.

3.3 Transient Structures and Imaging with X-rays

Tim Butcher, Stefan Eisebitt, Thomas Elsaesser, Kathinka Gerlinger, Simon Gaebel, Isabel Gonzalez Vallejo, Jasmin Jarecki, Lisa-Marie Kern, Maximilian Mattern, Tino Noll, Bastian Pfau, Daniel Schick, Clemens von Korff Schmising, Michael Schneider, Holger Stiel, Steffen Wittrock, Michael Woerner

The aim of the project is to gain a deep understanding of the structure-function relationship of complex and highly functionalized materials. Of particular interest are the dynamics of this relationship on ultrafast time scales. Methodologically, the project is largely based on the application of XUV and X-ray sources for structural investigation and imaging with very high spatial and temporal resolution. We investigate ultrafast, photoinduced structural changes in solids, such as phase transitions and atomic displacements in crystal lattices, with the help of ultrafast X-ray diffraction. From these measurements, we derive transient charge density distributions with femtosecond time resolution. A second focus is research on nanomagnetic materials. Here, time-resolved imaging and scattering methods with coherent soft-X-ray and XUV light are used to reveal the spin structure in these materials in and out of equilibrium.

In 2023, the junior research group led by Daniel Schick has finalized the construction of the main parts of the soft-X-ray laboratory [BBG23]. In this lab, X-ray radiation in the spectral range of 200-2000 eV is emitted from a plasma that is produced by focusing very short (2 ps) and intense (200 mJ per pulse) optical laser pulses onto a tungsten cylinder (Fig. 2). The group achieved a significant advancement by introducing X-ray magnetic circular dichroism (XMCD) measurements in their laboratory. This spectroscopic technique provides a unique view of complex spin and charge dynamics, but requires tunable light in the soft X-ray spectral region with full control of its polarization, which has limited its use to accelerator-driven sources at large facilities. Daniel Schick and his group succeeded for the first time in realizing XMCD experiments at the absorption L edges of iron at a photon energy of around 700 eV (Fig. 3, top). The broadband properties of the plasma X-ray source together with its temporal pulse duration of less than 10 ps open up new possibilities to observe and ultimately understand magnetization dynamics, e.g., when triggered by ultrashort laser pulses. [BEK23]

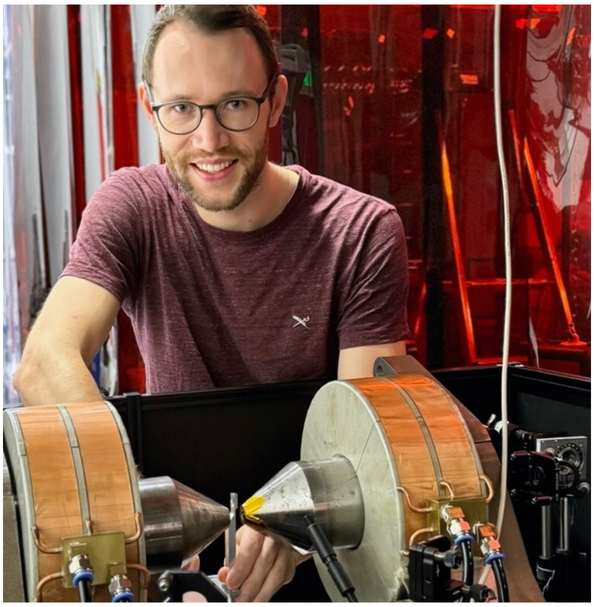


Fig. 1: PhD student Christopher Klose characterizing a magnetic thin-film sample using magneto-optical Kerr effect measurements.

Fig. 2: Image of the plasma produced by an intense laser pulse on a rotating tungsten cylinder. From the plasma, soft X-rays are emitted [BBG23].

Ultrashort pulses of hard X-ray radiation from a similar source are used in the group of Michael Woerner to study light-matter interaction in solids on an atomic scale. Joint activity of the teams of project 3.2 and 3.3 now showed for the first time that symmetry breaking by ultrashort light pulses opens new quantum pathways for coherent phonons in crystals [KGR23, RGG23]. In narrow-gap materials, one can generate electron-hole pairs via interband tunneling driven by long-wavelength radiation with large vector potentials, resulting in electron-hole wave packets with a size on the order of the thermal de-Broglie wavelength. The detailed interplay of inter- and intraband motions of such wave packets creates forces across several unit cells thereby breaking the symmetry in the crystal. Dynamically generated wave packets with an internal charge-density wave having a wave vector at the zone boundary of Brillouin zone of the crystal allow for excitation of coherent zone-boundary phonon wave packets in the excited volume underneath each electron-hole wave packet. In Fig. 3, we show exemplarily the extracted coherent-phonon oscillations observed in the fs-x-ray-probe experiment [KGR23].

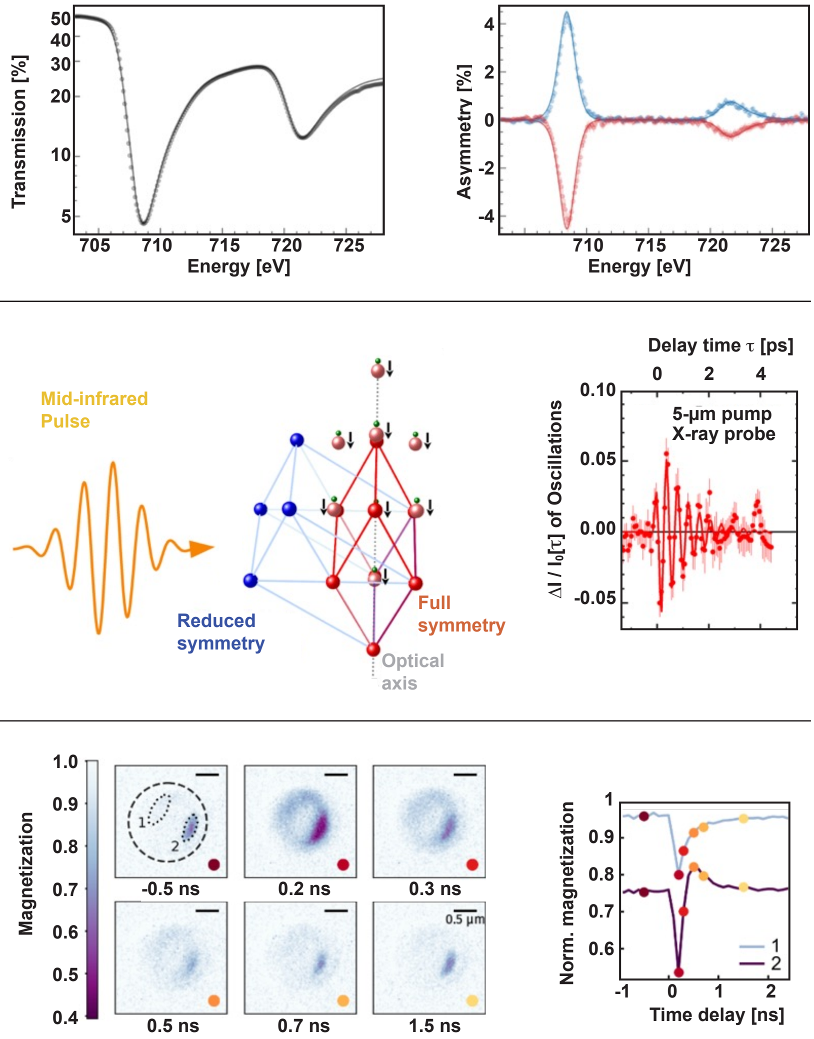


Fig. 3: Experimental results. (top) Resonant absorption (left) and XMCD (right) spectra taken at Fe L-edge with a plasma source in the lab [BEK23]. (center) Femtosecond x-ray probing of coherent zone-boundary phonons in the semi-metal bismuth [KGR23]. (bottom) Imaging of laser-induced demagnetization patterns in a FeGd alloy with X-ray microscopy at MHz repetition rates [GPH23].

The group of Bastian Pfau holds particular expertise in the research of nanomagnetic textures and their dynamics, investigated via soft-X-ray scattering and imaging methods at synchrotron-radiation (SR) sources and X-ray free-electron lasers (XFELs). In 2023, the group has published results from the first time-resolved imaging experiment using ultrashort laser excitation performed at a SR source at MHz repetition rate (Fig. 3, bottom). The experiment was performed at the MAXYMUS x-ray scanning microscope at BESSY where the MBI operates a dedicated pump laser system (see project 4.1). Key to mitigate the enormous heat load on the magnetic sample from the laser excitation at such high repetition rates was a special sample design realized in project 4.3 to reflect and absorb most part of the laser irradiation in aluminum masks. With this technique the group was able to image the local laser-induced demagnetization of a ferrimagnetic thin film on a nanometer scale with 50 ps temporal resolution [GPH23].

SHORT OUTLOOK

The capabilities of the SRX lab will be further enhanced with a synchronized Ti:Sa laser for femtosecond photoexcitation, new ZP optics expanding the wavelength spectrum of the instrument, and the implementation of diffuse scattering methods. Using the laser installed at MAXYMUS, research will focus on skyrmion dynamics in ion-patterned anisotropy landscapes. Additionally, coherent correlation imaging (CCI) will be applied to study skyrmion diffusion dynamics, advancing understanding of magnetic textures.

HIGHLIGHTS 2023

- Soft-X-ray lab for magnetism research became fully operational [BBG23]
- First demonstration of soft-X-ray circular magnetic dichroism in the lab [BEK23]
- Invention of coherent correlation imaging as a new method for resolving fluctuating states of matter [KBH23] (see MBI highlights)
- Quantum pathways of carrier and coherent phonon excitation in bismuth [KGR23]
- Demonstration of MHz repetition rate X-ray imaging with laser excitation [GPH23]
- Ultrafast X-ray imaging of the light-induced phase transition in VO_2 [JPS23]

4.1 Implementation of Lasers and Measuring Techniques

Martin Bock, Federico Furch, Uwe Griebner, Lars Oppermann, Johannes Tuemmler, Ingo Will, Tobias Witting

The general goal of this project is the development of laser-based sources and optical measurement systems tailored to applications specific to the MBI or laboratories of collaboration partners. The MBI constantly develops cutting-edge laser systems and novel characterization and measuring techniques. Many of these systems and techniques are later on implemented in different experiments around the institute in the context of topical areas 2 and 3, or at the premises of collaborative partners, in order to improve the experimental capabilities of these laboratories. This project focuses on the appropriate engineering efforts for the successful implementation of these systems and techniques. Research and development in this project has a strong connection with project 1.2.

Some of the unique optical parametric chirped pulse amplification (OPCPA) systems and laser systems developed in the last few years within the institute are optimized and tailored within this project for their implementation in particular applications.

The project is divided in three topics:
1. Lasers for particle accelerations, providing highly specialized photo-injector lasers and lasers for application experiments in different large-scale facilities;
2. OPCPA engineering currently implementing high power OPCPAs from the near-infrared (NIR) to the mid-IR for time-resolved X-ray diffraction experiments, attosecond pump-probe spectroscopy and material processing;
3. Implementation of measuring techniques, providing state-of-the-art pulse characterization methods for a variety of sources across the MBI.

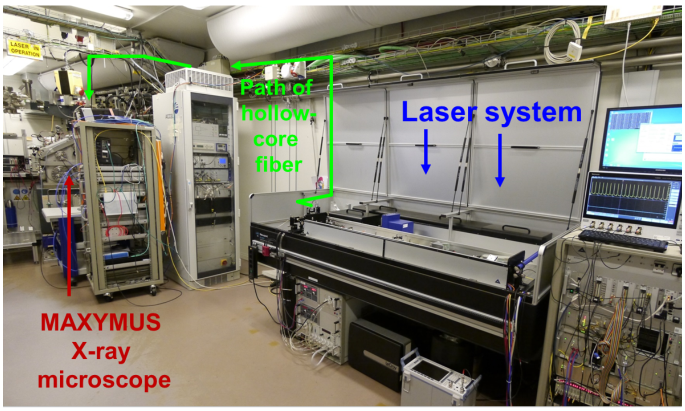


Fig. 1: Laser installation of the MBI at the MAXYMUS microscope at HZB/BESSY (in cooperation with HZB and the Max Planck Institute for Intelligent Systems in Stuttgart).

Fig. 2: Dr. Lisa-Marie Kern installing a sample at the MAXYMUS X-ray microscope.

MBI operates a laser installation custom developed for use with the MAXYMUS scanning transmission x-ray microscope (STXM) at BESSY II, where the laser pulses are transported into the STXM to allow for pump-probe experiments in conjunction with raster-scan imaging. The laser pulses are transported from the laser to the vacuum vessel of the microscope by a special hollow-core fiber (Fig. 1), resulting in a minimum pulse duration of 0.8 ps duration and a focus spot of ~7 µm at the sample.

The laser has been used for experiments on all-optical switching of magnetization in rare-earth/transition-metal alloys on the nanometer-scale as well as on the investigation of the nucleation of photo-induced magnetic skyrmions in a ferromagnetic multilayer.

Combining extreme ultraviolet (XUV) and near-infrared (NIR) pulses for pump-probe experiments has been the overwhelmingly dominant scheme in attosecond science. The photon energy of the NIR field is often lower than the separation between electronic levels of the system under study. This implies that in many cases the interaction of the sample under study with the NIR field is nonlinear and involves a multi-photon process. Reducing both interactions in the experiment (pump and probe) to single photon processes can greatly simplify the outcome of the experiment and provide more control over the physical processes involved. Replacing the NIR pulses in the pump-probe scheme by ultraviolet (UV) or vacuum ultraviolet (VUV) ultrashort pulses represents the next step in the development of attosecond pump-probe experiments.

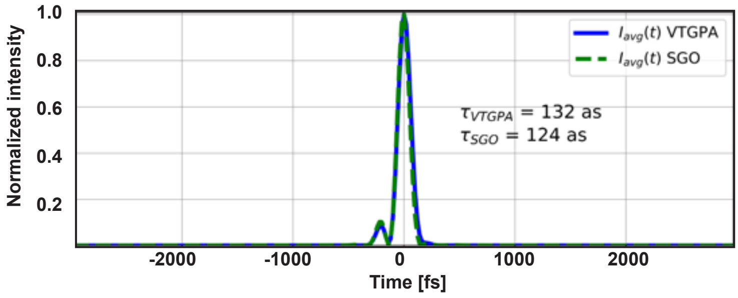


Fig. 4: Measured isolated attosecond pulses at 100 kHz. The two traces correspond to two different methods to retrieve the pulse shape from the experimental data.

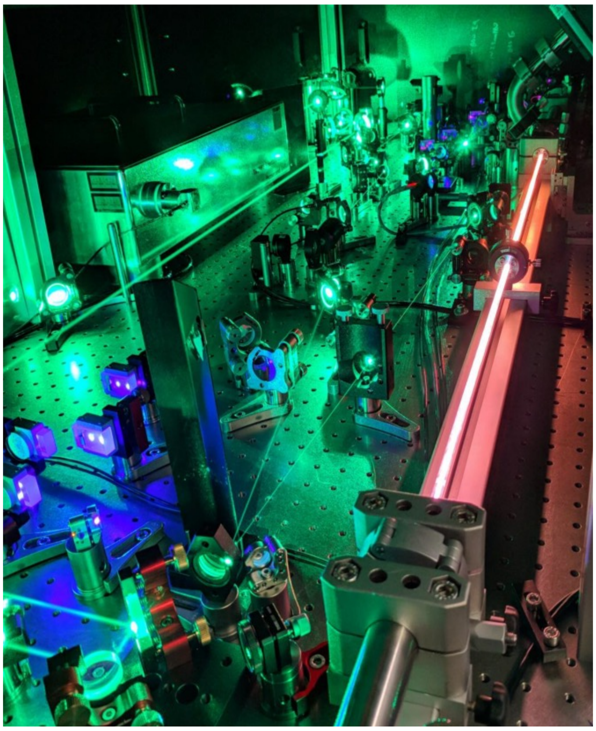


Fig. 3: Photograph of the high power OPCPA driving attosecond pump-probe experiments with high acquisition rates.

In the past, we have developed a high power, high repetition rate OPCPA for driving XUV-NIR pump-probe experiments with high acquisition rates (Fig. 3) and generated attosecond pulses at high repetition rate (Fig. 4). Generating ultrashort (V)UV pulses from the NIR pulses demands additional energy from the OPCPA. With this goal in mind, during 2023 the laboratory was adapted to build a new, more powerful OPCPA system. An additional laser amplifier was added to the laser system pumping the OPCPA (Fig. 5). The development of the new OPCPA is ongoing.

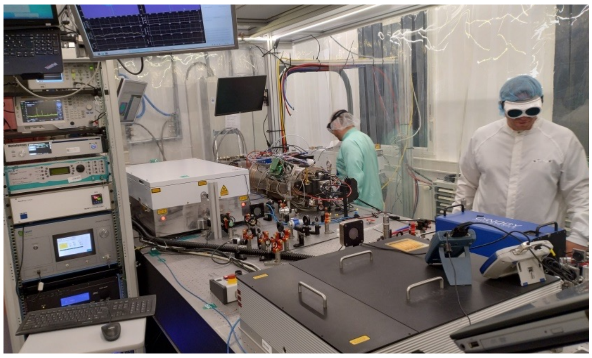


Fig 5: Tobias Witting working on the installation of the booster amplifier for the CPA that will pump the new high power OPCPA

SHORT OUTLOOK

- Upgrade of the high power NIR OPCPA for XUV-UV pump-probe experiments with electron ion coincidence detection.
- Complete remote control of the lasers at MAXYMUS, bERLinPro and in the SXR Lab at MBI by an EPICS-based control system
- Post-compression of the mid-IR OPCPA idler pulses at 5 µm to sub-two-cycle duration with multi-mJ energy.

HIGHLIGHTS 2023

- Spatio-temporal characterization of TW-level near single cycle pulses generated by cascaded compression in gas-filled tubes.
- Extension of the X-ray pump-probe setup by an additional few-cycle pump at 11.2 µm with 50 µJ energy and 180 fs duration
- Implementation of carrier-envelope phase single-shot tagging electronics for photoionization experiments with a Timepix camera.

4.2 Application Laboratories and Technology Transfer

Julia Bränzel, Pritha Dey, Lutz Ehrentraut, Gerd Kommol, Matthias Schnürer, Puloma Singh, Holger Stiel, Johannes Tümmler, MBI / Birgit Kanngießer, Wolfgang Malzer, Christopher Schlesiger, Leona Bauer, Christian Seim, Aurélie Dehlinger, Céline Dyhring, Valentina Alberini, Daniel Grötzsch, TU Berlin / Ioanna Mantouvalou, Richard Gnewkow, HZB

For time-resolved and imaging investigations with soft X-rays MBI operates application laboratories and develops infrastructure for internal and external users. The focus is on stability and reliability for routine operation. Since the experiments are looking for effects on ultrafast timescales and at short wavelengths where only low photon numbers are available, a very stable, reliable and reproducible light source is highly important. Therefore, emphasis is put especially on established methods and components with proven stability.

On the other hand also new measurement technologies are implemented and in cooperation with small and medium enterprises a development for commercial use is aimed for. This work is done within two topics, NanoMovie and BLiX.

NanoMovie

NanoMovie provides a laser infrastructure based on commercial components adapted to our needs and complemented by own developments. It consists of two MIR laser systems operating at 2 µm and 3 µm wavelength. Both systems are based on the same concept and technology platform, allowing for redundancy and efficient operation.

The 2 µm system gives access to 270 to 540 eV photon energy (water window) by high harmonic generation. The 3 µm system (still under construction) is expected to reach the 500 to 800 eV region. Both systems are based on a Dira500 (Trumpf Scientific Lasers) with 500 W output power @10 kHz combined with an OPCPA front-end (FASTLITE). The seed pulse is amplified in successive home build OPCPA stages based on YCOB (2 µm) or LNO (3 µm) s. Fig. 1 and 2.

Fig. 1: 2 µm and 3 µm OPCPA laser system

The 2 µm system works reliable on a daily basis. In 2023 mainly users from project 3.2 and external users from FSU Jena used this setup. A recent improvement is an OPCPA stage (Class 5), operating in three wavelength regions from UV, VIS to NIR. This upgrade is expected to be operational towards the end of 2024, providing further pump wavelengths in pump-probe experiments.

The 3 µm system is close to commissioning. Comparison with simulations (Sisyfos, G. Arisholm; Chi2D, T. Lang) agreed within 60-70 %. Some optimization work, e.g. on the pulse front tilt has still to be done. The output is aimed at >15 W with a pulse duration < 60 fs.

Within the ProFIT-funded project „Modular Spectrometer with Femtosecond Resolution for soft X-ray radiation" (MOSFER) an efficient soft X-ray spectrometer for laboratory sources has been set up (cooperation: PREVAC GmbH, IAP eV., nob GmbH).

Berlin Laboratory for innovative X-ray Technologies (BLiX)

BLiX is jointly operated by the Institut für Optik und Atomare Physik (TU Berlin) and MBI. It is a Leibniz-Applikationslabor of MBI.

BLiX operates at the interface of scientific research and industrial application to transfer research results into instrument prototypes focusing on laboratory scale systems without the need for large scale facilities. MBI contributes to BLiX predominantly in the following areas

Lab based Near-edge X-ray absorption (NEXAFS) spectroscopy

A laser produced plasma source (LPP) delivers sub-ns soft X-ray pulses in the photon energy range between 200 and 1200 eV. Due to a highly efficient reflection zone plate spectrometer with a high dynamic range CCD or CMOS detector data acquisition for a NEXAFS spectrum can be acquired in less than 20 s. At present, the main focus is on new sample systems relevant for catalysis and energy harvesting processes.

Laboratory Transmission X-ray microscopy (LTXM) and tomography in the water window

The full-field LTXM enables the detection of high quality images at 500 eV with a field of view of 30 µm, a spatial resolution of 30 nm and a typical accumulation time of

Fig 2: Scheme of the 3 µm OPCPA laser system

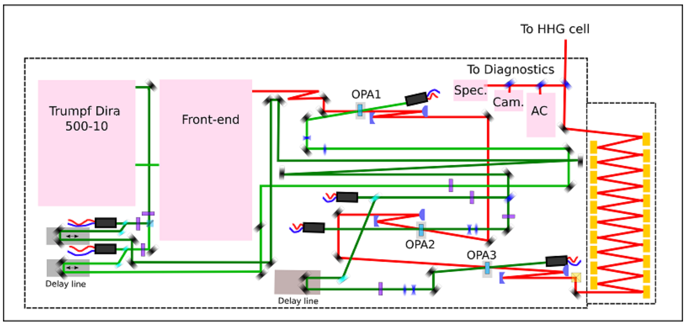


Fig 3: Scheme of the up-graded Laboratory X-ray Transmission Microscope (LTXM)

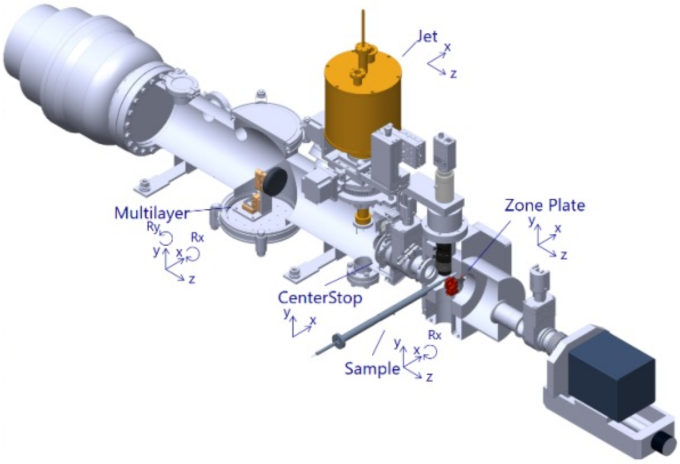
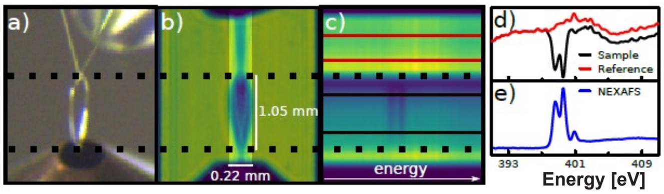


Fig 4: a) Camera image of flat-jet. b) Detector image of the RZP zero order. c) 1st diffraction order. Sample: lower black section. Reference: upper red part. d+e) Resulting NEXAFS spectrum. Negligible experimental noise due to self-reference.



less than 1 min. Emission from a plasma produced by thin disk laser focused on a liquid nitrogen jet is used as soft x-ray illumination source. The whole system was upgraded during the last year (Fig. 3).

SHORT OUTLOOK

- NIR-VIS-UV OPCPA to provide additional pump wavelength ranges
- Commissioning of the 3 µm beam and first results on output power and stability in the range of 500 to 800 eV
- Finalization of the MOSFER beam line
- User operation of the LTXM for in vivo Visualization of Extracellular Matrix Pathology within CRC 1340 (collaboration: Charité Berlin)
- Introduction of optical elements (e.g. reflection zone plates on bent substrates developed in MOSFER) and a new laser system for optical pump X-ray probe investigations in the liquid phase

HIGHLIGHTS 2023

- Upgrade of the LTXM with an advanced thin-disk laser developed at MBI, an improved cryo-target and a device control system allowing correlative light and X-ray microscopy investigations
- Application of a lab-based NEXAFS spectrometer to time-resolved investigations on a flat-jet (Fig. 4)

4.3 Nanoscale Samples and Optics

Denny Sommer, Michael Schneider, Christian Günther (TU Berlin), Dieter Engel

The Laboratory for Nanoscale Samples and Optics supports a variety of experiments in different scientific projects of the MBI via development and production of thin-film sample systems on various substrates with the focus on magnetic multilayers, alloys and metal foils using magnetron sputtering and thermal evaporation. To enable new experimental techniques as for example skyrmion nucleation via laser or current pulses, a UV-lithography system is used to create masks for lift-off processes. Topographic and magnetic characterization is carried out via atomic and magnetic force microscopy, electron microscopy, X-ray reflectivity and diffraction, Kerr-magnetometry and Kerr-microscopy.

In close cooperation with the central facility for electron microscopy (ZELMI) at the TU Berlin the 3D patterning on a few-micrometer and nanometer scale via electron beam lithography and focused ion beam milling (FIB) is carried out.

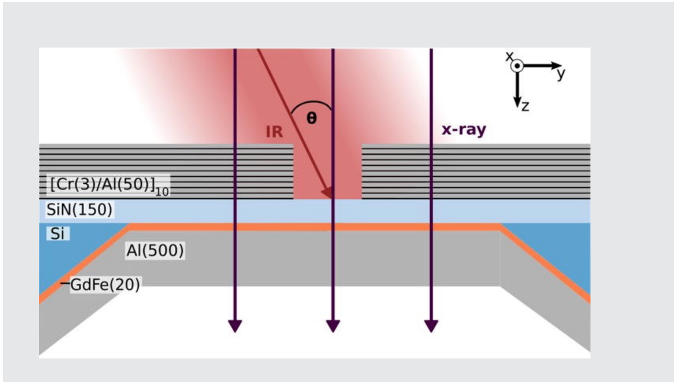


Fig. 2: Sample layout (vertical cross section) for the time-resolved measurements (not to scale, layer thicknesses in nm).

Fig. 1: Lisa Kern in front of the multi-source magnetron sputtering cluster used for the production of the GdFe film on Si_3N_4 membrane chips.

In order to perform time-resolved scanning X-ray microscopy measurements with picosecond photoexcitation by a customized infrared pump laser on a scanning transmission X-ray microscope (MAXYMUS, operating at the BESSYII synchrotron radiation facility), we want to utilize the orbital frequency of the storage ring to perform time-resolved imaging at SR sources at MHz repetition rates. However, at such high repetition rates, the extreme thermal load of solid-state samples poses an additional dilemma for laser-based pump-probe experiments, as it can alter the magnetic properties of the sample and even lead to sample destruction. To overcome this problem, we mask the sample with a reflective Cr/Au layer stack including an aperture with 1.4 µm diameter, milled via focused-ion beam (FIB). As shown in Fig. 2 we deposited in the magnetron sputtering system (see Fig.1) the Ta(3)/$Gd_{29}Fe_{71}$(20)/Pt(3) film direct on the Si_3N_4 membrane from the facet side. Additionally, a 500 nm thick Al heatsink layer was directly deposited on the GdFe layer with our electron-beam evaporator system to effectively conduct the heat away from the magnetic film. Using IR laser fluences of up to 3.1 mJ cm^{-2}, we successfully performed a non-destructive experiment on a magnetic thin film sample at a repetition rate of 50 MHz and investigated laser-induced demagnetization and recovery in GdFe alloys. The repetition rate used here is orders of magnitude higher than that typically used in experiments on photo-induced magnetization dynamics. This approach enables the light-triggered picosecond dynamics with a spatial resolution of 30 nm.

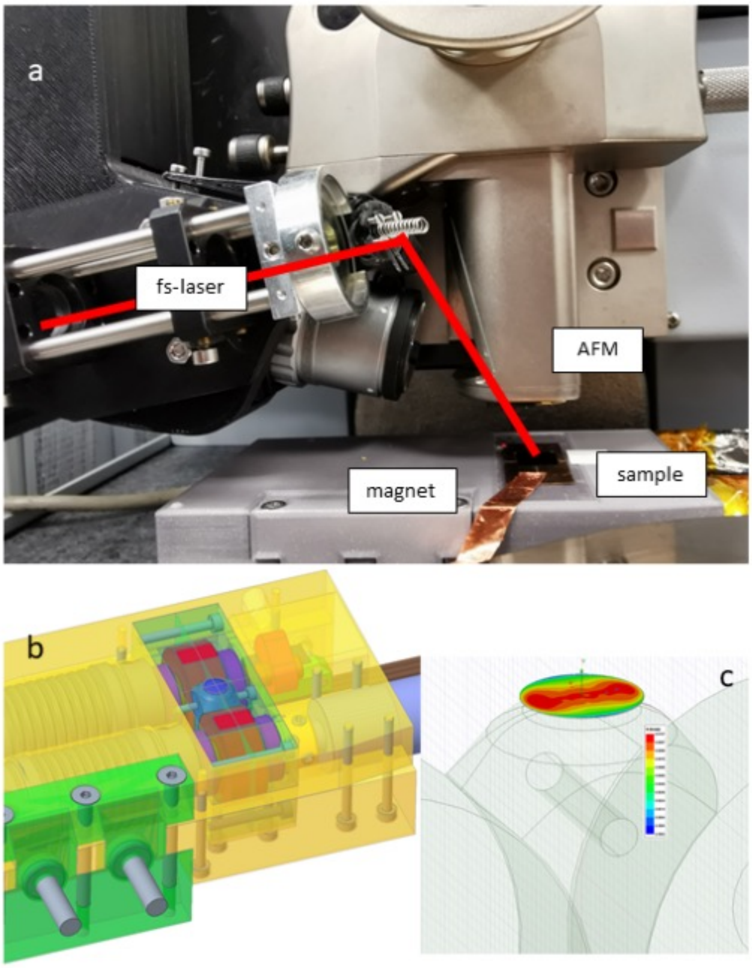


Fig. 3: (a) MFM extension with the fs fiber laser incoupling stage and the compact magnet table. (b) Schematic overview of the magnet, in which the two permanent magnets can be rotated via a stepper motor and thus the polarity and the field strength can be adjusted. (c) Shows the result of the simulation of the homogeneity of the maximum magnetic field.

An important technical advancement in our project was the extension of the atomic force microscope (AFM) with a compact, flat magnetic stage that enables measurements in a variably applicable, homogeneous magnetic field. Typically, the AFM is operated both in topography mode and in a non-contact magnetic phase mode to measure and image magnetic stray fields from domain patterns. We have developed a magnet consisting of two cylindrical permanent magnets that are radially magnetized and can be rotated in opposite directions with an electric stepper motor. By means of previous magnetic field simulations, an optimized pole piece geometry could be found that ensures a homogeneous out-of-plane field (+/- 450 mT) over a 5 mm round area and thus allows various measurement scenarios. Fig.3 (a) shows an overview of the extensions made to the AFM/MFM. It consists of a coupling unit for an fs fiber-laser with a wavelength of 1030 nm and the magnetic stage mentioned above. In Fig. (b) you can see schematically the structure of the magnet, in which the two permanent magnets can be rotated via a stepper motor and thus the polarity and the field strength can be adjusted. Fig. (c) shows the result of the simulation for the homogeneity of the maximum magnetic field.

SHORT OUTLOOK

- Set-up and commissioning of a fully automated 2D-material transfer microscope
- Start-up of a precision grinding machine
- Refurbishment of the electron beam evaporator

HIGHLIGHTS 2023

- new magnetic sample environment for AFM/MFM
- fabrication of bow-tie antennas for transient THz Stark effect method
- enhanced filter and calibration standard production

Interviews

The occasional breakthrough

Sangeeta Sharma, Professor of Theoretical Solid State Physics at Max Born Institute, wants to make it easier for women to pursue a career in science. In this interview, she talks about her scientific career and her plans for the future.

Can you remember exactly when you first became fascinated with science?

The male members of my family were engineers, so I was surrounded by science and technology from an early age. I was always asking questions, and very deep questions at that – for example, I wondered why matter is the way it is. That led me almost automatically to physics.

How did you decide where to do your master's thesis?

At first, I was torn between experimental and theoretical physics. In the end, my conservative family home was the deciding factor: I had to be home by 6 pm every evening. As a theoretical physicist, this is not a problem because you can read papers or work on the computer at home. But experiments sometimes have to be supervised at night. So I chose theoretical solid state physics. I was the only woman in my class to opt for PhD. But I held my own and won a national competition against strong candidates to get funding and was able to do my Ph.D. at a very good institute, the Indian Institute of Technology in Roorkee.

Were you pleased with your doctoral thesis?

I have always enjoyed programming – and still do! During my doctorate, I wrote computer code to describe the electronic properties of solids. I really enjoyed the work. It combined everything I like about science: Programming, theoretical physics, and understanding matter. Thereafter, I remained in this field. After postdoctoral work in Sweden and at the Max Planck Institute of Microstructure Physics in Halle, I came to Berlin.

What are you currently working on?

In my Theory group, we try to describe matter as accurately as possible. The thing is, we know the fundamental laws of nature, but in a solid state, with its huge number of electrons, it is impossible to calculate its properties exactly. So we have to make reasonable approximations to get useful results. For this purpose, we have written a software package called "Elk Code", which we are constantly improving. It allows us to help experimentalists analyze their results or design new experiments.

For example, we can describe the behavior of electrons when special light pulses hit a magnet and strongly change its properties. Or we can describe spin transport, which is the transport of the spin of the electrons when they are electromagnetically excited. In other words, the software can be used to describe very fundamental things. About 2,500 scientists around the world now use this code.

On many days, things don't go your way. But every few weeks you get the occasional breakthrough. Then you know it was all worthwhile!

What is your typical work day like?

My husband is also a physicist, so we talk about our work over coffee in the morning. Otherwise, there are the usual meetings and discussions with my research group. By the way, the majority of my group members are women and many of them are from abroad! The young people get along very well. I am really pleased with the atmosphere.

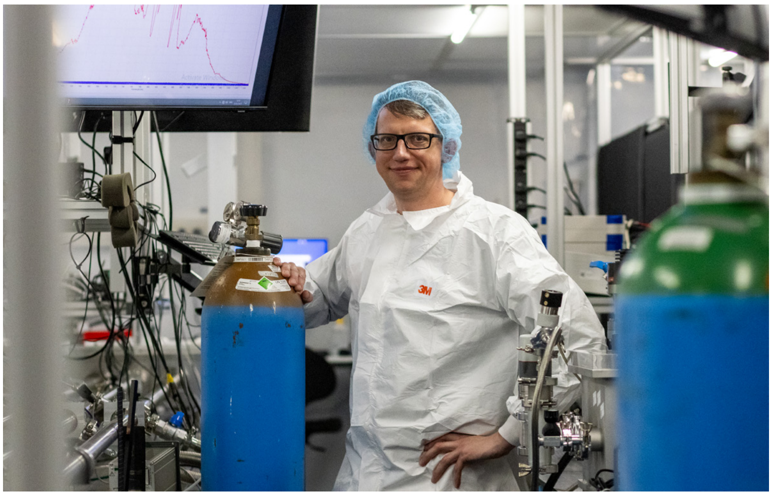
What advice can you give to young scientists?

First of all, I have to say that my job is a kind of passion – I've turned my hobby into my career. If you are not enthusiastic about physics, you won't be happy in the long run. But if you are passionate about it, it's great. Here in Germany, international scientists generally have good opportunities and are very welcome. There are good programs and support. But the system is not very flexible, so you have to be prepared for that. For young women in particular, there is also the question of how to combine a career in science with a family. There is government support for this, but it's also important to consider whether your boss understands your personal situation.

Interview: Dirk Eidemüller

Links:
https://mbi-berlin.de/de/p/sangeetasharma

Follow your curiosity!



An interview with Dr. Bernd Schütte (picture right side), who led the Attosecond XUV Nonlinear Optics group as junior research group leader until 2023, and Dr. Daniel Schick (picture left side) leader of the Complex Spin Structures in Time and Space Leibniz Junior Research Group at the MBI.

When did you get interested in physics? Have you always wanted to be a scientist?

Bernd Schütte: I was interested in astronomy as a child; the extreme distances and time scales fascinated me. Later I was more attracted to mathematics. But when it came to choosing what to study at university, I opted for physics. I hadn't thought about becoming a scientist at the time – I was keeping my options open.

Daniel Schick: My father is a physicist and my mother is a chemist, so I more or less grew up in a lab. One thing led to another and I ended up following in my parents' footsteps.

Where did you study and what was the subject of your doctoral thesis?

Daniel Schick: I studied in Rostock, my home town, and did my doctorate at the University of Potsdam. My thesis was on the ultrafast dynamics of crystal lattices. I used time-resolved X-ray diffraction, which was co-developed here at the MBI. My PhD supervisor worked at the Max Born Institute before changing to the University of Potsdam.

Bernd Schütte: I studied in Dresden and spent a year abroad in Lund, Sweden. After that I did my PhD in Hamburg. As part of my thesis, I built a terahertz field-driven streak camera, which I used to track very fast electron processes. In this specific case it was what we call "Auger decay". You take electrons from the inside of an atom and observe how quickly this "hole" decays.

Did you remain in your field of research?

Bernd Schütte: During my study abroad year in Sweden, I worked on a project with Nobel Prize winner Anne L'Huillier, and I have remained in this field ever since. What we are trying to do is resolve extremely fast electronic processes in time. This is the field of attosecond physics.

Daniel Schick: I now study the ultrafast dynamics of magnetic properties in solids, but I use a similar technique that has now been extended. During my PhD I worked with hard X-rays. You get a little bit softer with age, so now I work with soft X-rays!

What does it mean to be a junior research group leader?

Daniel Schick: Above all, it means taking on responsibility. The transition from postdoctoral fellow to junior research group leader means that you are in charge of supervising a group. You are responsible for students and PhD students, as well as postdocs. So you are no longer focused on the success of just your own project, but on that of many projects. I used to supervise students occasionally, but now I have to think through and design projects from start to finish, publish them, of course, and then start all over again to raise funds for new positions, and so on and so forth.

Bernd Schütte: I stopped being a junior in 2024. If you look at it from the other direction, as a junior you are already a full-fledged research group leader. You are competing with other groups led by professors. At the same time, you are not yet fully established. You haven't entirely found your research topic. This makes some things more difficult, such as recruiting the best people as doctoral candidates or postdoctoral researchers. Obviously, they go where the big names are. You also have a limited amount of time. Basic research is a lengthy process. But if you want to get a permanent position after the junior research project, you have to publish. So there's quite a bit of pressure on you.

Daniel Schick: As a junior research group leader, you step out of your director's shadow and are forced to establish yourself. At the same time, you suddenly become much more visible to others. As soon as you achieve success, your colleagues perceive you differently, which can be very rewarding.

What made you choose the Max Born Institute?

Bernd Schütte: The MBI is well known for its leading role in attosecond physics. As I had been interested in this topic since my time in Lund, this was what attracted me. At that time, when Marc Vrakking had not been director for very long, a new division was being developed in this field at the MBI. It was exciting to contribute to its establishment.

Daniel Schick: Our director in Division B, Stefan Eisebitt, is very successful and well known in my field, especially when it comes to research using large-scale facilities. During my first postdoctoral period at BESSY here in Adlershof, I was thrilled by the first successful experiments carried out in this division, which at that time could only be done at large-scale facilities. Then, as now, we use laser-based sources to generate light – in my research, soft X-ray light, which is otherwise only available at very large accelerator-based sources.

Does your responsibility as a research group leader have an impact on your passion as a researcher?

Bernd Schütte: You have to deal with a lot of organizational things, which means you have less time to think, less time in the lab – in other words, less time for everything a researcher needs to develop new ideas. But so far I've managed to strike the right balance. Of course, there are days or weeks when I'm very busy with organizational issues, but on other days I can devote myself entirely to science.

Daniel Schick: The same goes for me. An important skill you need to develop is the ability to delegate and pass on responsibility. You have to trust your own team members; you can't always look over their shoulder when they're working. Then again, it's important to manage your own time well so that you can disappear into the lab occasionally.

What is a typical day at the MBI like for you?

Daniel Schick: The great thing about the MBI is that we have a large number of experienced staff scientists. These colleagues have accumulated an enormous amount of knowledge over a very long period of time. You can work with them intensively, not just on a two-year basis – although sometimes that is the case. Friendly working relationships can develop here. In our division, we have a very open, cooperative relationship and flat hierarchies. We try to give early-career scientists responsibility quickly and work with them on an equal footing.

Bernd Schütte: We also have a good relationship with the technical staff, which is important because our experiments are very technical.

What advice would you give to young (would-be) scientists?

Bernd Schütte: It can be tempting to focus on the typical indicators of success – publications, conference presentations, and so on. My advice would be to try not to let these things guide you too much, not to let them determine what you should be doing. Instead, follow your curiosity! It's not always easy as a doctoral candidate, but it pays off in the long run.

Daniel Schick: If you have a concept, you should try to pursue it consistently and have confidence in yourself. It's important to achieve scientific independence as early as possible. Of course, this is not possible without grants, third-party funding, etc. But independence is always rewarded. Personally, it has done me a lot of good.

Interview: Dr. Patricia Löwe
Translation: Teresa Gehrs

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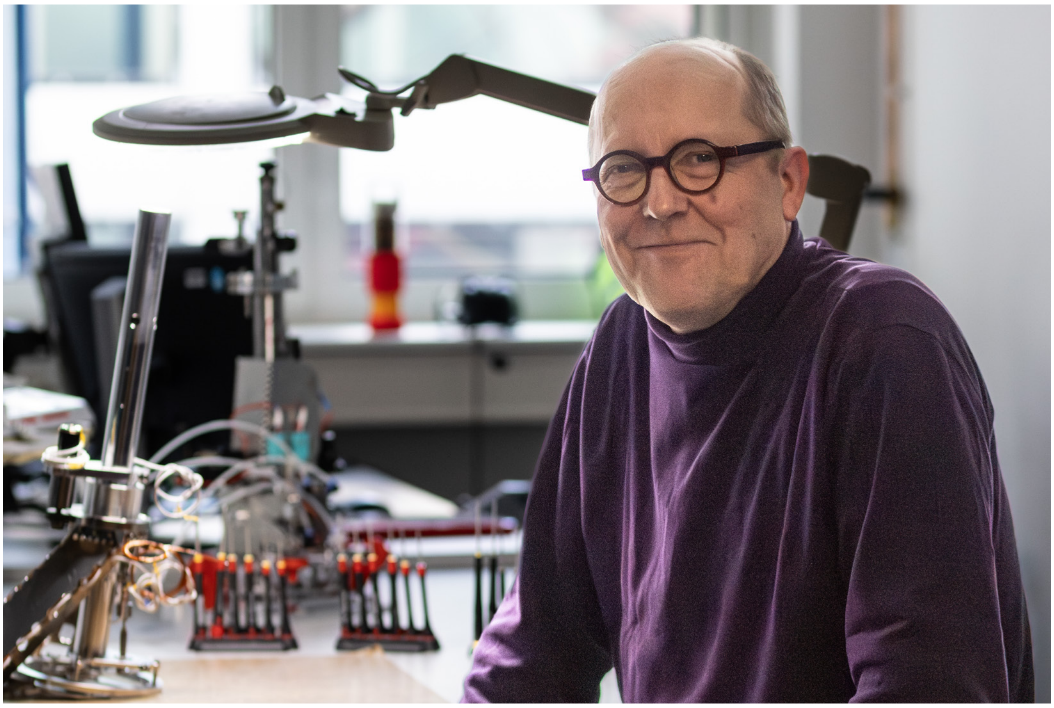


Roman Peslin and Dr. Tino Noll (in the picture) talked about 3D printing at the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy

Mr. Peslin, how did you come to work at the MBI?

Roman Peslin: In 1980, I began an apprenticeship as a precision mechanic at the Zentralinstitut für Optik und Spektroskopie of the Akademie der Wissenschaften der DDR and worked there in the mechanical workshop until 1991. Since 1992 I have been working as a technician in Department A of the MBI in the immediate vicinity of the experiments, where I am engaged in the production and application testing of different assemblies for cluster physics and laser spectroscopy.

How would you describe your work with the scientists?

Roman Peslin: My tasks consist of advising the scientists on solving mechanical problems in the test setups and laboratories as well as mechanical construction using a CAD system and its manual-technical implementation.

Mr. Noll, how did you come to the MBI?

Tino Noll: In my first life, I was a machine fitter. I grew up in the GDR. It wasn't that easy to get an Abitur there. So, I decided to do this training. Later I did my A-levels and studied machine tool construction at the TU Dresden. After that, I spent a year or two at the Zentrum für Wissenschaftlichen Gerätebau at the DDR-Akademie der Wissenschaften, then 20 years at the Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY) in Adlershof. There I met Stefan Eisebitt, whom I supported in the realization of some of his projects. In 2013 I followed him to the TU Berlin and after two or three years I went with him to the MBI.

Working here is very fulfilling because you have to be creative and new ideas are often gratefully accepted. Of course, modern science also requires modern equipment. Developing this or adapting it for special requirements is wonderful work for me as an engineering scientist. I often hear from colleagues in industry how little is being tried out. If you don't try out, there will be less or no innovation. This is quite different at the MBI.

When did you start working with 3D printing, Mr. Peslin?

Roman Peslin: The initial spark for the purchase of a 3D printer came at the Long Night of the Science 2019, where I had seen a demonstration at the Bundesanstalt für Materialforschung und -prüfung (BAM) in Adlershof and was immediately enthusiastic about the possibilities. After that, I acquired a lot of theoretical knowledge until we were finally able to acquire the first 3D printer in 2021.

What about you, Mr. Noll?

Tino Noll: During my time at BESSY, I worked in the field of optomechanics and later completed my doctorate in this field. This involves extremely complex mechanics in a vacuum for shaping and guiding radiation for optical experiments.

I have been using 3D printing in this context for quite some time. I had the first part printed for BESSY in 2007. It was a part that could not be made with conventional machines. I had learned about 3D printing at trade fairs and in journals. My first print was an elastic mechanism. I often work with elastic parallel kinematics – that's what this design method is called. You can integrate special deformation zones into solid materials to enable certain movements. This print was about the precise rotational adjustment of a mirror – essential to avoid influencing the beam shaping when the mirror rotates.

For what purposes do you use 3D printing here at the institute?

Roman Peslin: I use the 3D printer mainly for the rapid production of components which would not be possible or would be very difficult to produce with conventional machining methods. This technique allows me to construct with high geometric freedom, whereby the usual creation of technical drawings in conventional production is omitted and thus offers an enormous time advantage. I can thus very quickly create ideas for small parts and brackets in experimental setups, for samples, special housings for in-house developed electronic circuits or devices for processing glass, metal and other materials. Since I can only print plastics, constructions in combination with metal components are also very exciting.

The printers I use work according to the FDM principle, which stands for Fused Deposition Modeling. The plastic is pressed through a heated nozzle, the so-called extruder, melted and thereby moved in a targeted manner over a build platform, thus forming the 3D component layer by layer. The printing material, such as PLA, a Polylactide which is obtained from corn starch, is comparatively very inexpensive and costs on average about 30 €/kg. Since the printed parts are very light, the pure material costs are usually in the cent or single-digit Euro range. In addition, this manufacturing method is additive and little waste is produced.

Tino Noll: 3D printing allows us to design and manufacture parts that increase the accuracy of experiments, so that nothing wobbles, deforms or moves in the wrong direction in an uncontrolled manner. But it also allows us to quickly produce small tools, devices or operating equipment.

What's more, CAD programs enable us to visualize designs much more clearly, in three dimensions, than we could before. That makes our work much easier.

So, you only work with plastic at the institute?

Tino Noll: We process plastic. Metal printing requires very elaborate and expensive machines that are more difficult to handle.

For special requirements, I work with external companies that have a different range of printers than we have in-house. They can also process ceramics or metals, for example. You can't own all the machines, and there is no machine that can do everything.

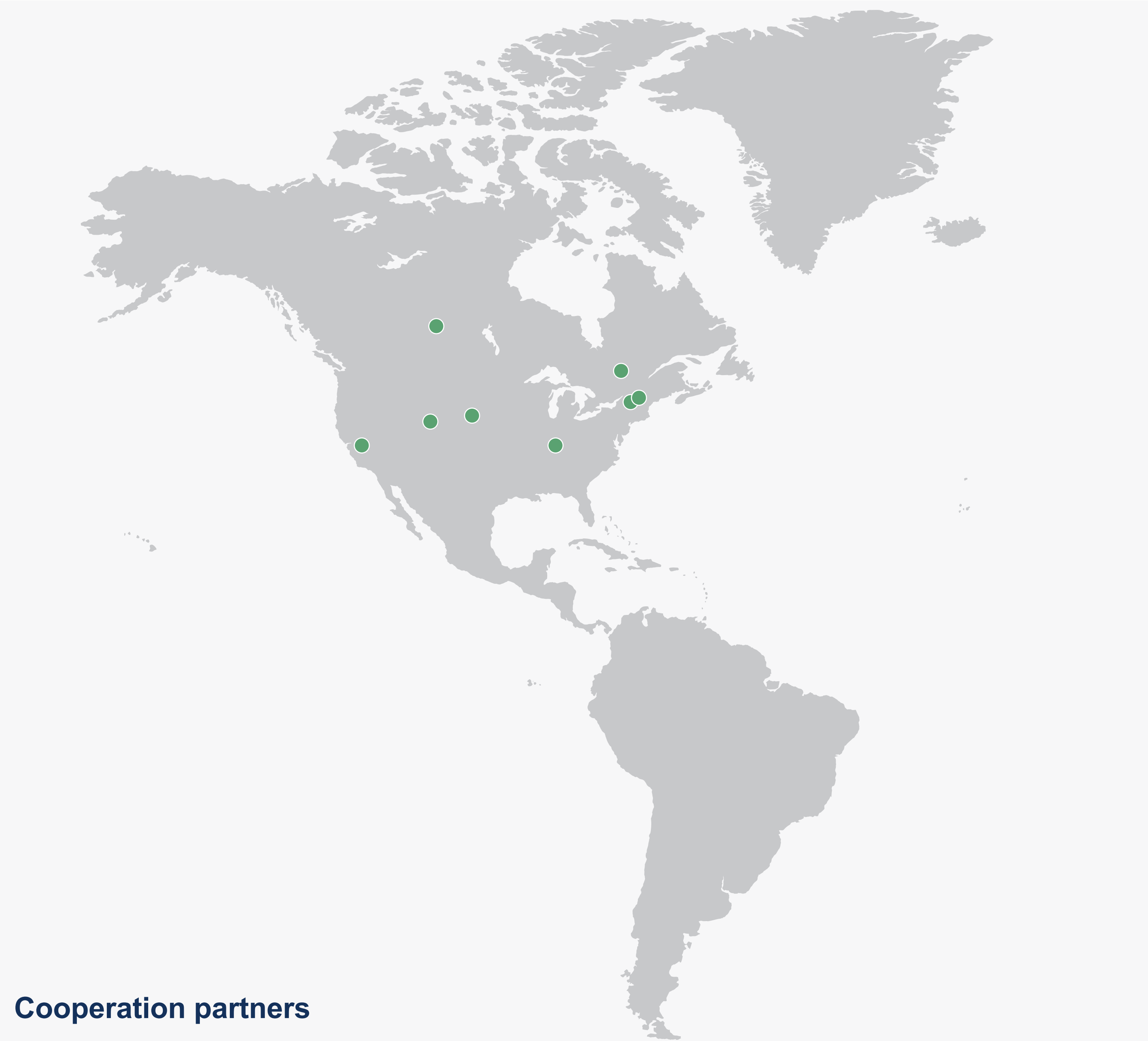
What was your most exciting print in 2023?

Roman Peslin: On optical tables, iris diaphragms are often used in the beam paths of the lasers, which were previously adjusted manually. Due to the 3D printing, in combination with commercial parts, I was able to develop a motorized iris diaphragm, which can be adjusted very precisely via a computer, as an independent assembly that is very cost-effective and can be reproduced quickly.

Tino Noll: We wanted to upgrade a magnetic force microscope by adding a laser coupler and an adjustable magnet. We used photogrammetry to measure the microscope. This means taking a hundred or more photos. Software then uses these to create a three-dimensional surface model. You can imagine it a bit like a plaster cast. In the CAD program, I was able to construct the mount for the laser and the magnets and optimally adapt them to the model. Most of the structural parts were produced by us on the 3D printer. It worked perfectly.

Interview: Dr. Patricia Löwe

Cooperation partners



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- University of Ottawa, Canada
- McGill University, Montreal, Canada
- Ben Gurion University of the Negev, Beer-Sheva, Israel
- Huazhong University of Science and Technology, Atto-Ultrafast Optics Laboratory, China

Appendix

Appendix 1

Publications

AHH23: F. R. Arteaga-Sierra, J. Herrmann, and A. Husakou; Ionization-induced susceptibility by nearly free electrons in gases influenced by the Coulomb potential; Phys. Rev. A **108** (2023) 063510/1-7

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BBG23: M. Borchert, J. Brenzel, R. Gnewkow, L. Lunin, T. Sidiropoulos, J. Tümmler, I. Will, T. Noll, O. Reichel, D. Rohloff, A. Erko, T. Krist, C. von Korff Schmising, B. Pfau, S. Eisebitt, H. Stiel, and D. Schick; Versatile table-top setup for picosecond time-resolved resonant soft-x-ray scattering and spectroscopy; Rev. Sci. Instrum. **94** (2023) 063102/1-12

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BDi23: A. Bharti and G. Dixit; Tailoring photocurrent in Weyl semimetals via intense laser irradiation; Phys. Rev. B **108** (2023) L161113/1-6

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CKW23: M.-A. Codescu, T. Kunze, M. Weiß, M. Brehm, O. Kornilov, D. Sebastiani, and E. T. J. Nibbering; Ultrafast proton transfer pathways mediated by amphoteric imidazole; J. Phys. Chem. Lett. **14** (2023) 4775-4785

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ZBG23: J. Zimmermann, F. Beguet, D. Guthruf, B. Langbehn, and D. Rupp; Finding the semantic similarity in single-particle diffraction images using self-supervised contrastive projection learning; NPJ Comput. Mater. **9** (2023) 24/1-7

ZLP23: H.-J. Zeng, Z.-L. Lin, V. Petrov, P. Loiko, Y. Chen, Y. Huang, G. Zhang, X. Mateos, W.-Z. Xue, H. Lin, L. Wang, and W. Chen; 56-fs diode-pumped SESAM mode-locked Yb:$YAl_3(BO_3)_4$ laser; Opt. Express **31** (2023) 10617-10624

ZLZ23: H.-J. Zeng, Z.-L. Lin, G. Zhang, P. Zhang, Z. Li, Z. Chen, P. Loiko, X. Mateos, V. Petrov, and W. Chen; Sub-30 fs mode-locked Yb:(Y,Gd)AlO_3 laser; SPIE Proc. **12760** (2023) 1276003/1-4

ZPJ23: Z. Zang, S. Peng, W. Jin, Y. Zuo, G. Steinmeyer, Y. Dai, and D. Liu; In-situ measurement and compensation of complex spatio-temporal couplings in ultra-intense lasers; Opt. Las. Eng. **160** (2023) 107239/1-8

ZSZ23: N. Zhang, Q. Song, J. Zhou, J. Liu, S. Liu, H. Zhang, X. Xu, Y. Xue, J. Xu, W. Chen, Y. Zhao, U. Griebner, and V. Petrov; 44-fs pulse generation at 2.05 µm from a SESAM mode-locked Tm:$GdScO_3$ laser; Opt. Lett. **48** (2023) 510-513

ZXM23: H. Zeng, W. Xue, R. T. Murray, W. Chen, Z. Pan, L. Wang, C. Cui, P. Loiko, X. Mateos, U. Griebner, and V. Petrov; Continuous-wave and mode-locked operation of an in-band pumped Tm,Ho,Lu:$CaGdAlO_4$ laser; App. Sci. **13** (2023) 12927/1-10

in press

BGU: M. Bock, L. v. Grafenstein, D. Ueberschaer, G. Steinmeyer, and U. Griebner; Nonlinear compression of few-cycle multi-mJ 5 µm pulses in ZnSe around zero-dispersion; Opt. Lett.

BCA: K. D. Borne, J. C. Cooper, M. N. R. Ashfold, J. Bachmann, S. Bhattacharyya, R. Boll, M. Bonanomi, M. Bosch, C. Callegari, M. Centurion, M. Coreno, B. F. E. Curchod, M. B. Danailov, A. Demidovich, M. D. Fraia, B. Erk, D. Faccialà, R. Feifel, R. J. G. Forbes, C. S. Hansen, D. M. P. Holland, R. A. Ingle, R. Lindh, L. Ma, H. McGhee, S. B. Muvva, J. P. F. Nunes, A. Odate, S. Pathak, O. Plekan, K. C. Prince, P. Rebernik, A. Rouzée, A. Rudenko, A. Simoncig, R. J. Squibb, A. S. Venkatachalam, C. Vozzi, P. M. Weber, A. Kirrander, and D. Rolles; Ultrafast electronic relaxation pathways of the molecular photoswitch quadricyclane; Nature Chemistry

BMS: R. Battistelli, D. Metternich, M. Schneider, L.-M. Kern, K. Litzius, J. Fuchs, C. Klose, G. K, K. Bagschik, C. Günther, W. D. Engel, C. Ropers, S. Eisebitt, B. Pfau, F. Buettner, and S. Zayko; Coherent x-ray magnetic imaging with 5 nm resolution; Optica

CWD: W. Chen, L. Wang, I. B. Divliansky, V. Pasiskevicius, O. Mhibik, K. M. Moelster, A. Zukauskas, L. B. Glebov, and V. Petrov; Narrowband, intracavity-pumped, type-II $BaGa_2GeSe_6$ optical parametric oscillator; Opt. Express

DWH: S. K. Das, M.-O. Winghart, P. Han, D. Rana, Z.-Y. Zhang, S. Eckert, M. Fondell, T. Schnappinger, E. T. J. Nibbering, and M. Odelius; Electronic fingerprint of the protonated imidazole dimer probed by x-ray absorption spectroscopy; J. Phys. Chem. Lett.

ELB: K. Eremeev, P. Loiko, S. Balabanov, T. Evstropov, D. Permin, O. Postnikova, V. Petrov, P. Camy, and A. Braud; Spectroscopy of thulium ions in solid-solution sesquioxide laser ceramics: Inhomogeneous spectral line broadening, crystal-field engineering and C_{3i} sites; Opt. Mater.

JGH: X. Jia, L. Guo, X. Hao, W. Becker, and J. Chen; High-order S-matrix theory of atomic nonsequential double ionization in intense laser fields; Phys. Rev. A

JRM: P. Jürgens, S. D. C. Roscam Abbing, M. Mero, C. L. Garcia, G. G. Brown, M. J. J. Vrakking, A. Mermillod-Blondin, P. Kraus, and A. Husakou; Linking High-Harmonic Generation and strong-field Ionization in bulk crystals; ACS Photonics

LLZ: Z.-Q. Li, Z.-L. Lin, H.-J. Zeng, H.-Y. Nie, G. Zhang, G. Wu, F. Yu, X. Zhao, H.-C. Liang, V. Petrov, P. Loiko, X. Mateos, G. Wu, and W. Chen; Continuous-wave and SESAM mode-locked operation of Yb:$YSr_3(PO_4)_3$ laser; Opt. Express

NIP: J. P. F. Nunes, L. M. Ibele, S. Pathak, A. R. Attar, S. Bhattacharyya, R. Boll, K. Borne, M. Centurion, B. Erk, M.-F. Lin, R. J. G. Forbes, N. Goff, C. S. Hansen, M. Hoffmann, D. M. P. Holland, R. A. Ingle, D. Luo, S.

B. Muvva, A. Reid, A. Rouzée, A. Rudenko, S. K. Saha, X. Shen, A. S. Venkatachalam, X. Wang, M. R. Ware, S. P. Weathersby, K. Wilkin, T. J. A. Wolf, Y. Xiong, J. Yang, M. N. R. Ashfold, D. Rolles, and B. F. E. Curchod; Monitoring the evolution of relative product populations at early times during a photochemical reaction; J. Am. Chem. Soc.

PHW: M. Pfeifer, D. N. Huynh, G. Wegner, F. Intravaia, U. Peschel, and K. Busch; Time-domain modeling of interband transitions in plasmonic systems; Appl. Phys. B - Lasers and Optics

PMS: H. Probst, C. Möller, M. Schumacher, T. Brede, J. K. Dewhurst, M. Reutzel, D. Steil, S. Sharma, G. S. M. Jansen, and S. Mathias; Unraveling femtosecond spin and charge dynamics with extreme ultraviolet transverse MOKE spectroscopy; Phys. Rev. Res.

Ste: G. Steinmeyer; Acoustic gigawatt laser deflection; Nat. Photonics

UFB A. J. Uzan-Narovlansky, L. Faeyrman, G. G. Brown, S. Shames, V. Narovlansky, J. Xiao, T. Arusi-Parpar, O. Kneller, B. D. Bruner, O. Smirnova, R. E. F. Silva, B. Yan, Á. Jiménez-Galán, M. Y. Ivanov, and N. Dudovich; Observation of interband Berry phase in laser-driven crystals; Nature

VGE: V. N. Valmispild, E. Gorelov, M. Eckstein, A. I. Lichtenstein, H. Aoki, M. I. Katsnelson, M. Y. Ivanov, and O. Smirnova; Sub-cycle multidimensional spectroscopy of strongly correlated materials; Nat. Photonics

ZWL: P. Zhang, W. Wu, Z.-L. Lin, Z.-Q. Li, P. Loiko, S. Normani, Z. Chen, Z. Li, G. Z. Elabedine, X. Mateos, H.-J. Zeng, G. Zhang, H.-Y. Nie, A. Braud, P. Camy, V. Petrov, and W. Chen; Growth, spectroscopy and SESAM mode-locking of a “mixed” Yb:Ca(Gd,Y)AlO_4 disordered crystal; Opt. Express

ZDZ: C. Zheng, T. Du, L. Zhu, Z. Wang, K. Tian, Y. Zhao, Z. Yang, H. Yu, and V. Petrov; Direct amplification of femtosecond optical vortices in a single-crystal fiber; Photonics Res.

XCH: B. Xu, Z. Chen, T. W. Haensch, and N. Picqué; Near-ultraviolet photon-counting dual-comb spectroscopy; Nature

Submitted

ELL: K. Eremeev, P. Loiko, S. Li, C. Zhao, Y. Hang, Z.-L. Lin, G. Zhang, X. Mateos, G. Z. Elabedine, P. Camy, A. Braud, U. Griebner, V. Petrov, and W. Chen; Growth, spectroscopy and laser operation of Tm,Ho:$GdScO_3$ perovskite crystal; Opt. Express

ESI: G. Exner, P. G. Schunemann, E. Ivanova, A. Grigorov, and V. Petrov; Nanohardness and Young’s modulus of II-IV-V_2 chalcopyrite nonlinear optical crystals; Opt. Mater. Express

FBM: B. Fetić, W. Becker, and D. B. Milošević; Can we measure the Wigner time delay in a photoionization experiment?; Phys. Rev. Lett.

GLS: K. Gerlinger, R. Liefferink, M. Schneider, L.-M. Kern, C. Klose, D. Metternich, D. Engel, F. Capotondi, D. D. Angelis, M. Pancaldi, E. Pedersoli, F. Büttner, S. Eisebitt, J. H. Mentink, and B. Pfau; Robust scenario for the generation of non-equilibrium topological fluctuation states; Phys. Rev. Lett.

GLZ: J. Guo, S. Li, C. Zhao, Y. Hang, H.-J. Zeng, Z.-L. Lin, G. Zhang, G. Z. Elabedine, X. Mateos, P. Loiko, X. Liang, V. Petrov, W. Chen, and X. Liang; SESAM mode-locked Yb:$GdScO_3$ laser; Opt. Express

HKY: M. Hennecke, C. von Korff Schmising, K. Yao, E. Jal, B. Vodungbo, V. Chardonnet, K. Légaré, F. Capotondi, D. Naumenko, E. Pedersoli, I. Lopez-Quintas, I. P. Nikolov, L. Raimondi, G. D. Ninno, L. Salemi, S. Ruta, R. Chantrell, T. Ostler, B. Pfau, D. Engel, P. M. Oppeneer, S. Eisebitt, and I. Radu; Ultrafast Opto-magnetic effects in the extreme ultraviolet spectral range; Commun. Phys.

JGB: P. Jürgens, C. L. Garcia, P. Balling, T. Fennel, and A. Mermillod-Blondin; Diagnostics of fs laser-induced plasma in solid dielectrics; Laser Photon. Rev.

KSV: M. Kretschmar, E. Svirplys, M. Volkov, T. Witting, T. Nagy, M. J. J. Vrakking, and B. Schütte; Compact realization of all-attosecond pump-probe spectroscopy; Sci. Adv.

LZL: Z.-L. Lin, H.-J. Zeng, P. Loiko, V. Petrov, X. Mateos, Z. Pan, G. Zhang, and W. Chen; Kerr-lens mode-locking of an Yb:SALLO laser generating 25 fs pulses at 1090 nm; Opt. Lett.

OSm: A. F. Ordonez and O. Smirnova; On the molecular information revealed by photoelectron angular distributions of isotropic samples; Phys. Rev. A

PKM: V. Petrov, K. Kato, and K. Miyata; Barium chalcogenides for nonlinear optics in the mid-IR: properties and applications; Opt. Mater.

PWE: V. Petrov, L. Wang, G. Exner, S. R. Vangala, A. Grigorov, E. Ivanova, P. G. Schunemann, and V. L. Tassev; Transmission and nanohardness studies of ternary $GaAs_{1-x}P_x$ layers grown from the vapor phase by heteroepitaxy; Opt. Mater.

SJM: P. S. Sneftrup, P. Jürgens, V. d. Michele, J. R. C. Andrade, M. J. J. Vrakking, P. Balling, and A. Mermillod-Blondin; Probing nonlinear excitation conditions: Photoluminescence and nonlinear absorption studies in laser-irradiated dielectrics; Appl. Phys. A

TMWa: T. Temel, R. T. Murray, L. Wang, W. Chen, A. Schirrmacher, R. A. Battle, and V. Petrov; Narrowband-seeded PPLN non-resonant optical parametric oscillator; Opt. Mater.

TMWb: T. Temel, R. T. Murray, L. Wang, W. Chen, A. Schirrmacher, I. B. Divliansky, O. Mhibik, L. B. Glebov, and V. Petrov; Energy scaling of a narrowband, periodically-poled $LiNbO_3$, nanosecond, non-resonant optical parametric oscillator; Appl. Opt.

YWS: C.-J. Yang, M. Woerner, O. Stockert, H. v. Löhneysen, J. Kroha, M. Fiebig, and S. Pal; Kondo coherence versus superradiance in THz radiation-driven heavy-fermion systems; Phys. Rev. B

General Publications

Bachelor, Master and PhD Theses

Bachelor Theses

Kor23: K. Korell; Bestimmung der transversalen Kohärenzlänge einer laser-getriebenen Weichröntgenquelle (Supervisor: S. Eisebitt), Technische Universität Berlin

Master Theses

Beh23: R. Behrends; *Ultrafast magnetization dynamics probed by linear polarized soft X-rays* (Supervisor: S. Eisebitt), Technische Universität Berlin

Li23: M. Li; *Optimierung von CoFeB-basierten Multilagensystemen zur Erzeugung von Skyrmionen* (Supervisor: S. Eisebitt), Technische Universität Berlin

Li23: X. Li; *Optical characterization of semiconductor saturable absorber mirrors* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

Loh23: A. G. Löhr; *Pulse compression by coherently rotating molecules* (Supervisors: M. Y. Ivanov and M. Khokhlova), Humboldt-Universität zu Berlin

Ma23: Y. Ma; *Carrier-envelope phase stabilization of a Cr:ZnS laser oscillator* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

Mol23: A. Molodtsova; *Ultrafast Dynamics of Spin-Profiles in Ferromagnetic Nanostructures followed by XUV Reflectometry* (Supervisor: S. Eisebitt), Technische Universität Berlin

Ven23: S. Vengaladas; *Optimized entanglement of two-photon light in photonic topological insulators* (Supervisor: K. Busch), Humboldt-Universität zu Berlin

Yi23: S. Yi; *Extreme quantum optics: Generation of quantum light in intense light-matter interaction* (Supervisors: M. Y. Ivanov and G. Steinmeyer), Humboldt-Universität zu Berlin

PhD theses

Bor23: M. Borchert; *Accessing magnetic order with a randomly polarised laser-driven plasma soft X-ray source* (Supervisor: S. Eisebitt), Technische Universität Berlin

Fue23: P. Fuertjes; *Compact few-cycle mid-wave and long-wave infrared OPCPA* (Supervisor: T. Elsaesser), Humboldt-Universität zu Berlin

Ger23: K. Gerlinger; *Nanometer scale observation of magnetization textures induced by ultrashort laser pulses* (Supervisor: S. Eisebitt), Technische Universität Berlin

Ker23: L.-M. Kern; *Controlled Manipulation of Magnetic Skyrmions: Generation, Motion and Dynamics* (Supervisor: S. Eisebitt), Technische Universität Berlin

Kle23: C. Kleine; *Ultrafast soft x-ray absorption spectroscopy of molecular systems in the water window with table-top high-order harmonic sources* (Supervisor: T. Elsaesser), Humboldt-Universität zu Berlin

May23: N. Mayer; *Ultrafast spectroscopy and control of quantum dynamics in tailored multicolor laser fields* (Supervisor: M. Y. Ivanov), Humboldt-Universität zu Berlin

Oss23: M. Osswald; *Energetic and microscopic characterization of the primary electron transfer reaction in the (6-4) photolyase repair reaction* (Supervisors: K. Busch and B. P. Fingerhut), Humboldt-Universität zu Berlin

Appendix 2

External Talks, Teaching

Invited lectures at conferences

K. Amini; IMAMPC 2023 (Innsbruck, Austria, 2023-06): *High repetition rate ultrafast electron diffraction*

D. Ayuso; Control of Ultrafast (Attosecond and Strong Field) Processes Using Structured Light (MPI-PKS, Dresden, 2023-07): *Tailoring light's polarisation for efficient chiral recognition on ultrafast timescales*

W. Becker; Quantum Battles in Attoscience 2023 (London, UK, 2023-06): *Rescattering quantum orbits with negative travel time*

K. Busch; DisoMAT 2023 conference (Plankstetten, Germany, 2023-06): *Modeling surface roughness: Application to plasmonic nanostructures*

K. Busch; PIERS 2023 conference (Prague, Czech Republic, 2023-07): *Models and the computation of atom-surface interactions*

S. Carlström; CAS Workshop: Molecular quantum dynamics (Oslo, Norway, 2023-05): *Photoionization spectra from (atoms &) small molecules*

S. Carlström; AttoChem Annual Meeting (Szeged, Hungary, 2023-09): *Spin-polarized photoelectrons generated by linearly & circularly polarized light*

U. Eichmann; Int. Workshop on Atomic Physics (MPI-PKS, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany, 2023-11): *Two-color stimulated Raman transitions in the XUV and soft x-ray range*

S. Eisebitt; X. Int. Symposium "Ultrafast Dynamics & Ultrafast Bandgap Photonics" (Hersonissos, Crete, Greece, 2023-06): *State of the art in soft x-ray lab sources: Probing magnetization dynamics with atomic selectivity in the femto- to picosecond range*

S. Eisebitt; GRC, "Spin Dynamics in Nanostructures" Gordon Research Conference (Les Diablerets Conference Center, Switzerland, 2023-07): *Coherent correlation imaging - a new approach to image stochastic dynamics in matter*

S. Eisebitt; Polish XFEL Hub Conference (Warszawa, Poland, 2023-09): *Ultrafast Birth and Death of Magnetic Skyrmions: Insight with XFEL pulses*

F. J. Furch; CLEO 2023 (San José, CA, USA, 2023-05): *An Overview of OPCPA, tutorial*

U. Griebner *together with* P. Fuertjes, M. Bock, and T. Elsaesser; X. Int. Symposium "Ultrafast Dynamics & Ultrafast Bandgap Photonics" (Hersonissos, Crete, Greece, 2023-06): *High energy few-cycle pulses around 12 µm for nonlinear spectroscopy in the longwave-infrared*

U. Griebner *together with* M. Bock, D. Ueberschaer, and P. Fuertjes; European Optical Society Annual Meeting (EOSAM) 2023 (Dijon, France, 2023-09): *Single-stage GaSe OPCPA delivering high-energy few-cycle pulses at 11 µm wavelength*

U. Griebner *together with* M. Bock, L. von Grafenstein, P. Fuertjes, A. Koç, M. Woerner, and T. Elsaesser; UltrafastX 2023: The 2nd Int. Conference on UltrafastX and 3rd Youth Forum on Ultrafast Science (Xi'an, China, 2023-11): *Generation of high-energy few-cycle laser pulses via OPCPA in the midwave and longwave infrared spectral region and their applications*

M. Hennecke; SXR2023, Principles of Functionality from Soft X-ray Spectroscopy Conference (Berlin, Germany, 2023-09): *Ultrafast element- and depth-resolved magnetization dynamics probed by transverse magneto-optical Kerr effect spectroscopy in the soft x-ray range*

A. Husakou; X. Int. Symposium "Ultrafast Dynamics & Ultrafast Bandgap Photonics" (Heronissos, Crete, Greece, 2023-06): *Linking high-harmonic generation and strong-field ionization in bulk crystals*

M. Y. Ivanov; The Frontiers of Attosecond and Ultrafast X-ray Science (Erice, Sicily, Italy, 2023-03): *Fundamentals of strong field ionization*

M. Y. Ivanov; The Frontiers of Attosecond and Ultrafast X-ray Science (Erice, Sicily, Italy, 2023-03): *Fundamentals of high harmonic generation: microscopic response*

M. Y. Ivanov; DPG Spring conference (Hanover, Germany, 2023-03): *Lightwave electronics in trivial, topological, and strongly correlated solids*

M. Y. Ivanov; OPTOlogic EU Meeting (Benasque, Spain, 2023-03): *Applications of structured light to control topology and valley selectivity in 2D solids*

M. Y. Ivanov; Non-Eqilibrium Dynamics of Condensed Matter (Ma'ale Hahamisha, Israel, 2023-04): *Sub-cycle quantum control of electron dynamics in "simple" and correlated solids*

L.-M. Kern; Young Research Leaders Group Workshop: Recent advances in non-equilibrium and magnetic phenomena (SPICE) (Ingelheim, Germany, 2023-07): *Controlling magnetic skyrmions: Generation, motion and dynamics*

L.-M. Kern; Soft X-ray Science at PETRA (Ingelheim, Germany, 2023-11): *Controlling magnetic skyrmions: Generation, motion and dynamics*

M. Khokhlova; PQE-23 Conference (Physics of Quantum Electronics) (Snowbird, Utah, USA (virtual), 2023-01): *Enantiosensitive steering of free-induction decay*

L.-M. Koll *together with* L. Maikowski, L. Drescher, T. Witting, and M. J. J. Vrakking; APS DAMOP (Spokane, USA, 2023-06): *Control of ion+photoelectron entanglement in attosecond experiments*

L.-M. Koll *together with* L. Maikowski, L. Drescher, T. Witting, and M. J. J. Vrakking; Atto 9 conference (Jeju, Republic of Korea, 2023-07): *Control of ion+photoelectron entanglement in attosecond science*

C. von Korff Schmising; Magnetofon Conference (Egmond aan Zee, The Netherlands, 2023-03): *Intrinsic vs. induced magnetic moment in ultrafast demagnetization dynamics*

C. von Korff Schmising; Intermag 2023 (Sendai, Japan, 2023-05): *Experimental evidence of ultrafast magnon generation in laser driven demagnetization*

C. von Korff Schmising; MagIC+ Magnetism, Interactions and Complexity (Poznan, Poland, 2023-07): *Ultrafast and ultrasmall: all-optical switching of magnetization*

C. von Korff Schmising; Int. Workshop "3rd WavemiX 2023" (Freiburg, Germany, 2023-09): *Exploring the role of ultrafast energy transport in nanoscale magnetization switching*

C. von Korff Schmising; NTP: Nanoscale Transport Phenomena Workshop (Trieste, Italy, 2023-11): *Exploring the role of ultrafast energy transport in nanoscale magnetization switching*

F. Morales; Control of Ultrafast (Attosecond and Strong Field) Processes Using Structured Light (MPI-PKS, Dresden, 2023-07): *Spin Polarization: from analytical predictions to multi-electron calculations*

E. T. J. Nibbering *together with* C. Kleine, M.-O. Winghart, Z.-Y. Zhang, M. Richter, M. Ekimova, S. Eckert, M. J. J. Vrakking, and A. Rouzée; $N2^+$ Workshop (Palaiseau, France, 2023-05): *Ultrafast N K-edge spectroscopy of strong field ionization and fragmentation dynamics of molecular nitrogen*

E. T. J. Nibbering *together with* M. Ekimova, C. Kleine, J. Ludwig, M. Ochmann, T. E. G. Agrenius, E. Kozari, D. Pines, E. Pines, N. Huse, Ph. Wernet, and M. Odelius; BESSY@HZB User Meeting 2023 (Berlin, Germany, 2023-06): *From local covalent bonding to extended electric field interactions in proton hydration*

E. T. J. Nibbering *together with* M.-O. Winghart, D. Rana, Z.-Y. Zhang, P. Han, C. Kleine, S. Das, D. Garratt, A. Cordones-Hahn, K. Kunnus, E. Ryland, J. Koralek, D. DePonte, M. Fondell, R. Mitzner, R. Jay, K. Gaffney, E. Pines, G. Dakovski, Ph. Wernet, and M. Odelius; SXR2023 - Principles of Functionality from Soft X-ray Spectroscopy Conference (Berlin, Germany, 2023-09); *Ultrafast proton transport probed with soft-X-ray spectroscopy*

S. Patchkovskii; SMART-X 3rd annual Symposium (Paris, France, 2023-04): *Electron-nuclear correlations in attosecond and strong-field dynamics*

V. Petrov; OPIC Optics & Photonics Int. Congress 2023 (Yokohama, Japan, 2023-04): *Tm and Ho host materials for sub-100 fs mode-locked 2-micron lasers*

V. Petrov; TILA-LIC'23 - The 9th Tiny Integrated Laser and Laser Ignition Conference (Yokohama, Japan, 2023-04): *Structured materials for micro lasers at 2 microns*

V. Petrov; CLEO Europe-EQEC (ICM Munich, Germany, 2023-06): *Towards few-optical-cycle generation from Thulium/Holmium mode-locked lasers*

V. Petrov; IS-OM'9 (Tarragona, Spain, 2023-06): *Acentric Barium chalcongenides for nonlinear optics in the mid-IR*

V. Petrov; 14th CIOP Conference (Conference on Information Optics and Photonics) (Xi'an, China, 2023-08): *Essential properties of Tm and Ho host materials for Sub-100-fs Mode-Locked 2-μm lasers*

V. Petrov; EOSAM - European Optical Society Annual Meeting (Dijon, France 2023-09): *Polarization-anisotropy of mid-infrared emission properties of* Er^{3+} *ions in* $YAlO_3$ *crystal*

V. Petrov; 2023 Pacific Rim Laser Damage (Shanghai, China 2023-10): *Barium chalcogenides for mid-IR nonlinear optics*

B. Pfau; MAX IV Laboratory – Science Advisory Committee (Lund, Sweden (virtual), 2023-09): *Coherent soft-x-ray imaging of magnetic and polar nanotexture at MAX IV*

M. Richter *together with* M. Lytova, F. Morales, S. Haessler, O. Smirnova, M. Spanner, and M. Y. Ivanov; AttoChem YSS 2023 (Vienna, Austria, 2023-09): *Towards remote air lasing by efficient generation of population inversion in molecular nitrogen ions*

B. Schütte; AttoChem 2023 (Szeged, Hungary, 2023-09): *Two-color all-attosecond pump-probe spectroscopy at 1 kHz*

B. Schütte; Optica Webinar (online, 2023-10): *All-attosecond pump-probe spectroscopy*

S. Sharma; DPG-Frühjahrstagung 2023 of the Condensed Matter Section, FV Magnetismus (Dresden, Germany, 2023-03): *Femto-phono-magnetism*

S. Sharma; APS March Meeting 2023 (virtual, 2023-03): *Femto-phono-magnetism*

S. Sharma; Quantum Battles in Attoscience 2023 (London, UK, 2023-06): *Femto-phono-magnetism*

O. Smirnova; The 53rd Winter Colloquium on the Physics of Quantum Electronics (Snowbird, Utah, USA, 2023-01): *Ultrafast chirality: twisting light to twist electrons*

O. Smirnova; DPG-Frühjahrstagung (Dresden, Germany, 2023-03): *Sub-Cycle multidimensional spectroscopy of strongly correlated materials*

O. Smirnova; Int. Workshop on Non-Equilibrium Dynamics of Condensed Matter (Ma'ale Hahamisha, Israel, 2023-04): *Sub-Cycle multidimensional spectroscopy of strongly correlated materials*

O. Smirnova; Quantum Battles in Attoscience 2023 (London, UK, 2023-06): *Tutorial: Chirality, symmetry, and tailored fields*

O. Smirnova; Control of Ultrafast (Attosecond and Strong Field) Processes Using Structured Light (MPI-PKS, Dresden, 2023-07): *Ultrafast chirality and geometric fields in chiral molecules*

O. Smirnova; Control of Ultrafast (Attosecond and Strong Field) Processes Using Structured Light (MPI-PKS, Dresden, 2023-07): *Sub-cycle, multi-dimensional spectroscopy of strongly correlated 2D materials*

O. Smirnova; 7th Int. Symposium on Intense Field, Short Wavelength Atomic and Molecular Processes (ISWAMP), A Satellite Meeting to ICPEAC 2023 (St. Sauveur, Québéc, Canada, 2023-07): *Ultrafast molecular chirality: a topological connection*

O. Smirnova; PHOTONICA 2023, IX Int. School and Conference on Photonics (Belgrade, Serbia, 2023-08): *Ultrafast chirality: efficient dynamical approaches to chiral discrimination*

O. Smirnova; Nobel Symposium NS172 - Attosecond Science and Technology (Lund University, Sweden, 2023-08): *Ultrafast chirality: from topological connection to charge-directed reactivity*

O. Smirnova; MITP Workshop: Twisted Light in Quantum and Sub-Atomic Systems (Mainz, Germany, 2023-09): *Ultrafast chirality: a topological connection*

G. Steinmeyer; IEEE Photonics Society Summer Topicals Meeting Series 2023 (Giardini-Naxos, Sicily, Italy, 2023-07): *Fixing entropy loopholes in multimode fiber thermodynamics*

H. Stiel; SPIE Optics+Optoelectronics 2023 (Prague, Czech Republic 2023-04): *Soft X-ray absorption spectroscopy in the lab using laser-based sources and novel eflection zone-plate optics*

H. Stiel; 18th Int. Conference on X-Ray Lasers 2023 (ICXRL) (Jiao Tong University, Tsung-Dao Lee Inst., Shanghai, China, 2023-07): *Laboratory based sources, optics and detectors for ultrafast soft X-ray spectroscopy in the water window and at transition metal L-edges*

C. Tzschaschel; DPG-Frühjahrstagung (Dresden, Germany, 2023-03): *Optical control of antiferromagnetism*

M. J. J. Vrakking; The Frontiers of Attosecond and Ultrafast X-ray Science (Erice, Sicily, Italy, 2023-03): *Attosecond molecular science*

M. J. J. Vrakking; Quantum Battles in Attoscience (University College, London, UK, 2023-06): *Control of attosecond entanglement coherence*

M. J. J. Vrakking; RAP Advisory Council meeting (RIKEN Wako Campus, Tokyo, Japan, 2023-06): *Control of attosecond entanglement coherence*

M.-O. Winghart *together with* C. Kleine, Z.-Y. Zhang, M. Richter, M. Ekimova, S. Eckert, E. R. Grant, M. J. J. Vrakking, E. T. J. Nibbering, and A. Rouzée; SXR2023 - Principles of Functionality from Soft X-Ray Spectroscopy (Berlin, Germany, 2023-09): *Tabletop ultrafast soft-x-ray spectroscopy in the gaseous and liquid phases*

Invited external talks at seminars and colloquia

K. Amini; Seminar (MPI Heidelberg, Germany, 2023-10): *High repetition rate ultrafast electron diffraction*

K. Amini; Seminar (University of Oxford, UK, 2023-10): *High repetition rate ultrafast electron diffraction*

G. Brown; Int. seminar on ultrafast dynamics with structured light (Dresden, Germany, 2023-06): *High harmonic generation in solids: a real-space perspective*

K. Busch; Nanooptics and polariton physics 2023 (Odense, Denmark, 2023-06): *Atom-surface interactions: Theory and computations*

U. Eichmann, Seminar (MPQ, Max Planck Institute of Quantum Optics, Garching, Germany, 2023-05): *Atomic excitation in strong laser fields from the optical to the soft x-ray regime*

P. Fuertjes, Laserkolloquium (Universität Bochum, Germany, 2023-04): *Generation of ultrashort laser pulses via OPCPA in the infrared spectral region*

U. Griebner, Seminar (Ningbo University, Physics Department, Ningbo, China 2023-11): *High-energy few-cycle pulses generation beyond 4 µm wavelength*

U. Griebner, Seminar (Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, Fuzhou, China, 2023-11): *High-energy few-cycle pulse generation in the mid-IR and its applications*

U. Griebner, Lecture (Jiangsu Key Laboratory of Advanced Laser Materials and Devices, Jiangsu Normal University, Xuzhou, China, 2023-11): *Generation of high-energy few-cycle pulses in the mid-IR and its applications*

M. O. S. Guzman *together with* M. J. J. Vrakking, E. T. J. Nibbering, and A. Rouzée; SMART-X symposium (Paris, France, 2023-07): *Ultrafast charge carrier dynamics in oxide semiconductors by time resolved XUV absorption spectroscopy*

A. Husakou; COST Action TUMIEE, final meeting (Serbian Academy of Sciences and Arts, Belgrade, Serbia, 2023-02): *Tunable Near-UV pulses by a transient plasmonic resonance*

M. Y. Ivanov; N2+ Air Laising workshop at LOA and Ecole Politechnique (Palaiseau, France, 2023-05): *Nitrogen lasing during laser filamentation in the air*

M. Y. Ivanov; Int. seminar on ultrafast dynamics with structured light (Dresden, Germany, 2023-06): *Control of ultrafast processes using structured light*

A. Jimenéz-Galán; Int. seminar on ultrafast dynamics with structured light (Dresden, Germany, 2023-06): *Lightwave control of topological properties in 2D semiconductors*

P. Jürgens; Seminar (University of Aarhus, Denmark, 2023-11): *Exploring High-Harmonic Generation in solids: From fundamentals to applications*

L.-M. Kern; 776. WE-Heraeus-Seminar: Re-thinking Spintronics: From Unconventional Materials to Novel Technologies (Bad Honnef, Germany, 2023-01): *Imaging nanometer-scale skyrmion (de)formation dynamics*

L.-M. Kern; Sol-SkyMag 2023 (San Sebastian, Spain, 2023-03): *Imaging nanometer scale Skyrmion (de)formation dynamics*

M. Khokhlova; Int. seminar on ultrafast dynamics with structured light (CUPUSL) (Dresden, Germany, 2023-06): *Steering of free-induction decay in a chiral fashion*

M. Khokhlova; 31st Annual Int. Laser Physics Workshop (LPHYS'23) (online, 2023-07): *From high-harmonic generation to high-order frequency mixing*

C. von Korff Schmising, TRR 227 Retreat, "Ultrafast Spin Dynamics" (Potsdam, Germany, 2023-10): *Ultrafast spin dynamics in metal heterostructures*

C. von Korff Schmising, TRR 227 Retreat, "Ultrafast Spin Dynamics" (Potsdam, Germany, 2023-10): *Exploring the fundamental spatial limits of all optical switching*

C. von Korff Schmising, Seminar "2D magnetic materials and heterostructures" (Paul Drude Institut, Berlin, Germany, 2023-12): *Ultrafast magnetization dynamics probed by transient spectroscopy in the extreme ultraviolet spectral range: recent results and prospects for 2D materials*

O. Kornilov; Quantum dynamics and spectroscopy of functional molecular materials and biological photosystems (Workshop) (Les Houches, France, 2023-09): *Electronic structure and excited state reactions of aqueous aminoazobenzenes studied by time-resolved XUV photoelectron spectroscopy*

N. Mayer; Int. seminar on ultrafast dynamics with structured light (Dresden, Germany, 2023-06): *Chiral vortex light for detecting robust enantiosensitive observables*

E. T. J. Nibbering, Photon Science Seminar (SLAC, Stanford, CA, USA, 2023-): *Ultrafast structural dynamics of elementary water-mediated proton transport processes*

S. Patchkovskii; RTG DYNCAM seminar (Freiburg, Germany, 2023-01): *Electron-nuclear correlations in attosecond and strong-field dynamics*

S. Patchkovskii; CFEL Molecular and Ultrafast Science seminar (Hamburg, Germany, 2023-02): *Electron-nuclear correlations in attosecond and strong-field dynamics*

S. Patchkovskii; Int. seminar on ultrafast dynamics with structured light (Dresden, Germany, 2023-06): *Theory of nuclear motion in RABBITT spectra*

S. Patchkovskii together with F. Morales; COST/ZCAM school (Zaragoza, Spain, 2023-06): *Calculation of (static) strong-field ionization rates in many-electron systems: a quantum-chemistry perspective*

V. Petrov; Seminar for research staff and PhD students at Xinjiang Technical Institute of Physics and Chemistry, CAS (Urumqi, China, 2023-08): *Nonlinear Barium chalcogenides for the mid-IR*

M. Richter; N2+ Air Laising workshop at LOA and Ecole Politechnique (Palaiseau, France, 2023-05): *Optimizing N2+ lasing in air: Rotational coherence and propagation effects*

M. Richter; Int. seminar on ultrafast dynamics with structured light (Dresden, Germany, 2023-06): *Towards remote air lasing by efficient generation of population inversion in molecular nitrogen ions*

D. Schick; DESY Photon Science Users' Meeting 2023 (DESY, Hamburg, Germany, 2023-01): *Probing electron & hole colocalization*

D. Schick, Seminar (Universität Portsdam, Inst. für Physik und Astronomie, Golm, 2023-02): *Tracing magnetic & structural dynamics in ar-tificial magnetic nanostructures*

D. Schick; 12th Ringberg Meeting on Science with FELs (Ringberg, Germany, 2023-02): *Mixing laser and X-ray beams*

D. Schick, Seminar (Radboud University Nijmegen, The Netherlands, 2023-09): *Following complex spin structures in time & space*

D. Schick, Seminar (Paris Sorbonne, France, 2023-10): *Following complex spin structures in time & space?*

D. Schick, Seminar (Universität zu Köln, Germany, 2023-11): *Following complex spin structures in time & space?*

B. Schütte; Seminar (ETH Zürch, Switzerland, 2023-03): *Two-color attosecond-pump attosecond-probe spectroscopy at 1 kHz*

S. Sharma, TRR 227 Retreat, “Ultrafast Spin Dynamics” (Potsdam, Germany, 2023-10): *Light dressed excitons: why they do what they do*

G. Steinmeyer, Seminar (Beijing University of Science and Technology, China, 2023-09): *Fixing entropy loopholes in multimode fiber thermodynamics*

G. Steinmeyer, Seminar (Tianjin University, China, 2023-09): *Fixing entropy loopholes in multimode fiber thermodynamics*

G. Steinmeyer, Kolloquium (Humboldt-Universität zu Berlin, Germany, 2023-10): *The 2023 Nobel Prize in physics: experimental methods that generate attosecond pulses of light*

C. Tzschaschel, Seminar (Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany, 2023-11): *Optical control of antiferromagnetism*

M. Volkov; Quantum Engineering at IMEC, Seminar (Leuven, Belgium, 2023-09): *Femtosecond electron beam probe of ultrafast electronics*

M. J. J. Vrakking; SPP Initiative (Max Born Institute, Berlin, Germany, 2023-03): *Control of attosecond entanglement coherence*

Academic Teaching

K. Amini, Vorlesung, 4 SWS (Freie Universität Berlin, SS 2023): *Advanced Atomic and Molecular Physics*

K. Busch, *together with* O. Benson, A. Peters, A. Saenz, S. Ramelow, F. Intravaia, M. Krutzik, J. Volz, and P. Schneeweiß; Seminar, 2 SWS (Humboldt-Universität zu Berlin, SS 2023): *Optik/Photonik: Projekt und Seminar*

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, SS 2023): *Computerorientierte Photonik*

K. Busch, Vorlesung und Tutorium, 4 SWS (Humboldt-Universität zu Berlin, SS 2023): *Theoretische Physik I Klassische Mechanik und Spezielle Relativitätstheorie*

K. Busch, *together with* O. Benson, A. Peters, A. Saenz, S. Ramelow, F. Intravaia, M. Krutzik, J. Volz, and P. Schneeweiß; Seminar, 2 SWS (Humboldt-Universität zu Berlin, WS 2023/2024): *Optik/Photonik: Projekt und Seminar*

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, WS 2023/2024): *Nicht-Hermitesche Photonik*

K. Busch, Vorlesung und Tutorium, 6 SWS (Humboldt-Universität zu Berlin, WS 2023/2024): *Theoretische Physik II Elektrodynamik*

U. Eichmann, Vorlesung, 2 SWS (Technische Universität Berlin, WS 2022/23): *Höhere Atomphysik*

S. Eisebitt, *together with* B. Kanngießer, B. Pfau, and C. von Korff Schmising; Vorlesung und Übungen, 4 SWS (Technische Universität Berlin, Institut für Optik und Atomare Physik, WS 2022/23): *Röntgenphysik I*

S. Eisebitt, *together with* B. Kanngießer; Vorlesung und Übungen, 4 SWS (Technische Universität Berlin, Institut für Optik und Atomare Physik, SS 2023): *Röntgenphysik II*

V. Petrov, Vorlesung für PhD Studenten, (FJIRSM, CAS, Fuzhou, China, 16.08./SS 2023): *Solid-State Lasers (SSL)*

V. Petrov, Vorlesung für PhD Studenten, 8 (Shandong University, Jinan, China, 23.08./SS 2023): *Solid-State Lasers (SSL)*

O. Smirnova, *together with* U. Woggon; Vorlesung und Übungen, (Technische Universität Berlin, Institut für Optik und Atomare Physik, SS 2023): *Attosecond Physics*

G. Steinmeyer, Vorlesung, 4 SWS (Humboldt-Universität zu Berlin, WS 2022/23): *Physik III Optik*

G. Steinmeyer, Tutorial, 2 SWS (Humboldt-Universität zu Berlin, WS 2022/23): *Physik III Optik*

G. Steinmeyer, Vorlesung, 4 SWS (Humboldt-Universität zu Berlin, SS 2023): *Physik ultraschneller Prozesse (Kurzzeitspektroskopie)*

G. Steinmeyer, Übung, 2 SWS (Humboldt-Universität zu Berlin, SS 2023): *Physik Ultraschneller Prozesse (Ultrakurzzeitspektroskopie)*

G. Steinmeyer, Vorlesung, 4 SWS (Humboldt-Universität zu Berlin, WS 2023/24): *Physik III Optik*

G. Steinmeyer, Tutorial, 2 SWS (Humboldt-Universität zu Berlin, WS 2023/24): *Physik III Optik*

M. J. J. Vrakking, Vorlesung und Übung, 3 SWS (Freie Universität Berlin, WS 2023/2024): *Ultrafast Laserphysics*

General talks (popular, science politics etc.)

M. Hennecke; „Technologie-Dialog Analytik“ Networking-Event der IGAFA (Berlin, Germany, 2023-10): NanoMovie - Applikationslabor: Zeitaufgelöste Spektroskopie mit XUV- und weicher Röntgenstrahlung

T. Elsaesser
Vortrag: Was ist Quantentechnologie? Die physikalische Sicht; Gymnasium Templin, Templin, 07.02.23 Neues Gymnasium Glienicke, Glienicke/Nordbahn, 14.02.23; Leibniz-Gymnasium, Potsdam-Golm, 18.12.23

T. Elsaesser
Vortrag: Licht und Materie - kann man Atome sichtbar machen?; Gymnasium der Bundtstift Schulen, Strausberg, 22.02.23; Freies Joachimsthaler Gymnasium, Joachimsthal, 13.12.23

T. Elsaesser
Vortrag: Kommunizieren mit Licht – die Physik des Internets; Wolkenberg Gymnasium Michendorf, Michendorf, 09.01.23; von Saldern Gymnasium, Brandenburg an der Havel, 23.01.23; Johann-Wolfgang-von-Goethe-Gymnasium Pritzwalk, Pritzwalk, 25.01.23; Emil-Fischer-Gymnasium, Schwarzheide, 26.01.23; Goethe-Schiller-Gymnasium Jüterbog, Jüterbog, 10.02.23; Evangelische Johanniter-Schulen Wriezen – Gymnasium, Wriezen, 28.02.23; Oberstufenzentrum Lausitz/Abteilung 1, Schwarzheide, 24.05.23; Kurt-Tucholsky-Schule, Berlin-Pankow, 08.12.23

Appendix 3
Ongoing Bachelor, Master, and PhD theses

Bachelor theses

V. I. Iwanaga: *Neural networks for low-noise ultrashort pump-probe spectroscopy (*Supervisor: S. Eisebitt), Technische Universität Berlin

R. E. Rochus; (Supervisor: S. Eisebitt), Technische Universität Berlin

Master theses

S. Gautam; *Pump-probe measurements on saturable absorber mirrors* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

J. Hofrichter; *Supercontinuum generation in bulk crystals at 2.4 µm wavelength* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

K. Korell; *X-ray magnetic circular dichroism with a picosecond laser-driven plasma source* (Supervisor: S. Eisebitt), Technische Universität Berlin

J. Lu; *Carrier-envelope phase stabilization of a Cr:ZnS oscillator* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

J. Nonbo; *Femtosecond soft x-ray absorption spectroscopy on metal oxide semiconductors* (Supervisors: M. J. J. Vrakking and M. Wolf), Freie Universität Berlin

N. Schneider; *Time-resolved magnetic small angle X-ray scattering using a laser-driven plasma source* (Supervisor: S. Eisebitt), Technische Universität Berlin

Wu, Ruikai; *Light matter coupling at partial dislocations* (Supervisor: S. Sharma), Freie Universität Berlin

PhD theses

Bender; *Modeling of non-linear and active material in interaction with plasmonic nanostructures* (Supervisor: K. Busch), Humboldt-Universität zu Berlin

M. Guzmán; *Ultrafast charge carrier dynamics in oxide semiconductors by time-resolved soft x-ray absorption spectroscopy* (Supervisor: M. Vrakking), Freie Universität Berlin

R. Heilemann; (Supervisor: O. Smirnova), Technische Universität Berlin

J. Jarecki; *Spatially resolved femtosecond spin dynamics at functionalized interfaces of magnetic heterostructures* (Supervisor: S. Eisebitt), Technische Universität Berlin

N. Klimkin; *Attosecond electron dynamics in light-driven solids* (Supervisor: M. Y. Ivanov), Humboldt-Universität zu Berlin

C. Klose; *Mesoscale Magnetization Dynamics* (Supervisor: S. Eisebitt), Technische Universität Berlin

L.-M. Koll; *2D XUV Spectroscopy* (Supervisor: M. J. J. Vrakking, and G. Sansone), Freie Universität Berlin

A. G. Löhr; (Supervisor: M. Y. Ivanov), Humboldt-Universität zu Berlin

P. M. Maier; (Supervisor: O. Smirnova), Technische Universität Berlin

L. Rammelt; *Direct laser writing of photonic chips for applicators in the classical and quantum regime* (Supervisor: M. Vrakking), Freie Universität Berlin

J. Richter*; Exploring all optical magnetization switching by ultrafast extreme ultraviolet spectroscopy* (Supervisor: S. Eisebitt), Technische Universität Berlin

F. A. Rodriguez Diaz; *Development of a high-repetition rate, short pulse ultrafast electron diffraction set-up for time-resolved structural dynamics* (Supervisor: M. Vrakking), Freie Universität Berlin

A. Roos; (Supervisor: O. Smirnova), Technische Universität Berlin

M. Runge; *Nonlinear terahertz spectroscopy of biomolecules* (Supervisor: T. Elsaesser), Humboldt-Universität zu Berlin

P. Singh; *Ultrafast vibrational probes of electric fields in hydrated molecular systems* (Supervisors: J. Kneipp and T. Elsaesser), Humboldt-Universität zu Berlin

P. Singh; *Time resolved x-ray absorption spectroscopy with HHG-generated soft x-ray pulse* (Supervisor: S. Eisebitt), Technische Universität Berlin

E. Sobolev, *Attosecond-pump attosecond-probe inner-shell spectroscopy* (Supervisor: M. J. J. Vrakking), Freie Universität Berlin

F. Steinbach; *All optical switching in complex magnetic structures* (Supervisor: S. Eisebitt), Technische Universität Berlin

N. Stetzuhn; *Ultrafast Magnetization Dynamics in van der Waals Ferromagnets* (Supervisors: K. Bolotin and S. Eisebitt), Freie Universität Berlin

E. Svirplys; *Entwicklung einer Attosekunden-Plasmalinse* (Supervisor: M. J. J. Vrakking), Freie Universität Berlin

J. Terentjevas; *Chiral topological light for new efficient and robust enantio-sensitive observables* (Supervisor: O. Smirnova), Technische Universität Berlin

S. Yi; *Quantum properties of High Harmonic Generation* (Supervisors: M. Y. Ivanov and G. Steinmeyer), Humboldt-Universität zu Berlin

Z.-Y. Zhang; *Soft X-ray spectroscopy of investigating charge transfer processes in push-pull chromophores* (Supervisor: M. J. J. Vrakking), Freie Universität Berlin

W. Zhao; *Free electron quantum optics* (Supervisor: K. Busch), Humboldt-Universität zu Berlin

Appendix 4

MBI Colloquia and Guest Lectures at the MBI

S. Witte, Advanced Research Center for Nanolithography (ARCNL) and Vrije Universiteit Amsterdam, The Netherlands; Institutskolloquium (Max-Born-Hall, 2023-01-25): *Lensless imaging using high-harmonic generation: Nanoscale imaging of 3D objects (and the HHG source itself)*

O. Kneller, Weizmann Institute of Science, Israel; Seminar (Max-Born-Hall, 2023-02-02): *Dynamical phase measurements via attosecond interferometry*

B. Maingot, Institut Physique de Nice and Fastlite, France; Seminar (Seminar room A, 2023-02-08): *Metrology of nonlinear effects for OPCPA development*

P. Dey, Indian Institute of Technology (IIT) Madras, India; Seminar (virtual, 2023-02-28): *Ultrafast nonlinear light-matter interaction in atomic to nanoscale systems*

K. Ueda, Tohoku University, Sendai, Japan; Lecture series (Max-Born-Hall, 2023-03-09, 03-13, 03-16): *Spectroscopy and dynamics I: From atoms to aggregates*

L. Drescher, University of California, Berkeley, USA and Max Born Institute, Berlin, Germany; Seminar (Seminar room C, 2023-04-18): *Ultrafast carrier relaxation dynamics in solids measured with XUV transient absorption spectroscopy*

J. Limpert, Friedrich Schiller University Jena, Germany; Institutskolloquium (Max-Born-Hall, 2023-04-26): *Ultrafast high-performance fiber lasers for scientific applications*

T. Petit, Helmholtz-Zentrum Berlin, Germany; Seminar (Seminar room C, 2023-04-27): *Intercalation processes in MXenes: from IR to soft X-ray spectroscopies*

S. Flewett, European XFEL, Hamburg, Germany; Seminar (Max-Born-Hall, 2023-05-04): *Modelling of resonant soft X-ray scattering from magnetic multilayers with a view towards the inverse problem*

J. Poon, Max Planck Institute of Microstructure, Halle, Germany; Institutskolloquium (Max-Born-Hall, 2023-05-26): *Lighting up the brain: Wafer-scale integrated photonics for implantable neural interfaces*

H. Pfau, Pennsylvania State University, USA; Seminar (Max-Born-Hall, 2023-06-01): *Nematicity in iron-based superconductors - Insights from strain-dependent ARPES*

A. Liu, Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany; Seminar (Seminar room C, 2023-06-12): *2-D terahertz spectroscopy of cuprate superconductors*

C. Koch, Freie Universität Berlin, Germany; Institutskolloquium (Max-Born-Hall, 2023-07-19): *Quantum control of atoms, molecules and their interaction*

D. Ertel, Albert-Ludwigs-Universität Freiburg, Germany; Seminar A (Seminar room C, 2023-09-26): *Attosecond time-resolved coincidence spectroscopy of methane and deuteromethane*

S. Das, Materials Research Centre, Indian Institute of Science, Bangalore, India; Joint MBI/IKZ Colloquium (Max-Born-Hall, 2023-10-10): *Manipulation and advances of polar topology*

P. Ranitovic, Lawrence Berkeley National Laboratory, Berkeley, USA; Seminar (Max-Born-Hall, 2023-11-14): *Electron holography and coherent control by XUV and IR laser fields – towards coherent quantum clock with a zeptosecond hand*

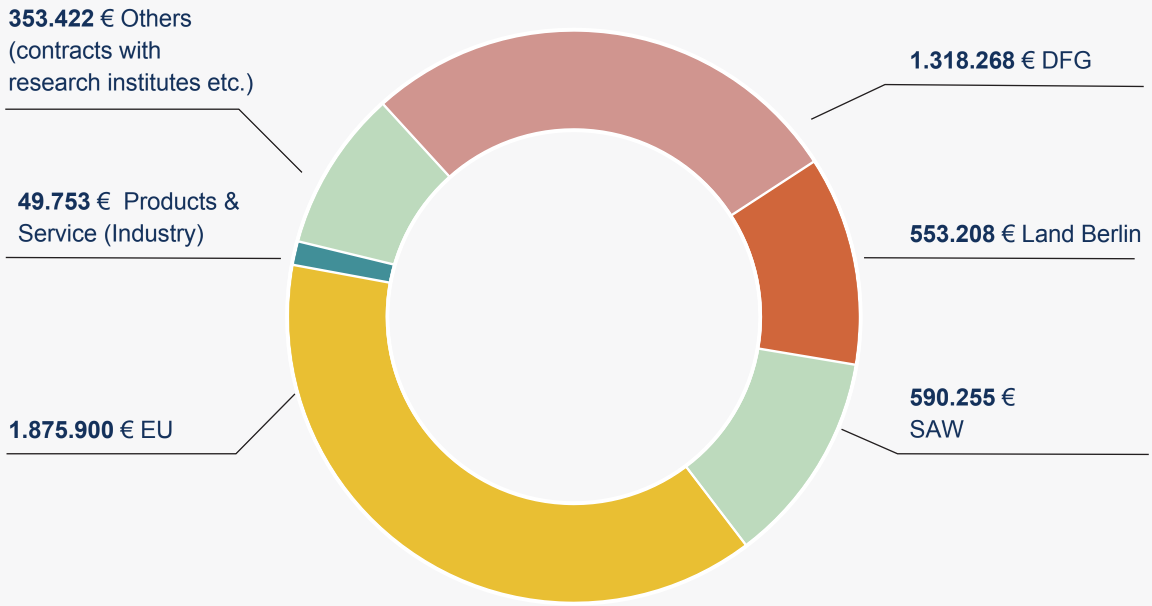
S. Petit, Centre Lasers Intenses et Applications (CELIA), Bordeaux, France; Seminar A (Seminar room A, 2023-11-17): *High power laser development at CELIA*

B. Senfftleben, European XFEL, Hamburg, Germany; Seminar (Max-Born-Hall, 2023-12-05): *Optimization and application of the TPX3CAM for velocity map imaging at the SQS instrument*

J. D. Cox, Southern Denmark University, Denmark; Seminar C (Seminar room C, 2023-12-19): *Nonlinear nanoplasmonics with atomically thin materials*

Appendix 5

Grants and Contracts



Total amount spent in 2023: 4.740.806,00 €

Appendix 6

Activities in Scientific Organizations

W. Becker

Member, Editorial Board, Applied Sciences

Member, Editorial Board Science Open

Member, Editorial Board Laser Physics Letters

K. Busch

Editor-in-chief, Journal of the Optical Society of America B

S. Eisebitt

Vorsitzender Vorstand, Physikalischen Gesellschaft zu Berlin (PGzB)

Sprecher des Vorstandes, Forschungsverbund Berlin e.V.

Chair, Scientific Advisory Council (SAC), Elettra Sincrotrone Trieste, Italy

Member, DESY Photon Science Committee, Hamburg

Member, FERMI Proposal Review Panel, Elettra Sincrotrone Trieste, Italy

T. Elsaesser

Secretary of the Mathematics and Science Class, Berlin Brandenburg Academy of Sciences

Chair, TELOTA steering group, Berlin Brandenburg Academy of Sciences

Conference Chair, Program Committee, 15th Femtochemistry Conference (FEMTO 15)

Member, IRIS Adlershof, Humboldt-Universität zu Berlin

Member, Kuratorium of the Max Planck Institute for Quantum Optics, Garching

Member, Standing Committee for the Evaluation of Int. Max Planck Centers, Max Planck Society, Munich

Member, Editorial Board, Chem. Phys. Lett.

Member, Advisory Board, Conference Series on Time Resolved Vibrational Spectroscopy

Member, Proposal Review Panel for the LCLS X-ray FEL facility, SLAC, Menlo Park

Associate Editor, Struct. Dyn., AIP

Member, Science Policy Committee, SLAC, Menlo Park

Member, FXE Proposal, Review Panel, Schenefeld, European XFEL

Chair, Physics Group, Gesellschaft Deutscher Naturforscher und Ärzte (GdNÄ)

Member, Advisory Board, Int. Conference on Coherent Multidimensional Spectroscopy

U. Griebner

Member, Programm Committee, Ultrafast Optics Conference (UFO) 2023, Bariloche, Argentina

Member, Programm Committee, Mid-Infrared Coherent Sources Conference (MICS)

R. Grunwald

Member, SPIE Fellows Committee

Associate Editor, Optics Express

Member, Programm Committee Photonics West, OPTO, Complex light and optical forces XVII

M. Y. Ivanov

Chair of session Airlasing, PQE-23, Physics of Quantum Electronics, 53rd winter meeting (Snowbird, Utah, USA)

Scientific coordinator, Int. seminar on control of ultrafast processes using strctured light (CUPUSL) (Dresden, Germany), MPIPKS

E. T. J. Nibbering

Member, Advisory Board, Conference Series on Time Resolved Vibrational Spectroscopy

Member, Editorial Board, Journal of Photochemistry and Photobiology A

V. Petrov

Chair of Session Optical parametric devices and applications, SPIE Photonics West LASE (San Francisco, CA, USA)

Chair of Session Characterization of NLO Materials, SPIE Photonics West LASE (San Francisco, CA, USA)

Chair of Session New nonlinear materials II, SPIE Photonics West LASE (San Francisco, CA, USA)

B. Pfau

Member of the Organizing Committee, Workshop on Soft X-ray Science at PETRA, DESY, Hamburg, Germany

N. Picqué

Deputy Editor, Optica

Co-Chair, Topical Meeting on Frequency Combs, European Optical Society, Annual Meeting

Chair, EPS-QEOD Prize For Research In Laser Science And Applications

Member, Steering Committee, CLEO/EQEC Europe

Board Member, Quantum Electronics and Optics Division of European Physical Society

Member, Breakthrough in Physical Sciences Committee, Falling Walls Foundation

Member, Quantum Electronics and Optics Prizes Committee, European Physical Society

A. Rouzée

Editor, Adv. Phys. X

O. Smirnova

Member, General Committee, ICPEAC, XXXIII Int. Conference on Photonic, Electronic and Atomic Collisions

Member, Int. Program Committee, 9th Int. Conference on on Attosecond Science and Technology, ATTO

Member, Advisory Board of the Max Planck School of Photonics

Member, dynaMENT Mentoring for Women in Natural Sciences, University of Hamburg and DESY

G. Steinmeyer

Member, Editorial Board, Phys. Lett. A

Associate Editor, Optica

Member, Program Committee, Ultrafast Optics 2023, Bariloche, Argentina

H. Stiel

Member, Scientific Committee Int. Conference on X-ray Lasers, EMPA, Dübendorf, Switzerland

Member, Advisory board of Institute of Applied Photonics (IAP) eV, Berlin

J. W. Tomm

Permanent Member, Int. Steering Committee, Int. Conference on Defects - Recognition, Imaging and Physics of Semiconductors, DRIP (Yokohama, Japan)

Associate Editor, Journal of Electronic Materials (JEMS)

Member Editorial Board, Communications in Physics (CIP)

M. J. J. Vrakking

Editor-in-chief, Journal of Physics B

Member of panel group, Science and Technology Facilities Council

CLF Review, Rutherford Appleton Laboratory (Didcot, UK)

Conference Chair, Program Committee, 15th Femtochemistry Conference (FEMTO 15)

Honors and awards

W. Becker: Foreign member of the Academy of Sciences and Arts of Bosnia and Herzegovina, Sarajevo

L.-M. Kern: Carl Ramsauer Award of the Berlin Physical Society (PGzB) Berlin

N. Picqué: Grand Prix Cécile DeWitt-Morette in Physics, French Academy of Sciences

O. Smirnova: one of the „100 wichtigsten Köpfe der Berliner Wissenschaft“ ausgewählt vom „Redaktionsteam der Berliner Wissenschaft des Tagesspiegels“

Max-Born-Institut (MBI)
für Nichtlineare Optik und Kurzzeitspektroskopie
im Forschungsverbund Berlin e. V.

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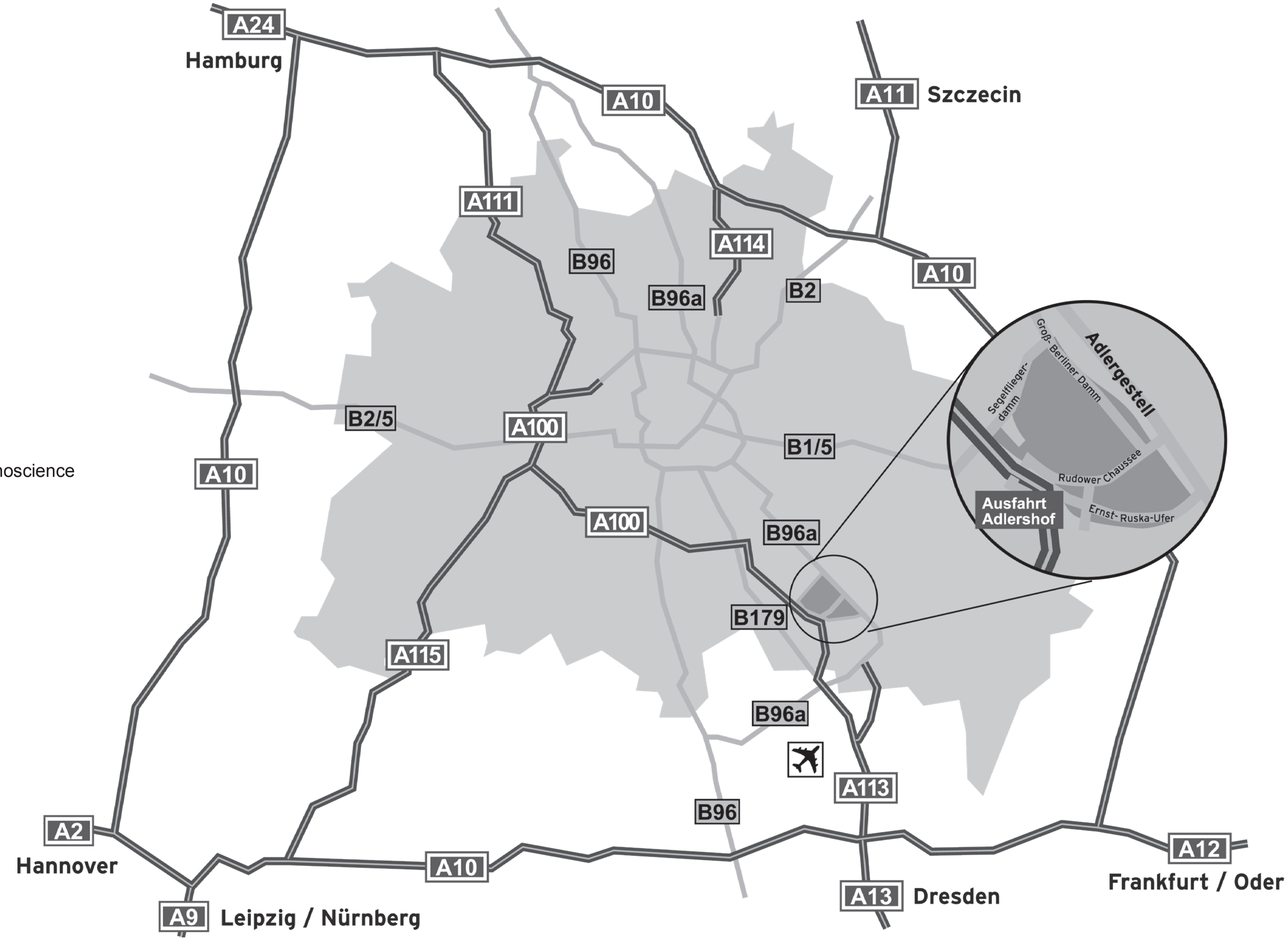

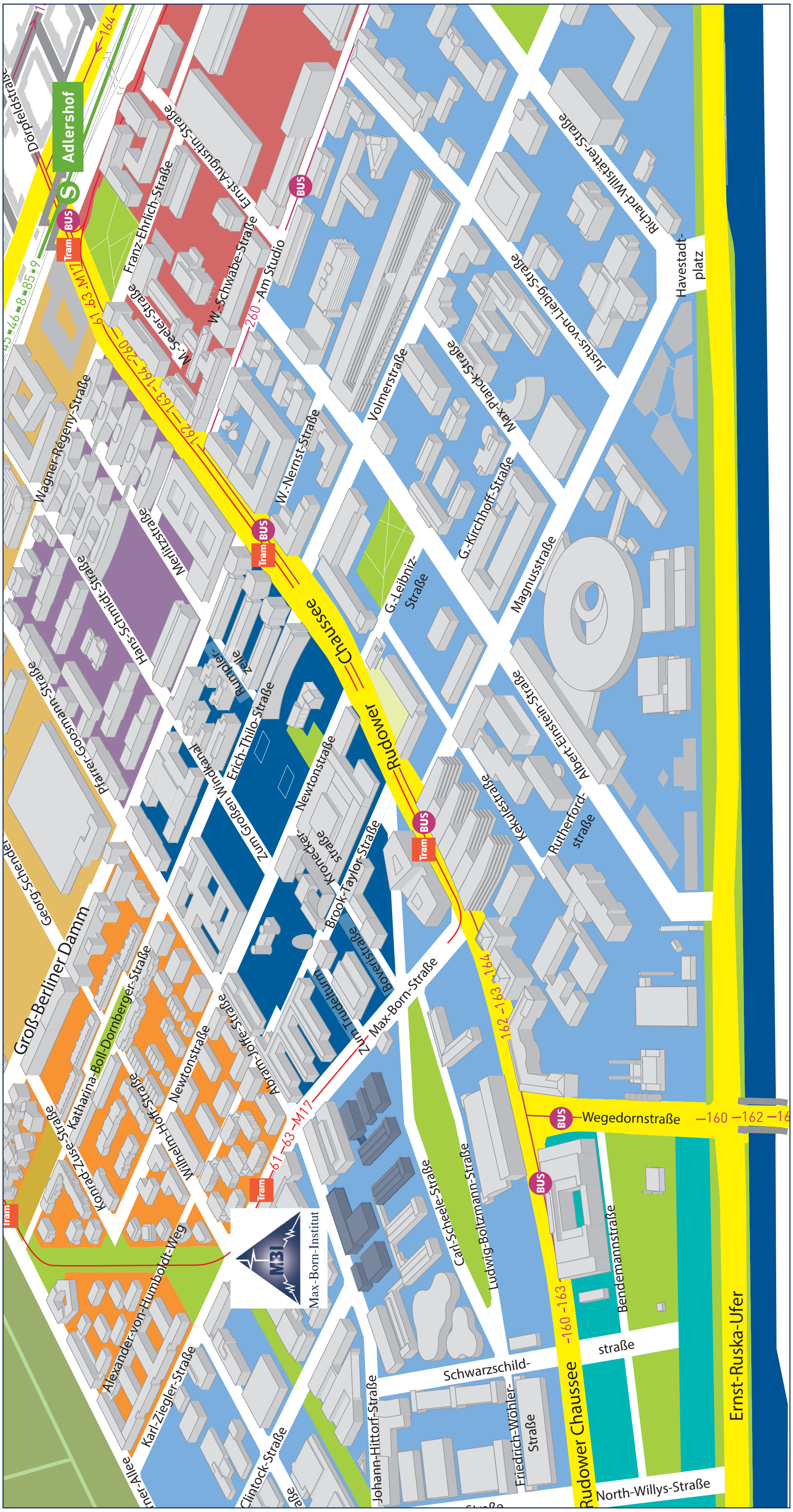
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