Max-Born-Institut

Annual Report 24|25

Max-Born-Institut

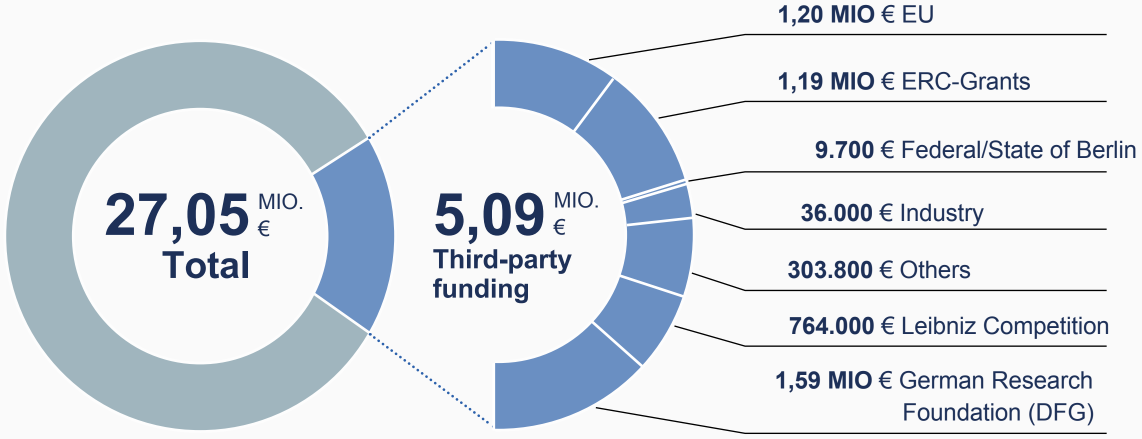
für Nichtlineare Optik und
Kurzzeitspektroskopie
im Forschungsverbund Berlin e.V.

Annual Report

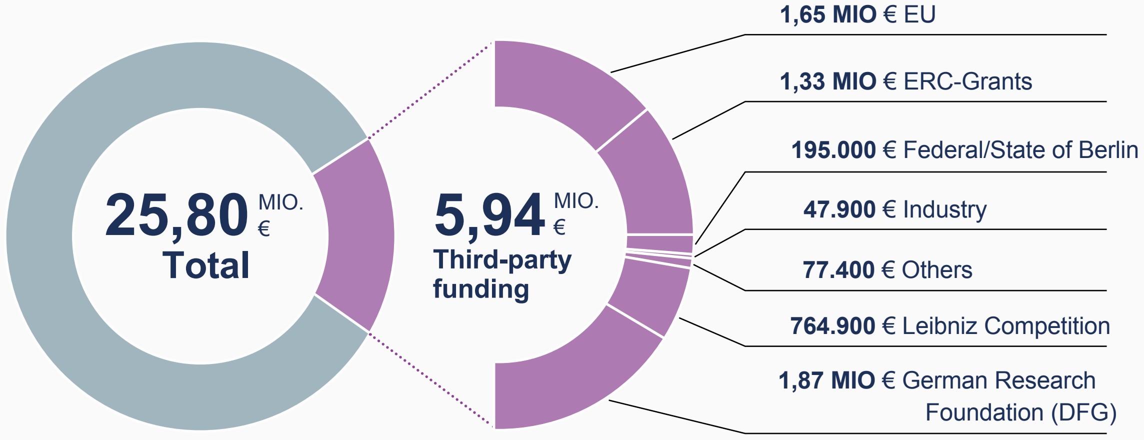
24|25

2024/2025 in Figures

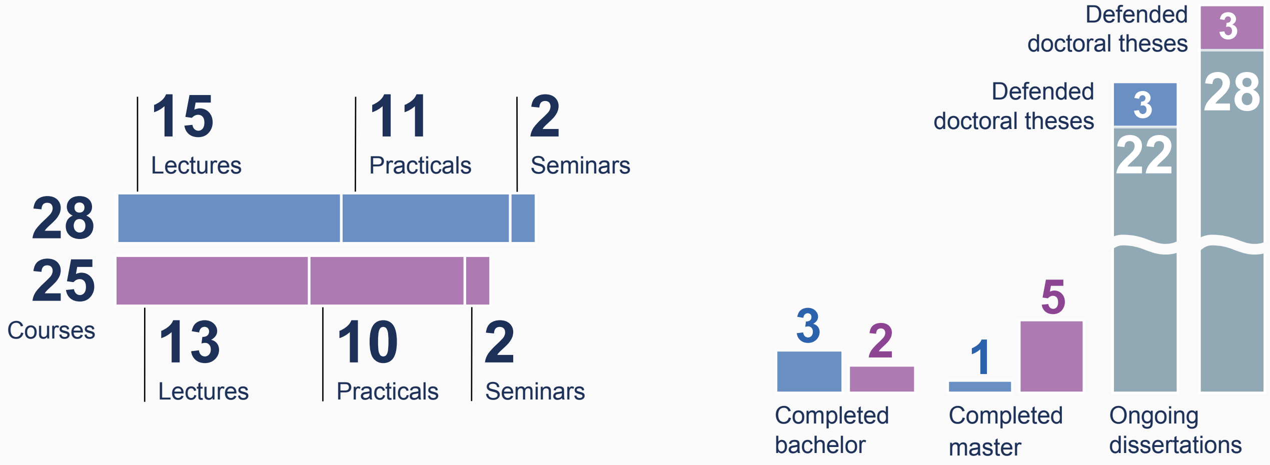
Budget 2024



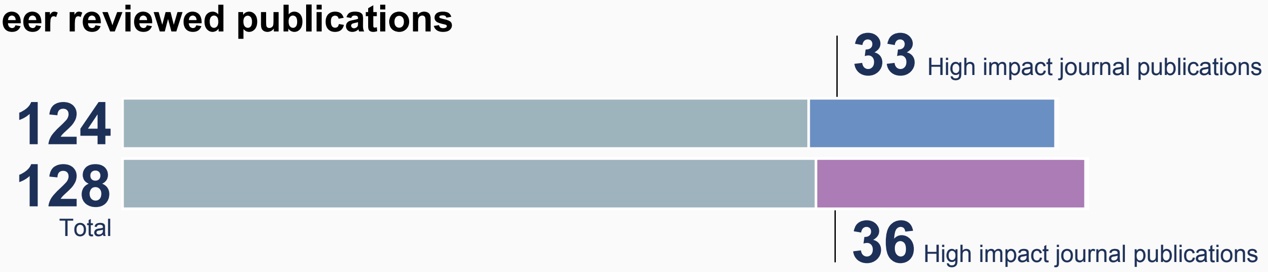
Budget 2025



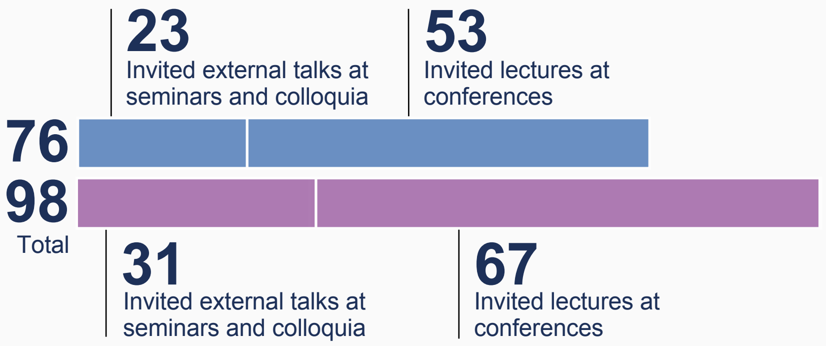
Education and Teaching



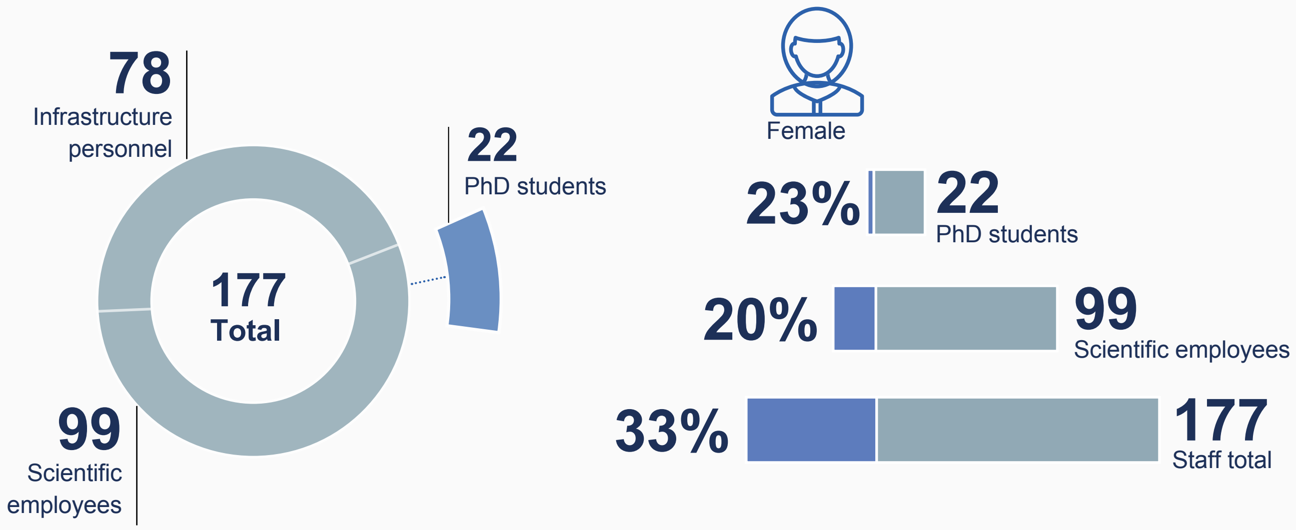
Peer reviewed publications



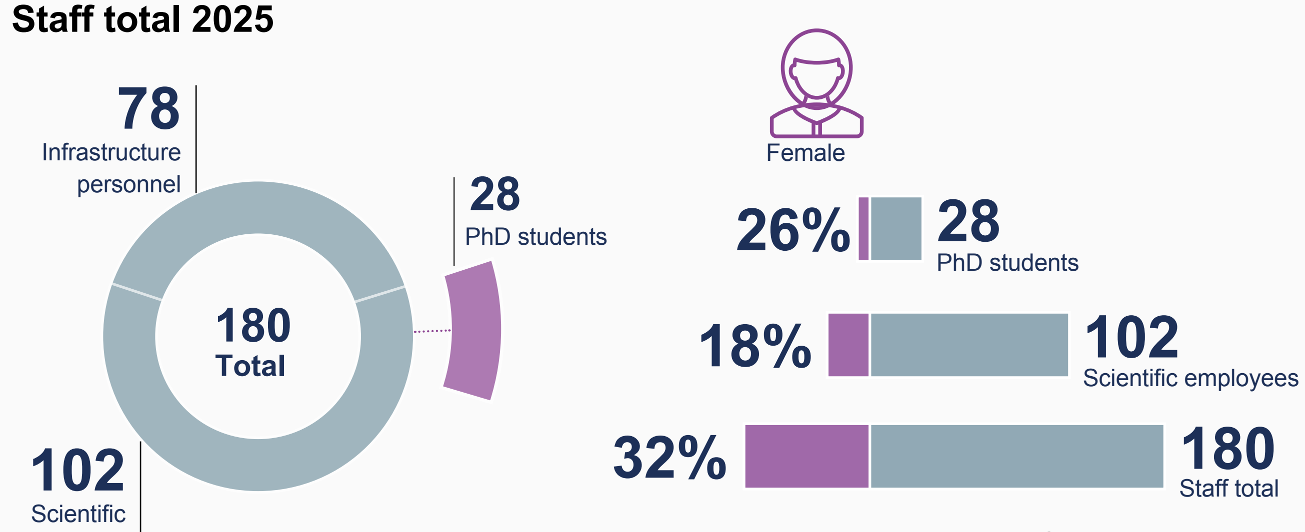
Scientific talks



Staff total 2024



Staff total 2025



There are two Junior Research Groups at MBI.

Research Structure of the Max Born Institute

Lasers and Light-Matter-Interaction

- Fundamentals of Extreme Photonics
- Ultrafast and Ultraprecise Laser Physics & Nonlinear Optics

Ultrafast and Nonlinear Phenomena: Gas Phase

- Ultrafast Electron Dynamics
- Ultrafast Molecular Dynamics
- Broadband Precision Spectroscopy of Molecules

Ultrafast and Nonlinear Phenomena: Condensed Phase

- Dynamics of Condensed Phase Molecular Systems
- Ultrafast Dynamics in Solids and Nanostructures
- Structural Dynamics and Emergent Texture

Infrastructure and Applications

- Implementation of Lasers and Measuring Techniques
- Application Laboratories and Technology Transfer
- Nanoscale Samples and Integrated Optics

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Attosecond Physics
Division A: M. Vrakking

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A2 Ultrafast XUV-Physics (O. Kornilov)

A3: Ultrafast Lasers and Nonlinear Optics (T. Nagy)

A4: Attosecond-pump Attosecond-probe spectroscopy (B. Schuette)

ERC Starting Grant Group: Time- and Energy-Resolved Electron Scattering (K. Amini)

Transient Electronic Structure and Nanoscience
Division B: S. Eisebitt

B1: Electron and Spin Dynamics (C. von Korff Schmising)

B2: Imaging and Coherent X-rays (B. Pfau)

B3: Laser Development (G. Rossi)

B4: Theory for Dynamics in Quantum Materials (S. Sharma)

Leibniz Junior Group: Complex Spin Structures in Time and Space (D. Schick)

Precision Physics
Division C: N. Picqué

C1: Femtosecond Spectroscopy of Molecular Systems (E. Nibbering)

C2: Solid State Light Sources (G. Steinmeyer)

C3: Frequency Comb Laser Systems (N. N.)

C4: Dual-comb Interferometry and Spectroscopy (N. N.)

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Attosecond Theory (M. Ivanov) | Strong Field Theory (O. Smirnova)
Theoretical Optics & Photonics (K. Busch, HU Berlin) | Attosecond Molecular Dynamics (Junior Group: M. Ruberti)

Administration: M. Loeser
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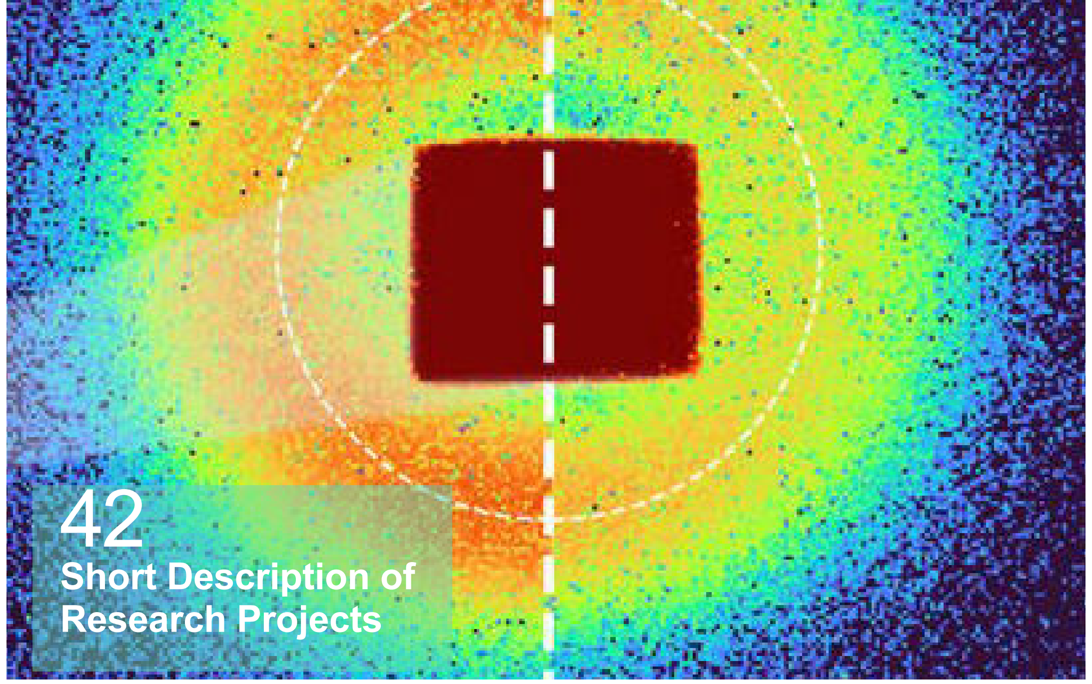
Senatsverwaltung für Wissenschaft, Gesundheit und Pflege, Ref. VI D, Berlin, Germany



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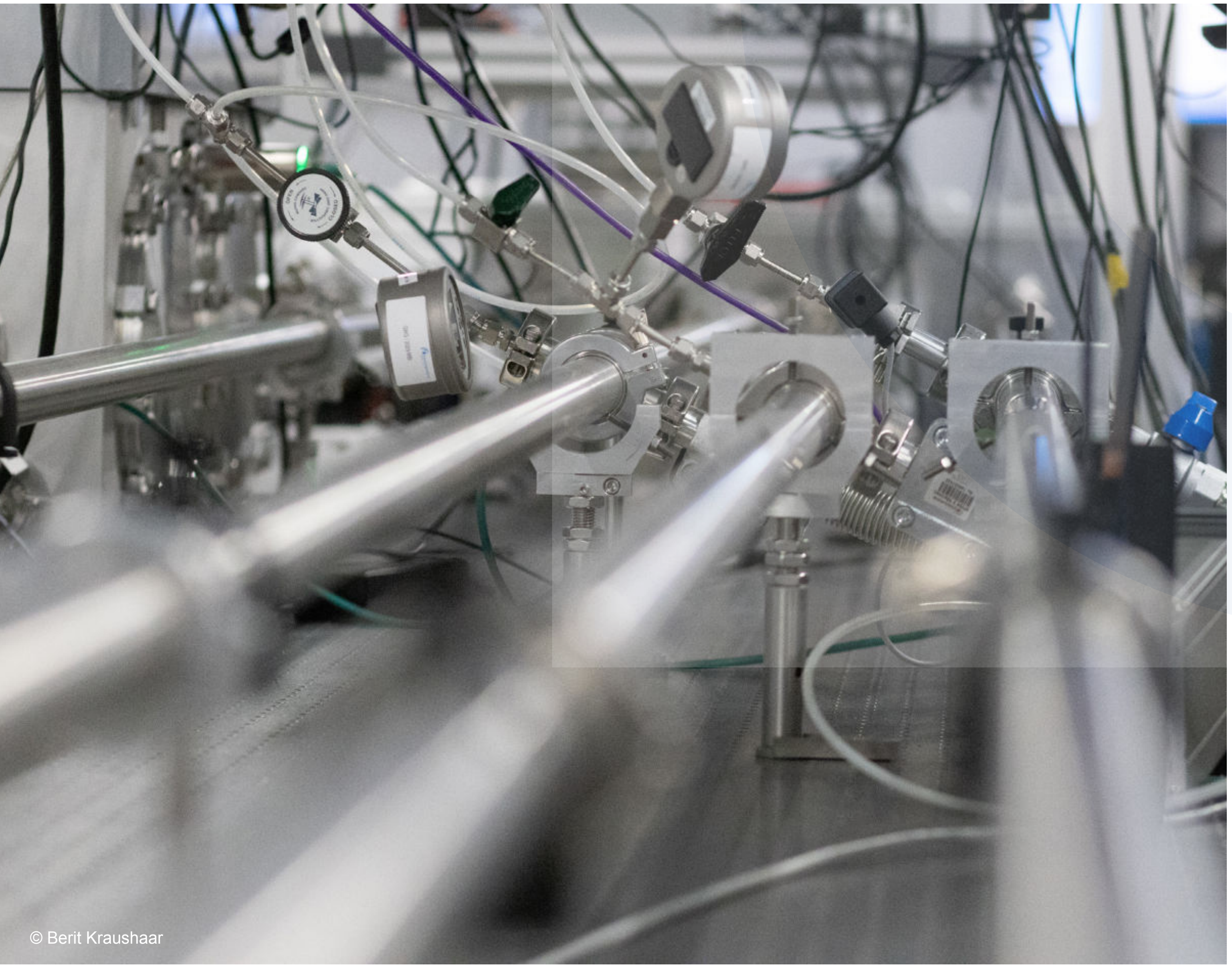

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Preface

This report provides an overview of research and activities at the Max Born Institute (MBI) in 2024 and 2025. It presents selected scientific highlights alongside concise project reports, complemented by key figures for the institute. It also includes elements reflecting life at MBI, highlighting staff, alumni, and notable events. A complete record of publications and invited talks is provided in the appendix, together with information on teaching, training, outreach, and activities in scientific organizations. Further details are available at www.mbi-berlin.de.

In 2024-2025, research at MBI advanced the understanding of light-matter interaction in a variety of different contexts. Highlights from the experimental divisions include table-top attosecond pump-attosecond probe spectroscopy revealing valence electron hole dynamics in atoms; establishing a pump-probe platform for studying magnetic skyrmion generation and motion, providing insight into topological phase transitions; and microresonator-based frequency combs applied to hyperspectral three-dimensional imaging, enabling rapid, chemically sensitive diagnostics of particulate matter such as microplastics. In parallel, the theory group introduced schemes to tailor light fields for enhanced enantio-sensitive interactions with chiral molecules, opening new directions in quantum-enhanced sensing. These advances reflect both the consolidation of established research lines and the emergence of new directions, including the restructuring of one division into a Division of Precision Physics.

Disseminating research results to both the scientific community and the broader public remains a key objective. In 2024-2025, one quarter of MBI publications appeared in journals with an impact factor above nine, and two thirds were published open access, ensuring broad accessibility.

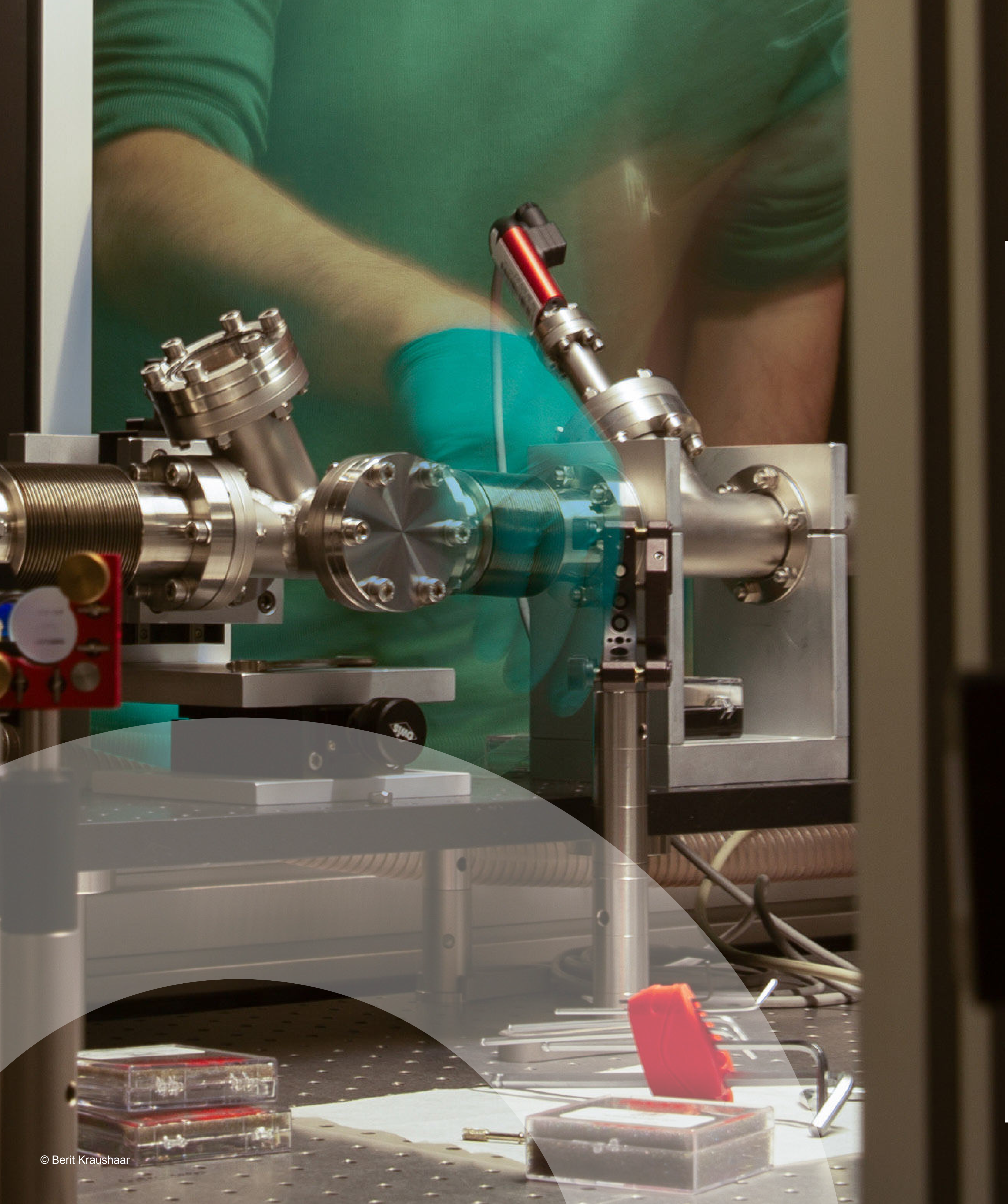
In a major infrastructure project carried out in 2024-2025, MBI upgraded the central heat exchanger system jointly used with IKZ. This resulted in annual savings of approximately 390,000 kWh of energy and 6,500 m³ of water, reducing both environmental impact and operating costs, with a projected amortization time of 4-5 years.

During the reporting period, several MBI researchers received prestigious individual distinctions. Lisa-Marie Kern was awarded the 2024 Dissertation Award of the Condensed Matter Section of the German Physical Society and the Klaus Tschira Foundation's KlarText Award for Science Communication in Physics. Kasra Amini received a Starting Grant from the European Research Council, Nathalie Picqué the OPTICA 2024 William F. Meggers Award, and Tim Butcher the Ferroic Young Researcher Award at the EMRS 2025 Spring Meeting.

We thank all members of the MBI community for their contributions during 2024 and 2025 and gratefully acknowledge the continued support of our funding bodies.

Berlin, April 2026

Stefan Eisebitt, Nathalie Picqué, Marc Vrakking



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Scientific Highlights

UV Pump-Probe Spectroscopy with Unprecedented Temporal Resolution

The generation of few-femtosecond pulses tunable across the ultraviolet (UV) has long remained a significant challenge in modern ultrafast optics. Since most materials exhibit electronic resonances in the deep- and vacuum-UV (VUV), such pulses enable the study of valence electron dynamics with unprecedented temporal resolution.

However, due to the Kramers-Kronig relation, the vicinity of resonances intrinsically induces strong material dispersion, which makes the manipulation and characterization of such pulses extremely difficult.

Recently, a technique pioneered by John C. Travers at the Heriot-Watt University, UK, was introduced to generate μJ-level, few-fs UV pulses with a broad wavelength tunability extending down to 110 nm. This approach relies on resonant dispersive wave (RDW) emission following soliton self-compression in hollow capillary waveguides. While RDW-based sources have been successfully employed across a wide spectral range down to the deep-UV (~230 nm), their extension into the shorter-wavelength VUV region (100-200 nm) has until now remained unexplored due to several technical challenges, most notably due to the high absorption and extreme dispersion of materials in this regime.

Our group at the MBI successfully extended the applicability of the RDW technique into the VUV spectral range. We fully characterized few-fs pulses tunable between 160 and 190 nm using a technique that we call electron FROG. This technique is a variant of frequency-resolved optical gating (FROG), using two-photon ionization of noble gases as the nonlinear interaction. It consists of recording a two-dimensional (2D) spectrogram of the photoelectron kinetic energy distribution as a function of the delay between two pulse replicas ionizing a gas target (see Fig. 1a). This 2D spectrogram contains information on the pulse shape that, similar to a conventional FROG, can be extracted using an iterative phase-retrieval algorithm.

Unlike standard all-optical FROG traces, electron FROG traces do not depend solely on the pulse shape, but also encode signatures of the atomic electronic structure of the target gas. To account for this additional complexity, we developed a dedicated numerical phase-retrieval approach based on differential evolution algorithms. The method was validated through a series of consistency checks, including direct comparison with ab initio quantum mechanical (TDSE) calculations. The in-situ measurements, together with our newly developed analysis, demonstrated that the RDW-generated VUV pulses have sub-3 fs durations (see inset of Fig. 1a), in accordance with earlier simulation-based predictions.

Using the few-cycle VUV pulses available at the MBI, we revisited the ultrafast electronic relaxation dynamics of ethylene and deuterated ethylene, the smallest carbon-carbon chromophores, using time-resolved photoelectron spectroscopy. Our exceptional sub-4 fs temporal resolution directly revealed previously unobserved nonadiabatic dynamics occurring on sub-10 fs timescales (see Fig. 1b). Supported by quantitative quantum-dynamical calculations employing recently developed quantum chemistry methods by our collaborators at the University of Ottawa, Canada, we uncovered a revised picture of ethylene's early photochemistry. Specifically, first-principles simulations, in remarkable agreement with experiment, allowed us to identify that the initial torsional motion about the C=C bond is driven by strong nonadiabatic couplings between the optically bright $\pi\pi^*$ state and the $\sigma\pi^*$ electronic state. We expect that this finding will have broad implications for understanding ultrafast photoisomerization of organic molecules with conjugated carbon-carbon double bonds.

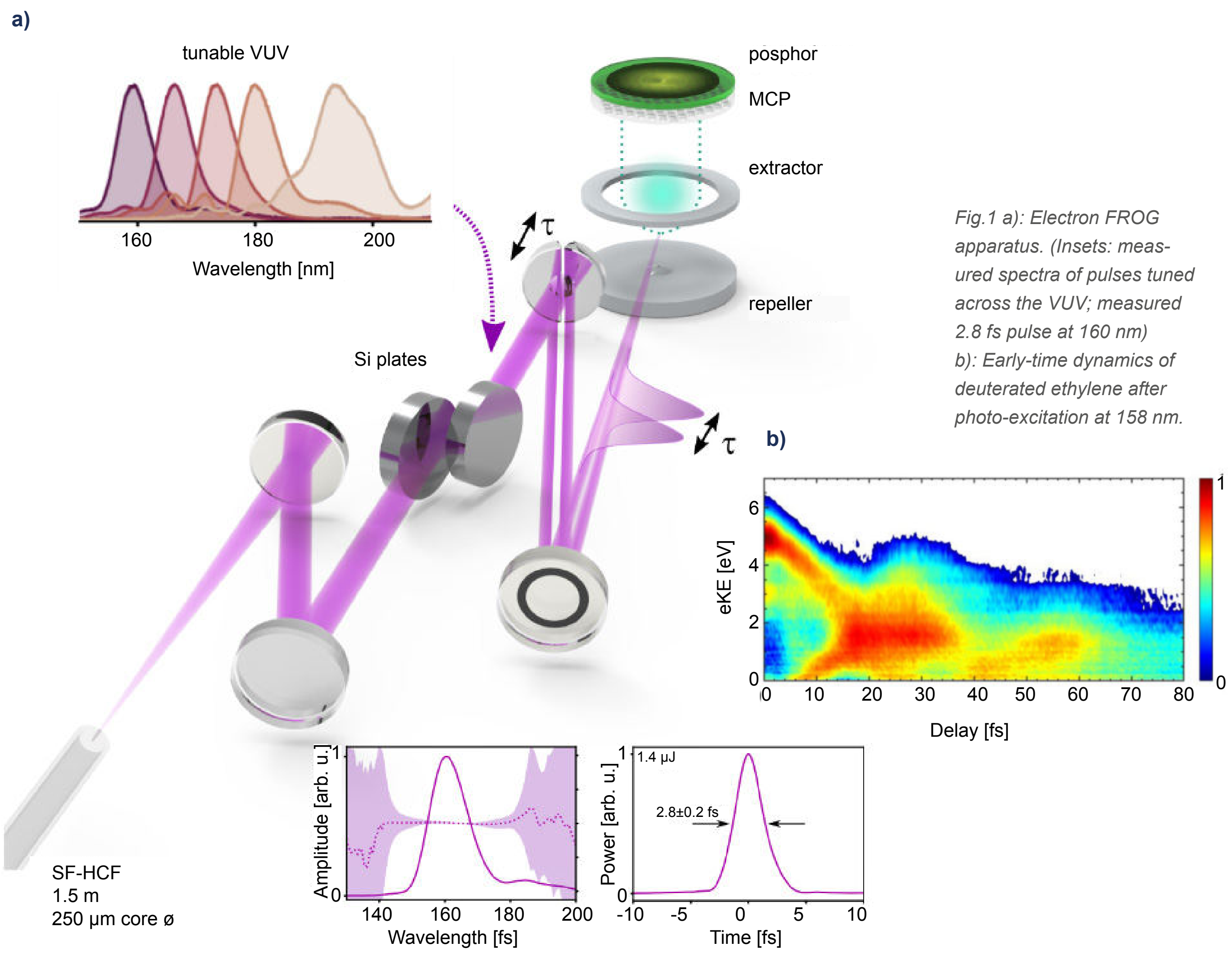

Fig.1 a): Electron FROG apparatus. (Insets: measured spectra of pulses tuned across the VUV; measured 2.8 fs pulse at 160 nm)
b): Early-time dynamics of deuterated ethylene after photo-excitation at 158 nm.

Publications

J. R. C. Andrade, M. Kretschmar, R. Danylo, S. Carlström, T. Witting, A. Mermillod-Blondin, S. Patchovskii, M. Y. Ivanov, M. J. J. Vrakking, A. Rouzée, and T. Nagy; Temporal characterization of tunable few-cycle vacuum ultraviolet pulses; Nat. Photonics 19 (2025) 1246; doi.org/10.1038/s41566-025-01770-6

SNK: A. Sen, S. P. Neville, M. Kretschmar, M. Y. Jouybari, R. Danylo, J. R. C. Andrade, M. J. J. Vrakking, A. Stolow, T. Nagy, M. S. Schuurman, A. Rouzée; A New Paradigm for the Dynamics of the Carbon-Carbon Double Bond: Ethylene; submitted to Nature (2025)

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Ultrafast Photoinduced Reaction Dynamics Using the Nitrogen K-edge as a Probe

Photo-induced ultrafast charge transfer processes in molecules are ubiquitous in nature and represent elementary photochemical processes that are pertinent in a broad range of research areas, from biochemistry and biology to molecular synthesis in organic and inorganic chemistry.

Beyond their fundamental importance, these processes are also central in real-world applications, most notably in light harvesting and solar energy conversion. To access and resolve these fundamental dynamics on their intrinsic timescales, experimental approaches capable of directly probing transient electronic structure with ultrafast temporal resolution are required.

Recently, we have developed a versatile, table-top experimental platform capable of probing the transient electronic structure of molecules using extreme high-order harmonic pulses extending into the soft-X-ray spectral region. In earlier work, this set-up was successfully used to study the strong field ionization dynamics of molecular nitrogen with ultrafast soft X-ray absorption spectroscopy at the nitrogen K-edge (395-405 eV) [1]. Building on this result, we now have expanded our activities to the investigation of the photo-induced bond fission of nitrogen dioxide in the gas-phase and photo-induced charge transfer dynamics of the metal-ligand complex ironII tris(2,2-bipyridine) $[\mathrm{Fe^{II}(bpy)_3^{2+}}]$ chloride in aqueous solution.

In particular, we have employed a combined experimental and theoretical approach to investigate the ultrafast photo dynamics of NO_2 in its first electronic excited state, $\tilde{A}\ ^2B_2\ (D_1)$. Using ultrafast UV-pump/soft-X-ray-probe spectroscopy together with full quantum-dynamical calculations, we correlated the time-dependent evolution of nitrogen K-edge marker transitions with changes in the underlying electronic molecular structure. This approach allowed us to directly follow the reaction pathway as the system evolves through the $\tilde{A}\ ^2B_2\ (D_1) \rightarrow \tilde{X}\ ^2A_1\ (D_0)$ conical intersection and subsequently dissociates into NO + O photoproducts [2] (see Fig.1 and 2). Although the temporal resolution achieved in the present experiments was limited, our theoretical analysis demonstrates that, when employing sufficiently short UV pump pulses with durations below 8 fs, the early wave-packet dynamics in the D_1 excited state – occurring within the first 35 fs along bending and symmetric stretching modes – can be directly mapped onto the transient X-ray absorption spectrum at the N K-edge.

By combining our femtosecond soft X-ray source with flatjet technology, we also investigated the ultrafast metal-to-ligand charge transfer (MLCT) dynamics in photoexcited $[\mathrm{Fe^{II}(bpy)_3^{2+}}]$ in solution. Upon 400 nm excitation of the low spin electronic ground state, a new absorption band emerged in the transient X-ray absorption spectrum at a photon energy of 400.3 eV, exhibiting a decay time of ~130 fs. This decay was accompanied by the rise of a second absorption band at 399.4 eV, with a rising time constant of ~160 fs, attributed to the formation of molecules in the high-spin quintet state. By comparing our measurements to calculated nitrogen 1s → LUMO X-ray absorption spectra for different electronic excited states, we unambiguously identified the short-lived feature at 400.3 eV as arising from nitrogen 1s → LUMO transitions occurring in photo-excited molecules in the short-lived 1,3MLCT manifold. Our results provide conclusive insight on the role of the MLCT process and subsequent intersystem crossing and spin-flip dynamics upon visible irradiation in $[\mathrm{Fe^{II}(bpy)_3^{2+}}]$ [3].

Taken together, these investigations demonstrate that time-resolved X-ray absorption spectroscopy is a powerful and versatile technique for probing ultrafast changes in the local electronic structure of molecules with element and site specificity. By directly accessing core-level transitions, this approach is sensitive to electronic-state populations, charge localization, and coordination environment at selected atomic centers, even in complex, solution-phase environments. The ability to correlate transient spectral signatures with underlying electronic and nuclear dynamics highlights the unique capability of time-resolved X-ray absorption spectroscopy to unravel coupled charge-transfer and structural processes on their fundamental timescales. Building on these advances, we are now applying this methodology to the investigation of photo-induced charge-transfer dynamics in donor-acceptor molecular systems that are directly relevant to light-harvesting and energy-conversion applications.

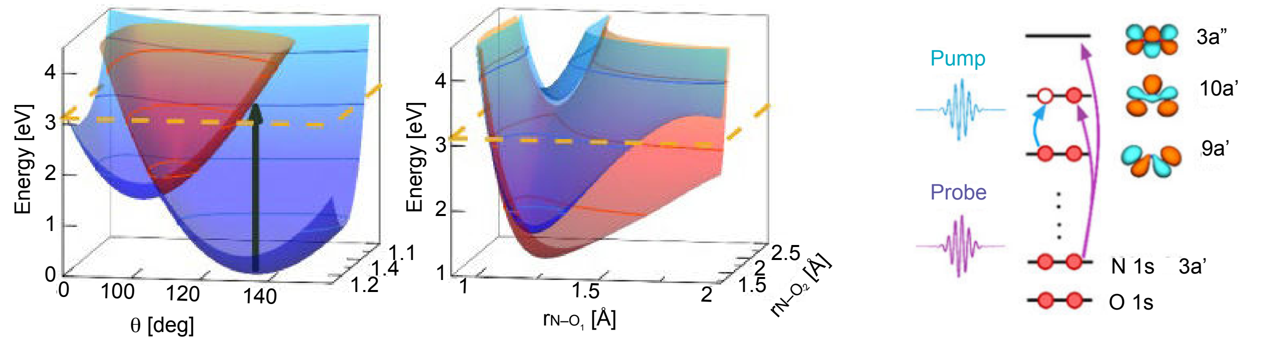

Fig. 1: (left) Potential energy surfaces of the D_0 and the D_1 states of NO_2 (right) Level scheme showing the principle of the experiment, where a UV pump pulse excited NO_2 from the SOMO to the LUMO, and a nitrogen K-edge probe pulse monitors the evolution of NO_2 molecule through the nitrogen K-edge 1s core to LUMO/LUMO +1 transitions.

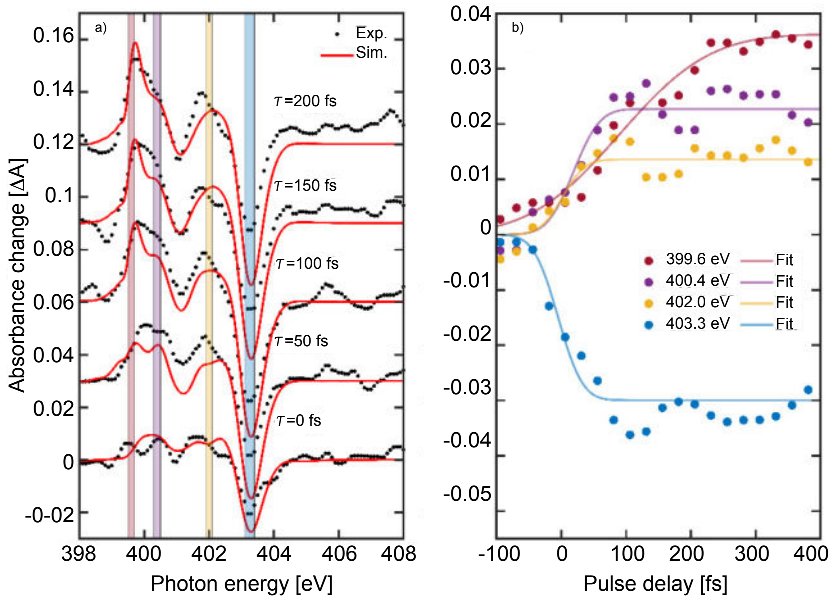

Fig. 2: a) Transient nitrogen K-edge X-ray absorption spectra for selected pulse delays showing the experimental spectra as dots and the calculated spectra as solid red lines.
b) Temporal behavior showing depletion of the ground state (bleach signal at 403.2 eV), the excited state (the transient absorption at 402.0 eV) and the NO product formation (marked by the transient absorption growing in at 399.8 eV), integrated over the spectral ranges as indicated with the color bars shown in a).

Publications

[1] C. Kleine, et al.; Ultrafast N K-edge spectroscopy of strong field ionization and fragmentation dynamics of molecular nitrogen, Phys. Rev. Lett. 129 (2022) 123002

[2] Z.-Y. Zhang,; el al.; Ultrafast mapping of electronic and nuclear structure in the photo dissociation of nitrogen dioxide; J. Phys. Chem. Lett. 15 (2024) 12025-12033; doi.org/10.1021/acs.jpclett.4c02808

[3] Z.-Y. Zhang, et al.; Primary Events of Metal-to-Ligand Charge Transfer Dynamics Probed with Table-Top Femtosecond Soft-X-Ray Spectroscopy at the Nitrogen K-edge, in preparation (2026)

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Attosecond Plasma Lens

Attosecond pulses – bursts of light lasting only billionths of a billionth of a second – are essential tools for observing and controlling electronic motion in atoms, molecules, and solids. However, focusing these pulses, which lie in the extreme-ultraviolet (XUV) or X-ray region of the electromagnetic spectrum, has proven highly challenging due to the lack of suitable optics.

Mirrors are commonly used, but they offer low reflectivity and degrade quickly. Lenses, though the most straightforward tool for focusing visible light, are not suitable for focusing attosecond pulses, because they absorb the XUV light and stretch the attosecond pulses in time.

In a project carried out at the MBI in close collaboration with DESY we have solved this problem by generating a plasma lens. To create it, strong electrical pulses are sent through hydrogen gas inside a tiny tube (see Fig. 1). This process strips the hydrogen atoms of their electrons, creating a plasma. The electrons naturally move outward toward the edges of the tube, shaping the plasma like a concave lens. Normally, such a lens would spread light out rather than focus it. But because plasma bends light differently than ordinary materials, it instead focuses the attosecond pulses.

In a recent Nature Photonics publication, we showed that the plasma lens can focus attosecond pulses across different ranges of XUV light, with a tunable focal length controlled by the plasma density. Moreover, a high transmission rate of more than 80 % was achieved. Importantly, the team found that the plasma lens serves as an effective filter for the infrared driving pulses, which normally require thin metal filters. This means those filters are no longer necessary, allowing more attosecond power to pass through. With stronger pulses now available, scientists have new opportunities to run attosecond experiments that are often limited by weak light sources.

To better understand how the focused attosecond pulses behave over time, the scientists ran computer simulations. They discovered that the pulses stretch only slightly, from 90 to 96 attoseconds. Under more realistic conditions – where different colors of the attosecond pulse arrive at slightly different times (a phenomenon known as chirp) – the plasma lens actually shortened the pulses. In this case, the pulse duration decreased from 189 to 165 attoseconds.

By experimentally demonstrating an attosecond plasma lens, the researchers have addressed a major limitation in attosecond science. The technique offers simple alignment, high transmission, and the ability to focus light across different colors. These advantages open the door to a wide range of applications, from mapping electron dynamics in complex materials to advancing quantum technologies and enabling the next generation of ultrafast microscopy.

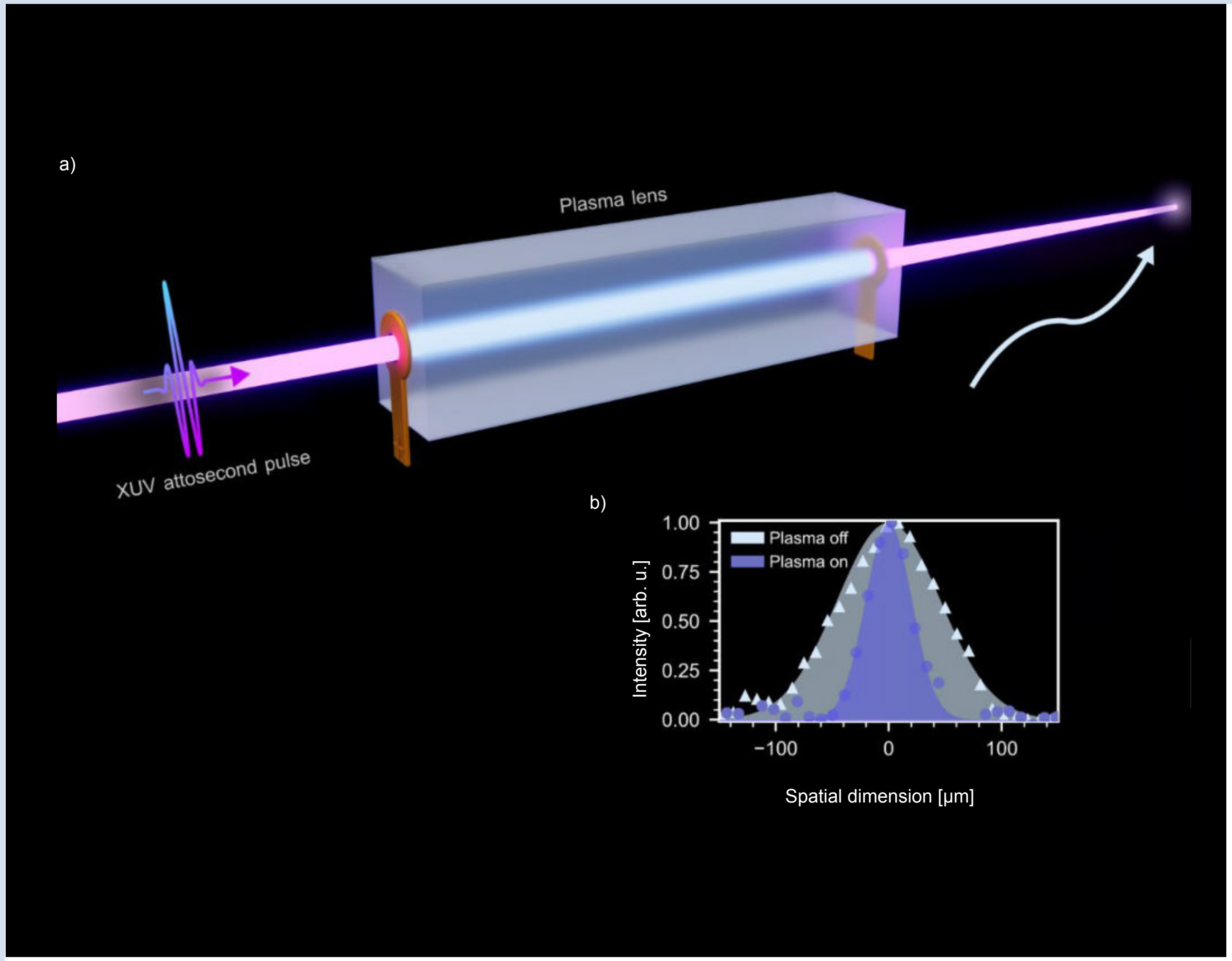

Fig. 1: a) An attosecond pulse enters a capillary, where a strong electrical pulse generates a hydrogen plasma. As the electrons move toward the capillary walls, they form a concave lens that focuses the attosecond pulse.
b) The attosecond pulses are focused in the presence of plasma.

Publication

E. Svirplys, H. Jones, G. Loisch, J. Thomas, M. Huck, O. Kornilov, M. J. Garland, J. C. Wood, M. J. J. Vrakking, J. Osterhoff, and B. Schütte; Plasma lens for focusing attosecond pulses; Nat. Photonics online (2025); doi.org/10.1038/s41566-025-01794-y

Contact

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Pushing Boundaries in Ultrafast Magnetization Switching

A single ultrashort laser pulse can change the magnetization of a suitable material. But even within a magnetic film of just a few nanometer thickness, this process is not homogeneous, but proceeds with a speed of about 2,000 meters per second.

The field of ultrafast magnetism explores how flashes of light can manipulate a material's magnetization in trillionths of a second. In the process called all-optical switching (AOS), a single laser pulse of several femtoseconds ($\approx 10^{-15}$ seconds) duration flips tiny magnetic regions without the need for an externally applied magnetic field. Enabling such an ultrafast control over magnetization, orders of magnitude faster than what can be achieved using a conventional magnet-based read/write head as in a magnetic hard drive, AOS is a promising candidate for novel devices in spintronics and data-storage applications that use magnetic spins with their associated magnetic moments as information carriers. Such devices typically consist of a stack of nanometer-thin materials, with the actual magnetic material being one of them.

Until now, the switching process was thought to happen uniformly in the magnetic material wherever the laser pulse deposits a sufficient amount of energy. In a recent study, we revealed that this is not the case. Instead, there is an ultrafast propagation of a magnetization boundary into the depth of the material.

Combining ultrashort infrared (IR) excitation with table-top femtosecond soft-X-ray spectroscopy (see Fig. 1), we studied an only 9.4 nm thin gadolinium-cobalt (GdCo) film in a typical stack with platinum and copper layers on top and a tantalum layer below. Using broadband X-rays tuned to an atomic resonance of the rare earth atom Gd, we applied a technique recently developed at MBI that allows following magnetization changes along the depth of the sample in time. The result is a movie of the magnetization as it evolves along the film's depth, with femtosecond temporal resolution.

This movie revealed what has been hidden so far: Immediately after the arrival of the infrared pulse of 27 fs duration, the entire GdCo layer first heats up and its magnetization drops nearly uniformly, in line with the conventional thinking. But after two picoseconds, two domains of opposite magnetization appear: the top region – receiving an additional stimulus from the more strongly heated up platinum layer on top of the GdCo – flips first, while the magnetization direction at the bottom remains unchanged. A boundary between these two domains is formed and subsequently propagates downward at about 2,000 m/s, sweeping through the entire GdCo layer in roughly 4.5 ps (see Fig. 2). In particular, only the surface-near slice of the GdCo is initially excited strong enough to overcome the threshold required for AOS; nevertheless, the switching succeeds as the rest of the film follows due to the propagating boundary.

This discovery forces a rethink of AOS as a combination of local and non-local processes, challenging the current understanding of the process by the established theoretical models. The moving boundary, possibly driven by a combination of angular-momentum exchange between the switched and unswitched regions and the thermal gradients across the heterostructure established on an ultrashort time scale, ultimately determines both the switching speed and the final magnetic state.

Looking forward, these insights open new routes to engineer light-actuated magnetic devices, by tuning the material properties that define where the boundary nucleates and how fast it travels. Such design freedom could enable fast and energy-efficient memory and logic elements that exploit light-driven magnetization reversal.

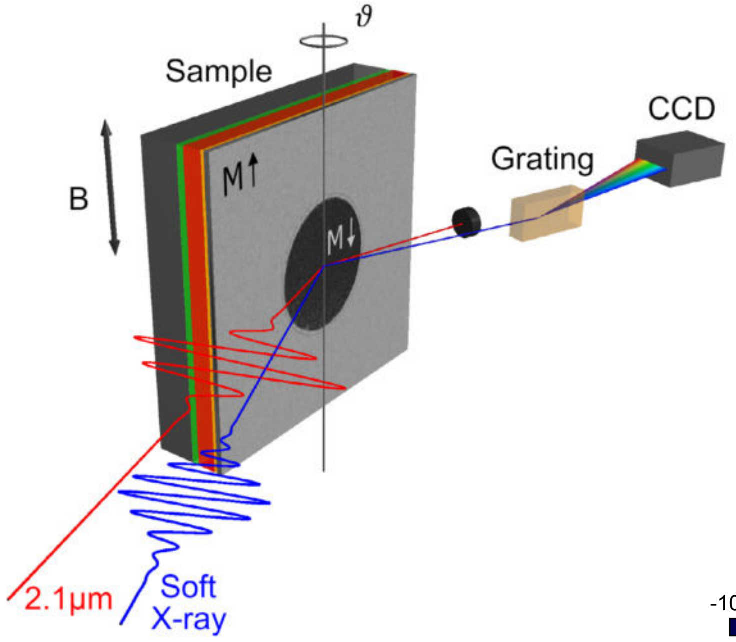

Fig.1: Schematic illustration of the experimental approach. The magnetic heterostructure is first excited by a femtosecond infrared laser pulse (2.1 µm wavelength), initiating the process of all-optical magnetization switching. A second soft X-ray pulse probes the magnetization after a variable amount of time. The spectrum of the soft X-rays reflected by the sample is then recorded using a spectrometer consisting of an optical grating and a CCD camera.

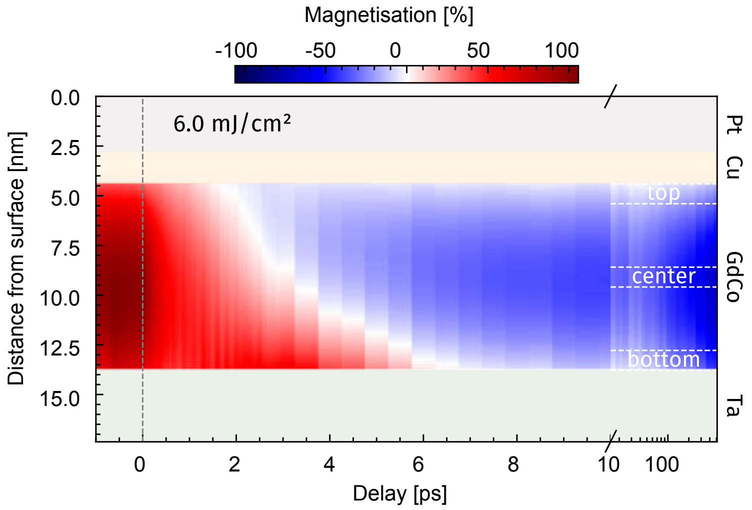

Fig. 2: Laser-induced magnetization switching of the 9.4 nm thin GdCo layer. The graph depicts the cross-section of a Pt/Cu/GdCo/Ta heterostructure and shows how the magnetization (false color scale) switches over time (x-axis) and along the depth (y-axis).

Publication

[1] M. Hennecke, D. Schick, T. P. H. Sidiropoulos, J.-X. Lin, Z. Guo, G. Malinowski, M. Mattern, L. Ehrentraut, M. Schmidbauer, M. Schnuerer, C. v. K. Schmising, S. Mangin, M. Hehn, and S. Eisebitt; Transient domain boundary drives ultrafast magnetisation reversal; Nat. Commun. 16 (2025) 8233/1-10; doi.org/10.1038/s41467-025-63571-3

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Bagged Skyrmions – Controlling Complex Magnetic States with Light

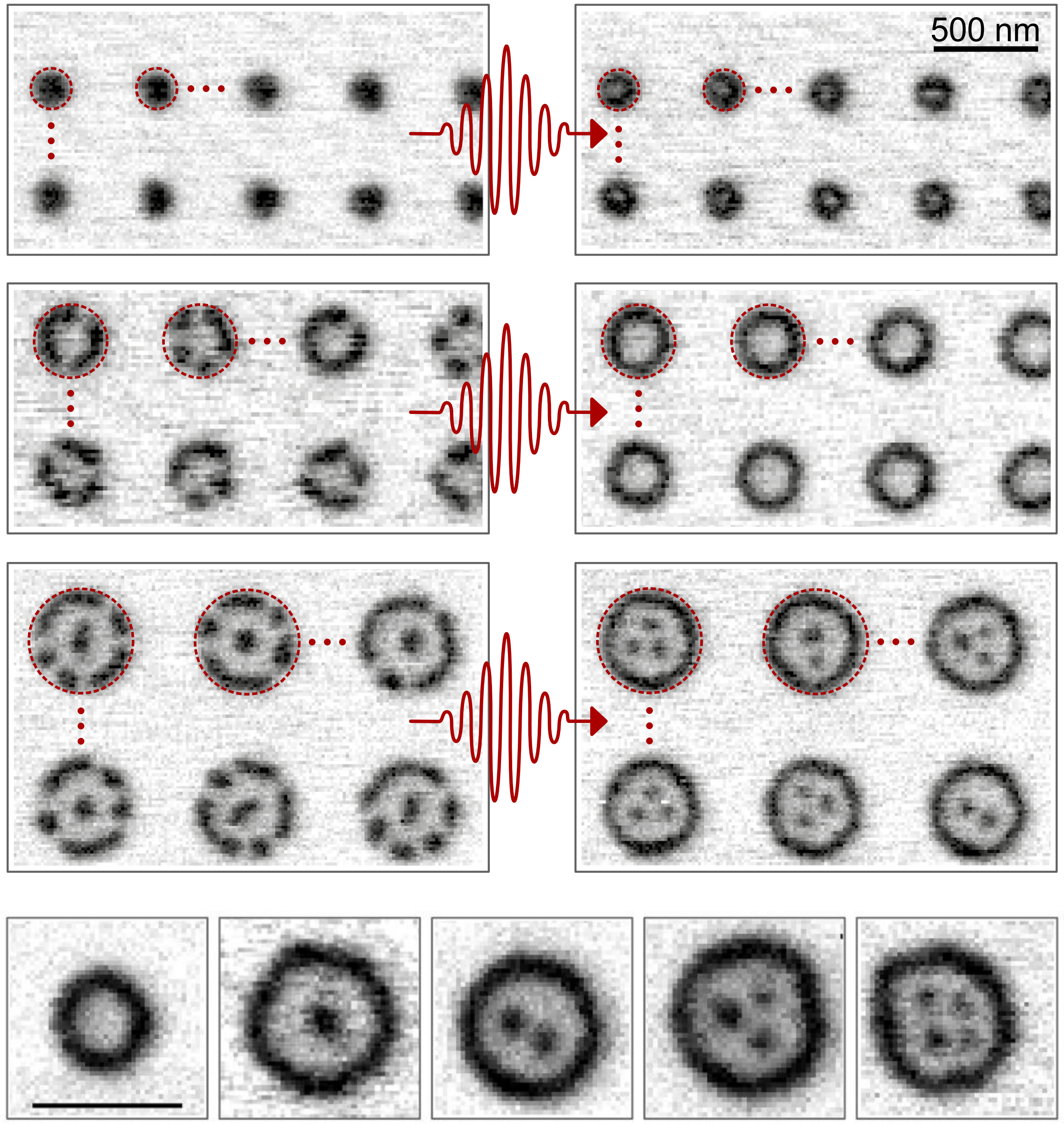
Magnetic skyrmions are topologically non-trivial nanoscale spin vortices that behave like stable, movable particles. Because they can be created, erased, and shifted by electric currents or light in thin magnetic films, they are promising building blocks for future magnetic memory and computing technologies.

While single skyrmions have been studied extensively, theory has long predicted that much more complex magnetic objects, so-called skyrmion bags, should exist. In these spin structures, several skyrmions are bundled together inside a circular magnetic domain. Until recently, however, such structures could not be generated in a controlled and reproducible way.

In 2025, researchers at the Max Born Institute (MBI) and collaborating institutions have demonstrated a practical route to create these higher-order magnetic states in thin-film materials used in modern spintronics. The key idea is to locally modify the magnetic properties of the film on the nanometer scale using a focused helium-ion beam. This process creates tiny circular regions in which the magnetic anisotropy is slightly reduced, without changing the surface topography. These invisible "magnetic templates" act as preferential sites where complex spin textures can form.

When the sample is exposed to a single ultrafast laser pulse, circular magnetic domains that can trap one or more skyrmions are reliably formed in the anisotropy-engineered regions. Depending on the size of the modified area, the researchers were able to generate empty rings as well as bags filled with up to four skyrmions (see figure), constituting objects with different topological charge. High-resolution X-ray microscopy, combined with a custom laser system developed at MBI, allowed these nanometer-scale structures to be imaged directly. This development makes it possible to now individually generate these well-defined magnetic objects. Importantly, this establishes a platform which now opens the door to study the dynamics of such structures when driven by current pulses or laser pulses in pump-probe experiments. While for simple skyrmions the dependence of the dynamics on the topology is well known, it is completely unchartered territory for more complex topological structures such as skyrmions bags.

The use of topologically non-trivial structures has been discussed in the context of novel data storage and processing applications schemes. These schemes typically depend on the dynamics of the systems to realize the desired functionality. The ability to now create these structures on demand enables systematic studies of the underlying principles of how magnetic topology determines dynamics in nanoscale systems of increasing (topological) complexity. Importantly, it will also enable the study of how such structures interact with defects and with each other, which will be pivotal for potential applications.



Magnetization maps obtained by X-ray microscopy showing the laser-induced creation of magnetic skyrmion bags. The skyrmion bags can be reliably generated from magnetic precursor configurations via a single ultrafast laser pulse at positions predefined via local anisotropy engineering. The bag size and the number of enclosed skyrmions depends on the size of the modified regions (red outlines). The bottom row of images shows a selection of skyrmion bags created with increasing number of internal skyrmions from zero to four; scalebar is 500 nm. The approach developed at MBI now enables pump-probe experiments of the dynamics of such structures.

Publication

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Light Created Information Bits

Ultrafast laser pulses generate electronic states via excitation of band extrema in two dimensional materials that can encode information states.

The writing of information in solid matter underpins the entire present day "information economy". However, this writing process, so central to contemporary life, is classical, slow, and highly energy intensive. That is to say, information is encoded as a classical bit in which definite states of 1 and 0 are represented, e.g. by the magnetization direction of a ferromagnetic film, the writing and processing occurs on time scales of hundreds of picoseconds to nanoseconds, and manipulating such information involves charge currents that generate heat. A sustainable information economy of the future requires a paradigm shift in information storage and manipulation, and light-matter interaction with quantum materials provides a key potential route by which this might be achieved.

This forms the basis of the field of "valleytronics" – the light activated excitation of one out of a pair of two inequivalent "valleys" by circularly polarized light. This particular manifold feature is illustrated in the case of graphene, as shown labeled by K and K* in panel (a), with whether charge is excited at K or K* representing the states 0 and 1. Such activation can occur on femtosecond times, orders of magnitude faster than the time to switch the magnetization in a hard drive. Well established for two dimensional materials such as certain transition metal dichalcogenides, fundamental physics related to valley wavefunction topology precludes this from occurring in materials whose spectrum is gapless, excluding key materials such as the graphene family or Weyl semi-metals.

We were able to bypass this restriction [1]. While fundamental physics dictates that a light pulse cannot excite charge at a single valley in the absence of a gap, a light pulse combining excitation and de-excitation pathways can: light is excited at both valleys, but then de-excited by the very same pulse an only one of the two valleys. This is achieved by combining a circularly polarized infrared pulse, that excites charge equally at both valleys, with a linearly polarized THz transient that induces an excitation pathway at one valley, but a de-excitation pathway at its conjugate partner. The overall result, shown in panel (b), reveals charge exclusively excited at one valley in pristine gapless graphene, on a time scale of 100 fs. This represents a strikingly novel light-matter coupling: while ultrafast laser excitation is associated with femtosecond and faster time scales, de-excitation typically occurs after the pulse on picosecond time or longer time scales, associated with relaxation processes involving an increase in entropy. Here the light pulse itself coherently drives both excitation and de-excitation at femtosecond times.

The band manifold in two dimensional materials necessarily involves two types of extrema: valleys, representing local minima and maxima, and saddles, that combine a minima in one direction with a maxima in an orthogonal direction. These can be seen labeled by "M" in panel (a). Such saddles represent a second potential feature for the lightwave imprinting of information on the Brillouin zone, but here symmetry dictates that in a hexagonal material of two inequivalent valleys there will be three inequivalent saddles. We were able to show that these three saddles can be selectively activated by pulses of linearly polarized light [2], with the polarization direction – indicated by the arrows in panels (c-e) – determining which configuration is excited. This manifests a "saddletronics" analogous to the well-established "valleytronics", but with a number of advantageous features. In particular saddles, as the band manifold is of low symmetry, are inherently current carrying unlike the high symmetry valley manifolds.

These results, taken together, thus reveal an unsuspected richness in the possibilities of employing band manifolds to "write information on a quantum material". Light pulses inducing coherent de-excitation pathways expand the class of "valley active" materials to include semi-metals such as Weyl semi-metals and graphene, while the saddle selection rule expands the available band features itself for which selective excitation by light is possible.

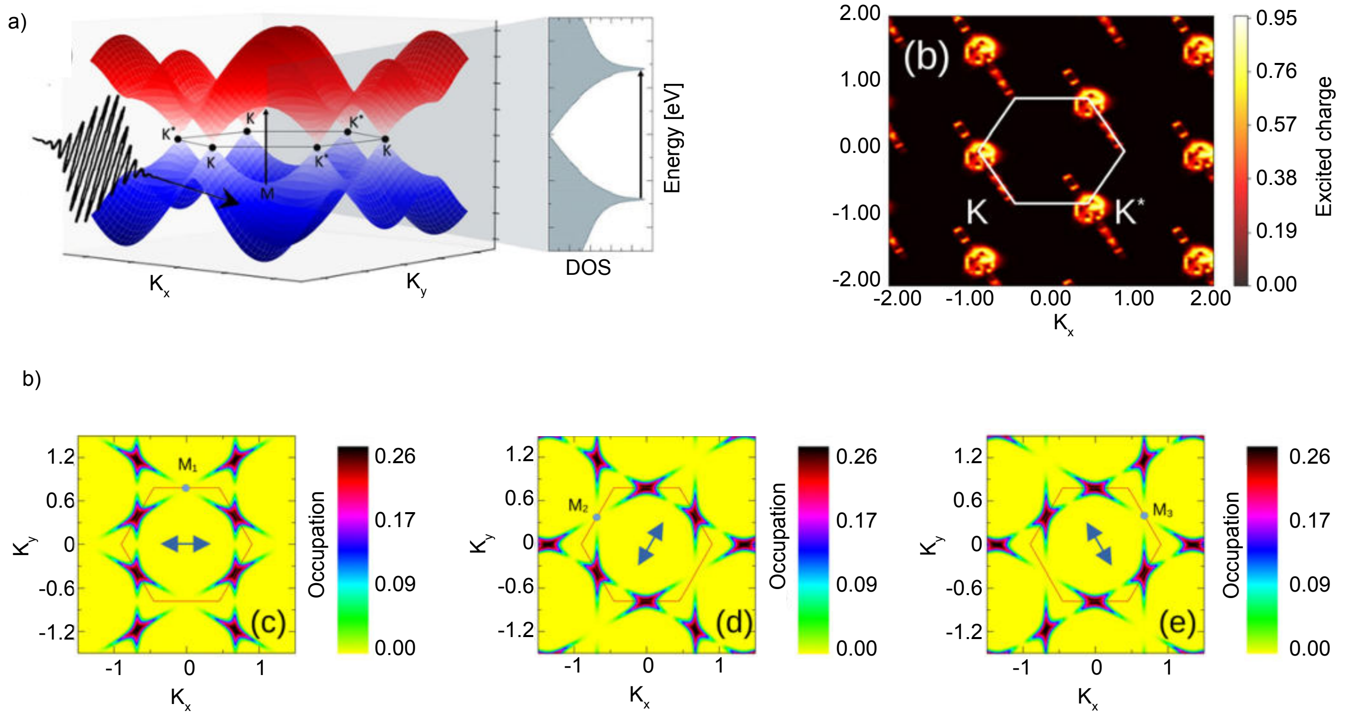

Fig 1: a) The bands of graphene possesses two distinct features characteristic of all two dimensional materials: valleys (indicated by K) and saddles (indicated by M).
b) An energy gap at the valley was widely believed to be essential for activating a specific valley with a light pulse. Combing THz and infrared light pulses we were able to design a hybrid lightform that bypassing this fundamental restriction, as can be seen in the momentum resolved excitation in graphene in which charge is excited exclusively at the K valley. (c-e) Remarkably, not only the valley but also the saddle points feature selective excitation by light. The three symmetry inequivalent M points are excited in pairs by linearly polarized light, with the polarization direction indicated by the blue double arrow. This represents a saddle analogy to the field of valleytronics: "saddletronics".*

Publications

[1] S. Sharma, D. Gill, J. Krishna, J. K. Dewhurst, P. Elliott, and S. Shallcross; Combining THz and infrared light to control valley charge and current in gapless graphene; Nano Lett. 25 (2025) 3791-3798; doi.org/10.1021/acs.nanolett.4c05487

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A New Optical Tool for Fast 3D Identification of Tiny Particles

We developed a new optical imaging method based on miniaturized frequency comb light sources that can rapidly determine both the three-dimensional shape and the chemical composition of tiny particles in a single measurement. By combining frequency combs with holographic imaging, this approach enables fast and comprehensive characterization of particulate matter, including environmentally relevant microplastics.

We developed a new imaging method that allows us to see not only the shape of tiny objects, but also what they are made of, all at once and at very high speed. Our approach makes it possible to determine the chemical composition and three-dimensional structure of small particles – from a few micrometers to several millimeters in size – in a single measurement. This combination of chemical and spatial information is particularly important for studying complex materials and pollutants that are difficult to analyze with existing techniques.

The key innovation behind our work is the use of optical microresonator frequency comb generators, a special type of light source that emits many precisely defined colors of light at once. We use microcombs with unusually large spacing between these colors, which turns out to be ideal for fast imaging. By recording how light from the microcomb interacts with a 3D object, we can capture detailed information about both its structure and its chemical properties at the same time. Because all this information is collected in parallel rather than step by step, our method reaches acquisition speeds of more than one million measurement points per second, making it one of the fastest hyperspectral imaging techniques available.

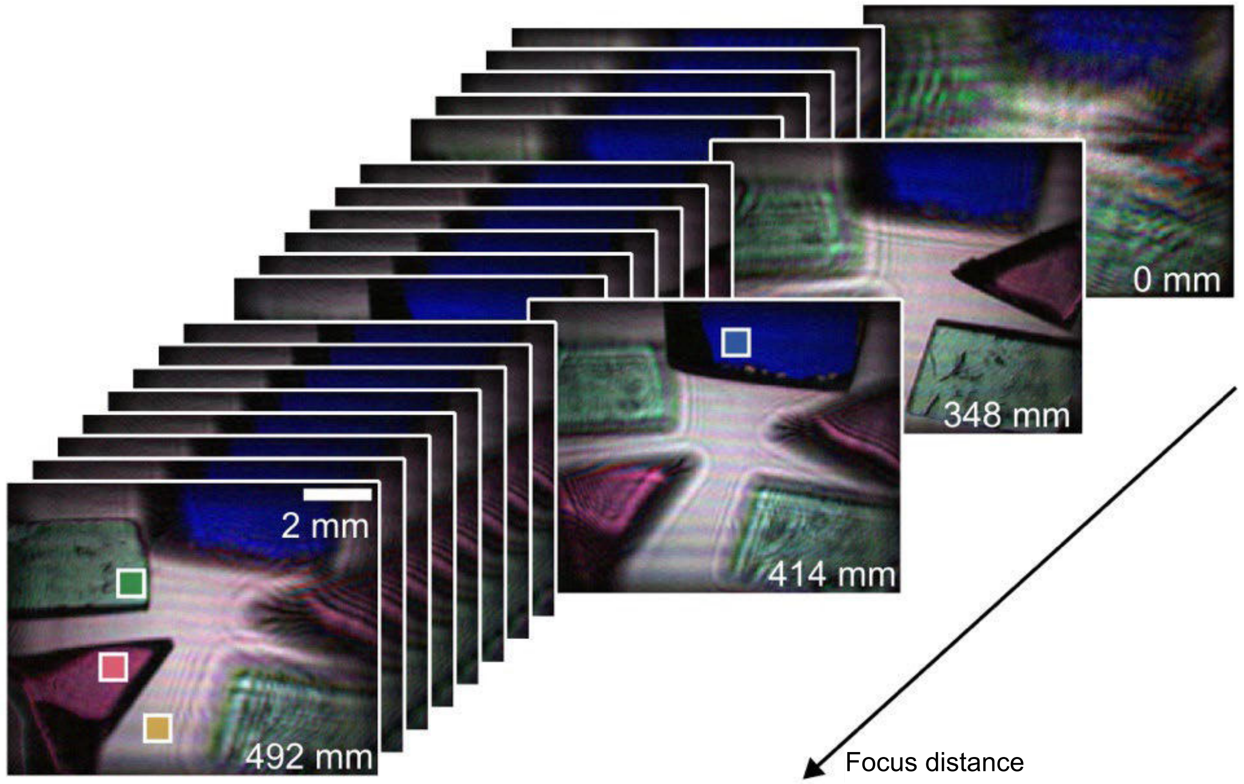
Our method combines this light source with a lensless holographic imaging approach. Instead of forming a conventional image with lenses, we record how light waves interfere after interacting with an object. From this interference pattern, we reconstruct images at different depths, effectively allowing us to “refocus” the object after the measurement. This provides true three-dimensional images. In addition, by analyzing subtle changes in the light waves, we can measure depth with very high accuracy – better than what is normally possible with standard optical imaging.

To demonstrate the relevance of our approach, we focused on particulate matter, in particular microplastics. Microplastics are now recognized as a serious environmental problem because they persist in water, soil, and air, and can accumulate in ecosystems and living organisms. Identifying microplastics is challenging, as it requires both chemical identification and information about particle size and shape. Using our technique, we showed that different types of plastic can be clearly distinguished while their three-dimensional form and position are measured at the same time, all within a single, rapid acquisition (Fig.).

Overall, our work opens the door to compact and fast instruments capable of analyzing complex particulate samples in real time. In the future, this technology could support environmental monitoring of microplastics, as well as applications in materials science, industrial inspection, and health-related studies, where rapid and reliable identification of small particles is essential.

The work has been performed in a collaboration with E. Vicentini, T. W. Hänsch (Max Planck Institute of Quantum Optics), W. Xie, J. Bowers (University of California at Santa Barbara), Y. He, Q. Lin (University of Rochester), K. Vahala (California Institute of Technology).

Fig.: Microcomb-based three-dimensional hyperspectral imaging. The samples are pieces of plastic and optical filter in transmission. Hyperspectral holographic hypercube of 256x320 pixels, reconstructed at different focus distances from 0 mm to 492 mm. They are generated from RGB color coding of the reconstructed amplitude of only three comb lines. To each pixel corresponds actually a spectrum of 25 comb lines. The measurement time is 29 s.



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100-mJ Class Few-ps Ho:YLF CPA - Transfer to Industry

100 mJ-class, few-ps, kHz Ho:YLF CPA systems operating at a wavelength of 2.05 µm have been developed to drive high-harmonic generation (HHG) and to pump midwave- and longwave optical parametric chirped-pulse amplifiers (OPCPA). In 2025, the Ho:YLF CPA technology was successfully transferred to Class5 Photonics.

In recent years, the development of high-energy, ultrashort-pulse lasers with wavelengths around 2 µm has attracted considerable interest due to their numerous applications, including the generation of high harmonics, XUV frequency combs and hard X-rays. Apart from basic research, powerful 2 µm sources substantially benefit several applications in laser-based medical treatment, atmospheric sensing, and material processing. Furthermore, high-performance pump sources operating at wavelengths of around 2 µm and beyond are effective in generating high-energy, ultrashort pulses in the mid- and long-wave infrared spectral range via parametric down-conversion.

The most attractive approach to generating high-intensity laser pulses centred around 2 µm is direct amplification of ultrashort pulses using the chirped pulse amplification (CPA) technique. The preferred optical transitions in the 2 µm spectral range are based of Ho-, Tm- or Cr-ions. Although Cr- and Tm-doped ultrafast amplifiers have been demonstrated with multi-mJ pulse energy at kHz repetition rates, no system has yet exceeded the 10 mJ level. Of the Ho-doped gain media, only Ho:YLF has been able to surpass few-ps pulses at this energy level.

The Ho:YLF CPA systems developed at MBI have been successfully used as drivers for HHG and as pumps for midwave and longwave OPCPAs, delivering exceptional performance parameters. Ho:YLF CPA is implemented with a high-gain regenerative amplifier (RA) and a two-stage booster amplifier (Fig. 1a). Generation of 75 mJ pulses with a duration of 2.2 ps at a repetition frequency of 1 kHz is demonstrated. A peak power of 31 GW is achieved for the 2050 nm pulses. The CPA exhibits remarkable stability with a rms pulse-to-pulse variation as low as 0.19 %. The RA operates without any signs of bifurcation, delivering 22 mJ pulses. Seeding the booster amplifier with the RA output linearly scales the pulse energy beyond 70 mJ. The amplifier system is operated at room temperature and shows a high extraction efficiency of 22 % with respect to the optical pump power. [1] Building on the demonstrated feasibility of post-compression of high-energy, 2 µm, few-ps pulses to sub-100 fs, we plan to shorten the pulse duration using cascaded post-compression stages to further increase the peak power.

The core component of the Ho:YLF CPA is the RA. Due to operating at repetition rates close to the inverse upper state lifetime of the active medium, nonlinear dynamics influence the operation (Fig. 1b). This was carefully analyzed, resulting in the control of the bifurcation dynamics in the RA and an outstanding stability (Fig. 1c).

Our Ho:YLF CPA systems are unique in terms of the output parameters delivered. This achievement attracted the attention of industry leaders, resulting in a successful transfer of this technology to Class5 Photonics in 2025. his Ho:YLF CPA contains a compact, Yb-fibre-driven, single-stage OPA front end and has an overall footprint of less than 3 m². We achieved further energy scaling exceeding 100 mJ at 1 kHz repetition rate by adding a third booster stage. [3]

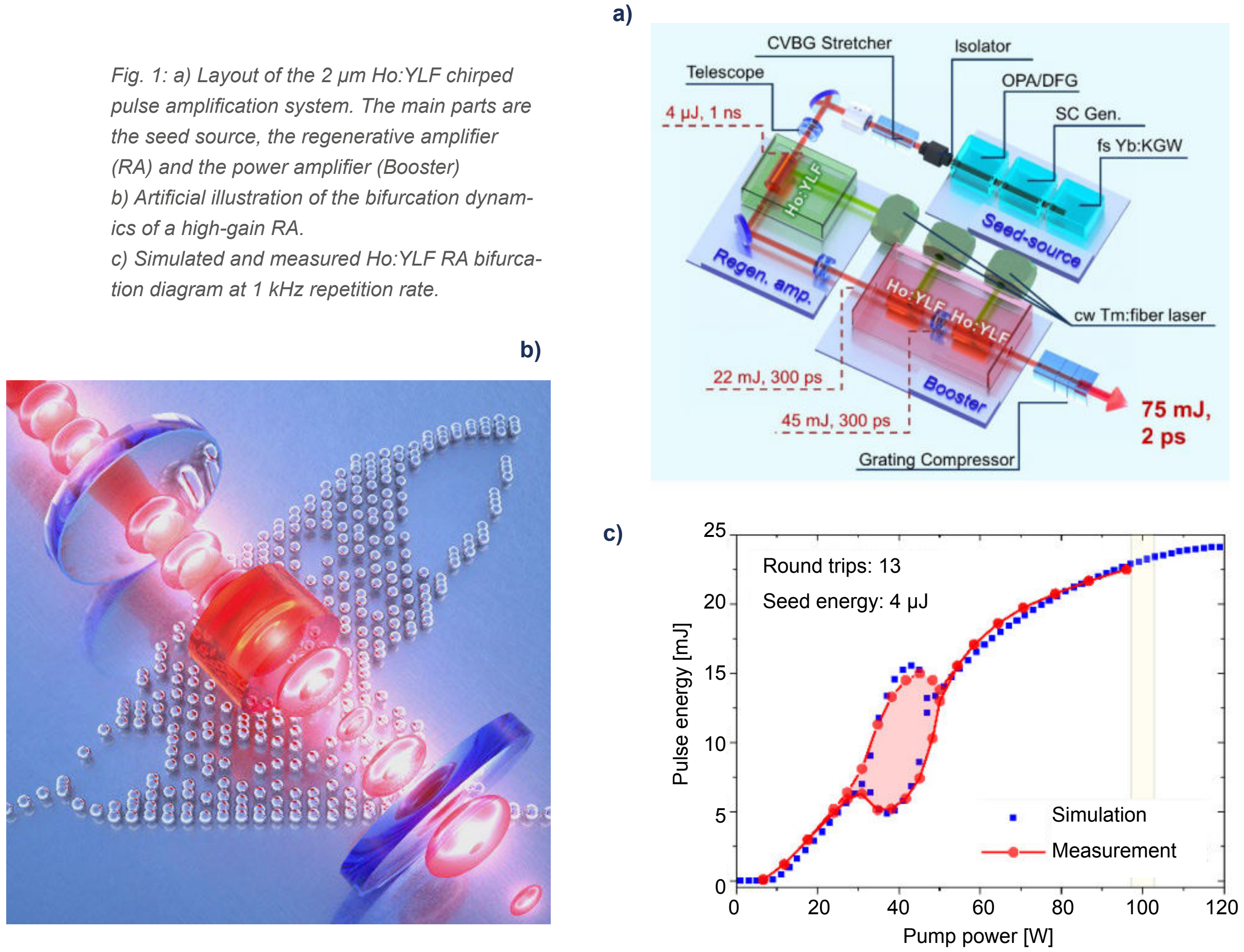

Fig. 1: a) Layout of the 2 µm Ho:YLF chirped pulse amplification system. The main parts are the seed source, the regenerative amplifier (RA) and the power amplifier (Booster)
b) Artificial illustration of the bifurcation dynamics of a high-gain RA.
c) Simulated and measured Ho:YLF RA bifurcation diagram at 1 kHz repetition rate.

Publications

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[2] www.class5photonics.com/

[3] P. Merkl, et al.; Photonics West 2026, PW13873-16

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Breaking Geometric Limits in Broadband Spectroscopy

We demonstrate a broadband spectrometer that breaks the geometric limits traditionally linking spectral resolution to optical path length. Using frequency-comb-based dual-comb interferometry, we achieve megahertz-level resolution over terahertz bandwidths within fractions of seconds, accessing a regime that was previously unattainable with any conventional spectrometer.

Broadband optical spectroscopy has a long history, beginning with Newton's use of the prism to reveal the spectral composition of light and to associate color with a measurable physical quantity. Fraunhofer's discovery of discrete spectral lines and his invention of the diffraction grating enabled the first precise wavelength measurements, while Michelson's interferometer, with further input from Rayleigh, introduced an alternative, powerful route to spectral analysis based on interference. This latter approach ultimately evolved into Fourier transform spectroscopy, which became the dominant technology for broadband spectroscopy in the second half of the twentieth century and remains widely used across physics, chemistry, and biology.

Despite their diversity, all broadband spectrometers developed so far share a fundamental limitation: their resolving power is set by geometry. Whether dispersive or interferometric, spectral resolution is determined by the ratio between a maximum optical path difference and the wavelength. Achieving high resolution therefore requires large path differences, leading to bulky instruments whose performance is ultimately constrained by optical aberrations, wavefront distortions, and mechanical stability. This geometric constraint has shaped spectrometer design for over a century.

In this work, we demonstrate a fundamentally different class of broadband spectrometer – one that is freed from geometric limitations. Using a dual-comb interferometer based on optical frequency combs, we perform broadband spectroscopy in which the resolving power is determined by time rather than by physical path length. We experimentally achieve a resolving power of 4 10^{8}, corresponding to a spectral resolution of 1 MHz, over a bandwidth exceeding 1 THz. Achieving such a resolution with a conventional Fourier transform spectrometer would require an excursion in optical path difference of approximately 300 m, far beyond any practical implementation.

Crucially, this resolution is reached within fractions of seconds and in a single measurement. To reach an equivalent 300 m path difference within the same measurement time using a Michelson interferometer, a moving mirror would have to be scanned at velocities approaching 100 m s^{-1}. A regime of spectral resolution, bandwidth, and acquisition speed that was previously unattainable in any broadband instrument is thus open.

Our approach relies on pulse-picked dual-comb spectroscopy, in which two frequency combs interfere to directly map optical frequencies into the radio-frequency domain. By generating a comb with a very narrow line spacing while maintaining a broad spectral span, we directly interrogate the spectrum with high resolution and precision, while our very long mutual coherence is key to these new frontiers.

By experimentally demonstrating broadband spectroscopy at resolutions previously unreachable in a single recording, we establish a new paradigm for precision spectroscopy. This geometry-free spectrometer concept paves the way for compact, high-resolution, and high-speed instruments, with potential impact ranging from fundamental tests of physics to applications in atomic and molecular spectroscopy, metrology, and beyond.

The work has been performed in a collaboration with T. W. Hänsch (Max Planck Institute of Quantum Optics, Ludwig Maximilian University of Munich).

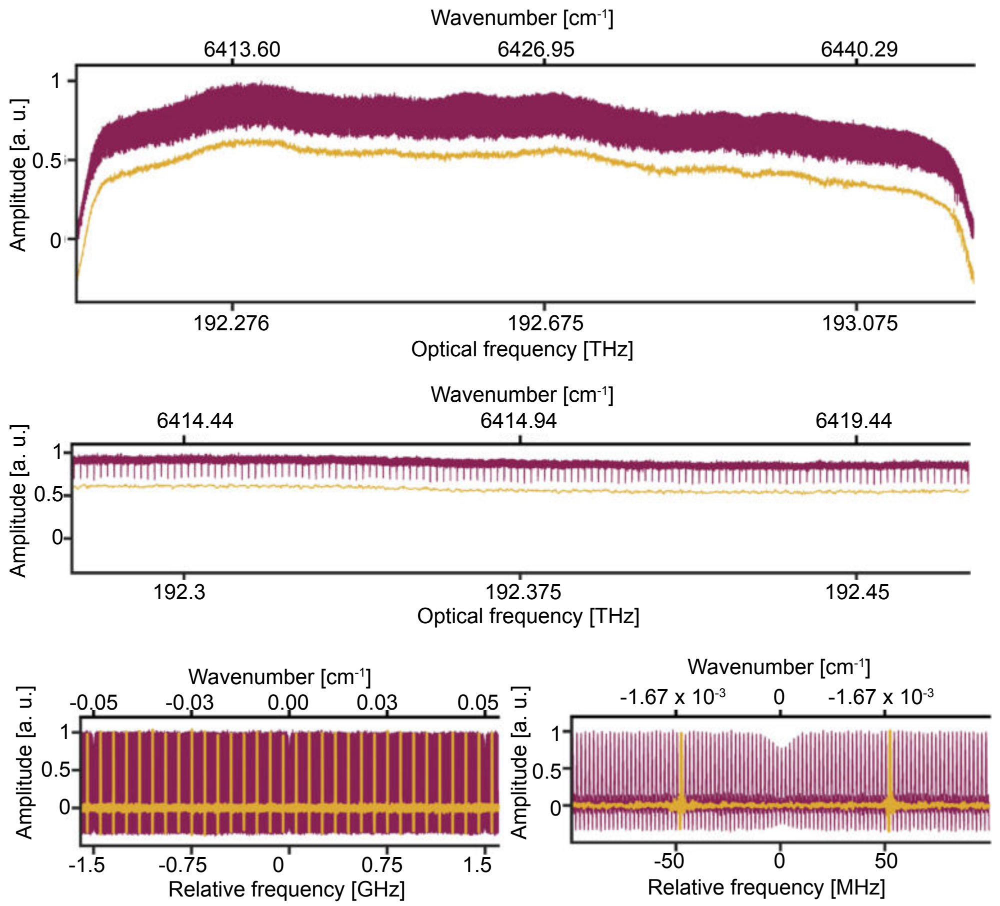

Fig.: Experimental dual-comb spectra of a high-finesse Fabry-Perot resonator interrogated with a comb of 1 MHz line spacing (red) and 100 MHz line spacing (yellow) with different magnifications. The resonances are not observed when the sampling is performed with the 100 MHz comb.

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Ultrafast Sensing and Manipulation of Chirality

Chirality is of paramount importance in nature. At the molecular scale, two molecules that form non-superimposable mirror images of each other form a pair of chiral enantiomers. Like choosing between our chiral left or right hand for a handshake, choosing one of the enantiomers to interact with another chiral entity will result in a different outcome.

Most biological molecules are chiral, with their chirality controlling metabolic reactions in living organisms. Not surprisingly, chirality a key property for drug design, with the ever-growing need for efficient and fast sensing of chiral molecules. Traditional chiro-optical sensing methods using conventional linear or circularly polarized light are limited in their efficiency and speed for small and medium-size chiral molecules in small quantities. Can we tailor light to maximize the efficiency of its enantio-sensitive interaction with chiral molecules?

The MBI team has developed such light. Its chirality is encoded in time: the electric field vector of this light traces a chiral figure during a laser cycle. This temporally chiral light is able to imprint spatial chirality on achiral objects and/or trigger enantio-sensitive ultrafast electronic or vibronic current, such that these currents are significantly different in left-handed or right-handed molecules. As a result, the temporally chiral light can generate enantio-sensitive non-linear optical response that is orders of magnitude stronger than the optical response in conventional chiro-optical methods, which rely on linear optical response and utilize weak interaction with the magnetic field component of light. Endowing temporally chiral light with spatial structures, such as using vortex beams, leads to yet another new object: chiral topological light [1]. This light triggers nonlinear optical response with different spatial structures and intensities in left-handed and right-handed molecules, leading to enantio-sensitive rotation of the spatial profile of high harmonics, see figure. It also makes enantio-sensitive response robust with respect to fluctuations in laser intensity, imperfect focusing, temporal shapes, or polarization. What is more, ultrafast chiral currents triggered in molecules by light pulses can control enantio-sensitive outcomes of photo-chemical reactions, opening a new field of enantio-sensitive attosecond photo-chemistry [2, 3].

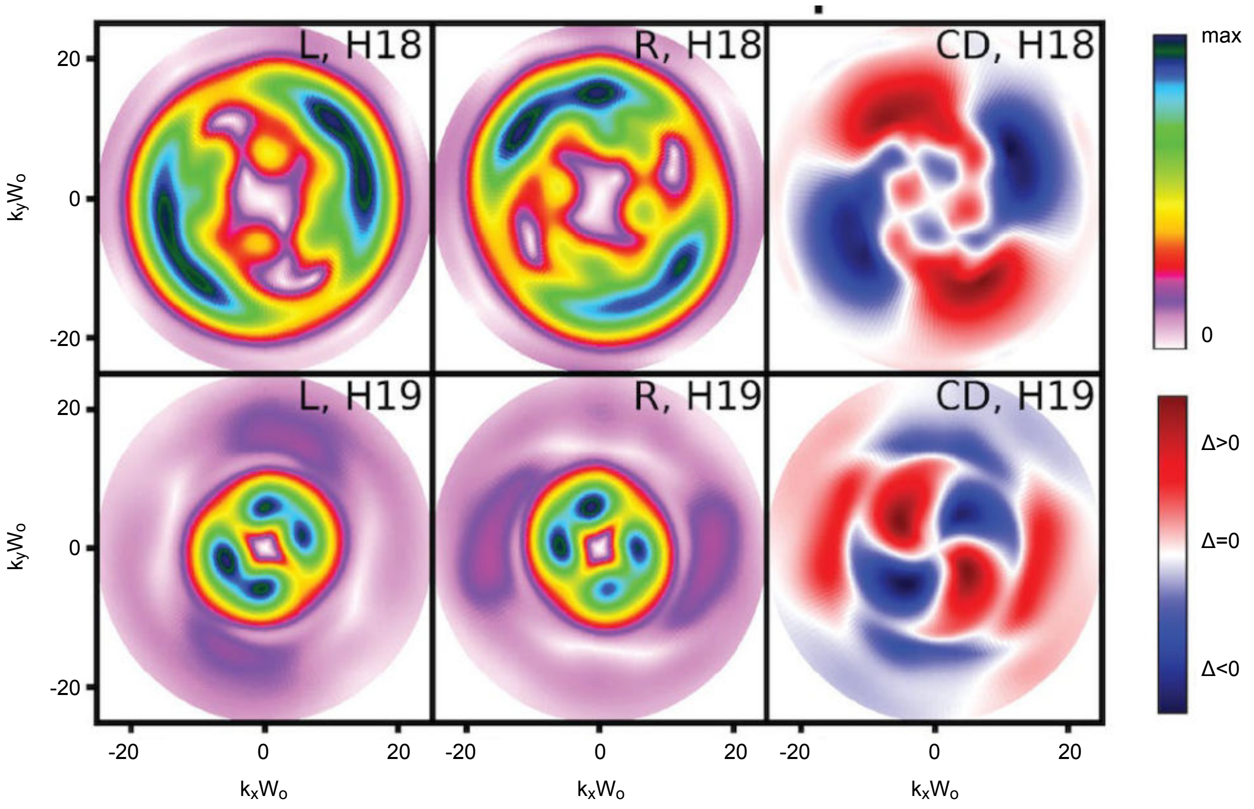

Fig.: Distinguishing left-handed vs. right-handed enantiomers of fenchone using chiral topological light. The chiral topological light is created by focusing two vortex beams of counter-rotating 800 nm and 400 nm elliptically polarized beams to 10 mm focal spot. The two vortex beams carry opposite topological charges of +/- 1. The figure shows far-field profile of harmonic 18 (top row) and harmonic 19 (bottom row) for left-handed (L) and right-handed (R) fenchone molecules and the circular dichroism in emission intensity (adapted from [1]).

Publications

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Ultrafast Valleytronics in Inversion-Symmetric Multilayer MoS_2

The valley degree of freedom in 2D materials such as Transition Metal Di-Chalcogenides (TMDCs) opens an intriguing route towards information storage and processing. In such materials, the hexagonal lattice leads to the hexagonal structure of the Brillouin zone (see figure).

The six corners of the hexagon show energy minima – the so-called valleys – in the conduction band, and the corresponding energy maxima in the valence band. While the adjacent valleys are energy degenerate, they have nonzero Berry curvature with opposite signs. Excitation of one or the other of the two adjacent valleys can be viewed as a single qubit of information. Selective excitation of the desired valley can be done by using circularly polarized laser pulse tuned in resonance with the transition between the valence and the conduction bands. The valley is selectively excited when the light circularity matches the sign of the Berry curvature. Changing the circularity of the exciting pulse excited the opposite valley. So far, utilizing this degree of freedom could only be done in 2D materials with broken inversion symmetry. However, readily accessible TMDC materials come as ‘‘sandwiches’’ of multiple monolayers stacked on top of each other, with each new layer rotated by 180 degrees relative to the previous one. In such ‘‘sandwiches’’, the inversion symmetry is restored, the Berry curvature is equal to zero, and optical selection of the desired valley appears no longer possible. Our recent work [2] has changed this common view, extending our proposal [1] to multi-layer materials.

We have shown [2] that valley selective excitation can be achieved in inversion symmetric materials by using non-resonant light field made of counter-rotating fundamental and its second harmonic. This field creates a trefoil structure during its laser cycle, which field breaks both inversion and time-reversal symmetries, turns a trivial material into topological, and lifts the energy degeneracy of the two valleys. What is more, the energy difference between the two valleys is controlled by the orientation of the trefoil petals relative to the hexagonal structure of the lattice, i.e. by tuning the sub-cycle delay between the two pulses. This allows one to select the desired valley by simply rotating the trefoil petals, tuning the difference between the valley energies on the sub-optical cycle time-scale.

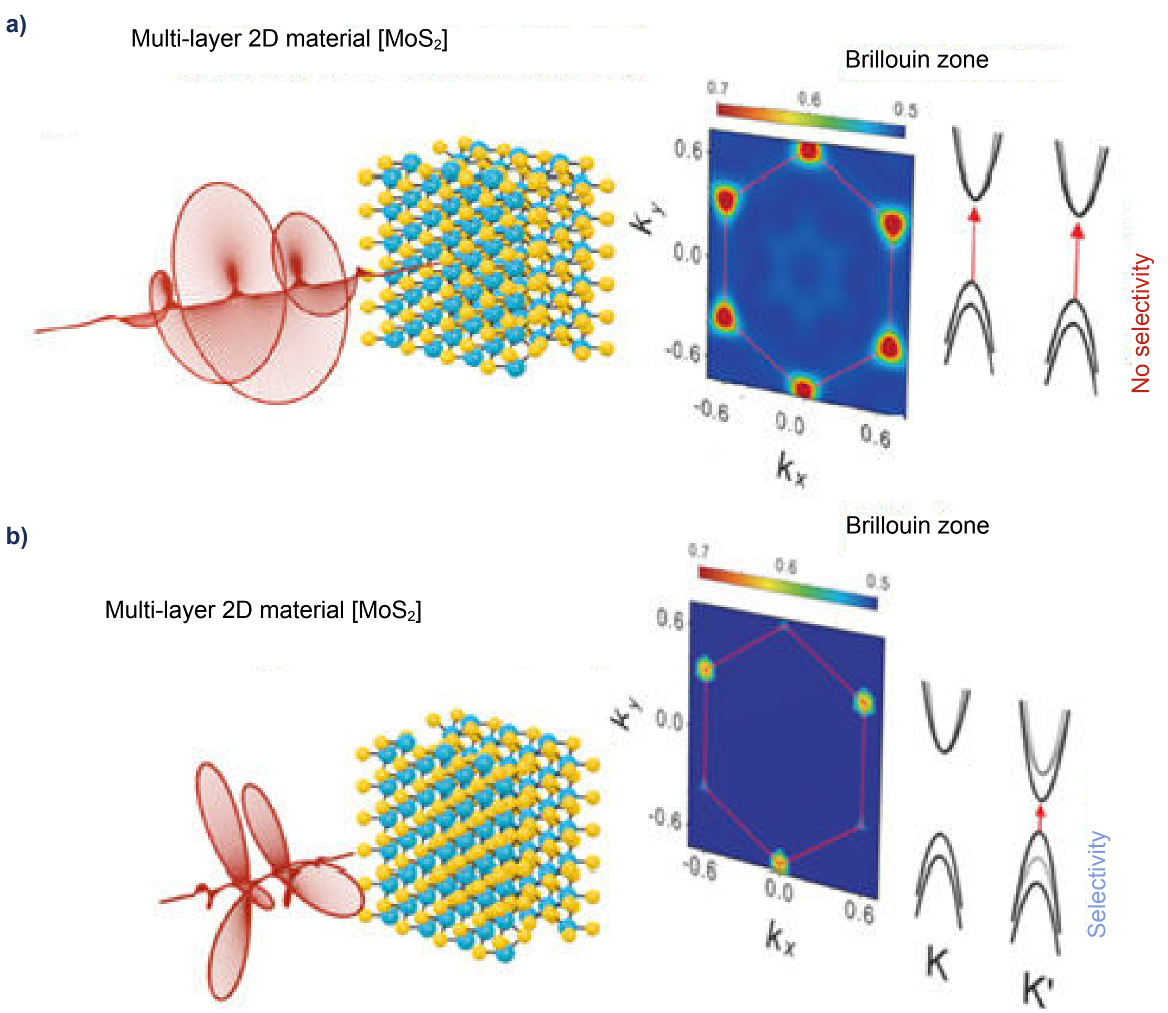

Fig.: Valleytronics in inversion-symmetric multilayer hexagonal TMDC materials.
Conventional approach developed for monolayers with broken inversion symmetry uses circularly polarized light tuned on resonance with the bandgap. In monolayers, the valley is selected by matching the light circularity to the Berry curvature, which is opposite in the two valleys. In multi-layer materials with restored inversion symmetry this standard method no longer works (panel a). However, a field created by combining counter-rotating fundamental and second harmonic restores valley selectivity even in inversion-symmetric multi-layer materials (panel b). Valley selection is achieved by simply rotating the trefoil created by the two-color field relative to the hexagon of the lattice (adapted from [2]).

Publications

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doi.org/10.1038/s41586-024-07156-y

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High Harmonic Generation of Massively Entangled Bright States of Light

At the fundamental level, light-matter interaction is fully quantum – both for matter and for light. However, for standard laser sources, classical description of light during intense laser-matter interaction is expected to be adequate.

This expectation extends not only to the incident light, but also to the nonlinear optical response it generates. However, new light frequencies generated by non-equilibrium dynamics in matter start from the vacuum state: no photons at new frequencies are initially present. Why should one apriori assume that the generated light should be classical, i.e. arise in the displaced coherent state? What are the conditions under which this assumption is valid? Is large number of generated photons at the new frequencies sufficient to neglect the intrinsic quantum properties of the generated light? Can one ignore entanglement between the generated light and the quantum state of the material system, or can one find ways to harvest it?

Surprisingly, up until very recently, these questions have not even been on the horizon of ultrafast spectroscopies or quantum optics. The same can be said about high harmonic generation, the workhorse of attosecond technology: the quantum aspects of high harmonic light and the associated attosecond pulses have been virtually ignored.

The situation has started to change in the last two-three years, propelled by two complementary approaches. The first relies on using bright quantum states of light as the driving field. The second uses standard light sources to drive harmonic generation, but takes advantage of conditional measurements to transform the generated states of light from classical into quantum.

We have developed a completely new concept for generating massive quantum states of light in the UV-XUV frequency range, complementary to the two routes above. We show that non-trivial quantum states of harmonics are generated as soon as one induces real excitations into different electronic states of the quantum system dressed by a semi-classical laser field. Such states are typically referred to as the Floquet states. Real excitations of several Floquet states imply resonances induced between them. We have been able to show that resonances induced by dynamic Stark shifts lead to controlled entanglement between multiple high harmonics, and that continuous resonances during the whole driving pulse lead to strong squeezing of the generated light, as shown in figure.

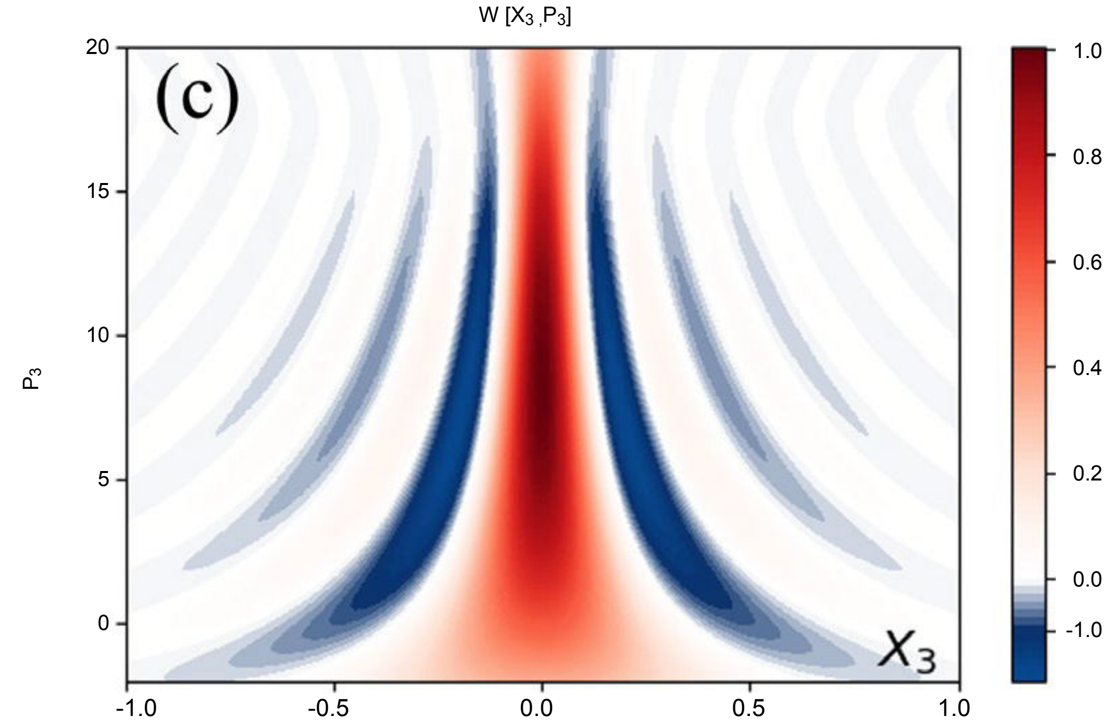

Fig.: Quantum nature of resonant harmonic generation in Na vapors
The figure shows the Wigner function of the third harmonic of a 1770 nm incident laser field which drives a Na vapor. The driven is chosen such that its third harmonic is one-photon resonant with the strong 3s-3p transition in Na. The driving field intensity is 3.1011 W/cm^2, while the third harmonic is 10$_4$ times weaker.

Publication

S. Yi, N. D. Klimkin, G. G. Brown, O. Smirnova, S. Patchkovskii, I. Babushkin, and M. Y. Ivanov; Generation of massively entangled bright states of light during harmonic generation in resonant media; Phys. Rev. X 15 (2025) 011023/1-15, doi.org/10.1103/PhysRevX.15.011023

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Short Description of Research Projects

Lasers and Light-Matter-Interaction

Ultrafast and Nonlinear Phenomena: Gas Phase

Ultrafast and Nonlinear Phenomena: Condensed Phase

Laser Infrastructure and Knowledge Transfer

Fundamentals of Extreme Photonics

The project focuses on the development of theoretical concepts and tools for describing ultrafast, nonlinear light-matter interaction. It aims at both aiding and guiding experimental developments at the MBI and worldwide in ultrafast spectroscopy. The research includes studies of ultrafast electron and spin dynamics in atoms, molecules, and solids triggered by tailored light fields, light propagation in complex plasmonic systems and nano-structured materials, generation of quantum states of light during nonlinear light-matter interaction, studying how structured light can be used for efficient sensing chiral molecules and for tailoring optical response in quantum materials.

Topic 1 Real time description of Ultrafast Electron and Structural Dynamics

This topic covers theoretical modeling of charge and spin dynamics in atoms, molecules and solids interacting with light. In atoms, we have shown very high degree of spin polarization generated both in one-photon and multi-photon ionization, with applications to generating relativistic spin-polarized electron beams in compact particle accelerators. In solids, the project develops theoretical and computational tools for studying the response of electron charge and spin dynamics to light. In particular, THz switching of magnetization at metallic interfaces was predicted, opening a remarkable new route in spintronics. In transition metal dichalcogenides (TMDCs), attosecond control over light polarization and carrier oscillations under the envelope has revealed the possibility to control selective population of the desired parts of the Brillouin zone on few femtosecond time-scale.

The use of multi-color light with attosecond control over the time-delay between the colors allows one to control the topological properties of 2D materials. We have shown how the combination of counter-rotating fundamental and its second harmonic fields, phase locked with attosecond precision, allows one to generate selective valley excitation in inversion-symmetric multi-layer TMDC materials, where traditional valley control approaches fail.

In strongly correlated materials, our work predicts the possibility of switching between metallic and insulating phase of a cuprate LaCuO4, a high-temperature superconductor, on a sub-optical-cycle time scale, and proposes a novel multi-dimensional spectroscopic approach for its experimental observation.

Topic 2 Attosecond Quantum Optics

This topic focuses on theoretical studies at the interface of attosecond science, quantum optics and fundamental quantum mechanics. Until recently, intense light-matter interaction has been described using the so-called semiclassical approximation, where both the incident and the generated light are treated classically while the material dynamics is treated quantum mechanically. However, it was discovered that fundamental quantum mechanics also manifests in the quantum states of the generated light. In particular, high harmonic generation, the foundation of attosecond technology, may yield harmonic light in squeezed or entangled quantum states. Recent results include the development of a completely new concept for generating massive quantum states of light and the design of photonic structures for tailoring the nonclassicality of light states. In particular, new methods for generating bright squeezed states of light in the UV-XUV frequency range, for tailoring the nonclassical properties of two interacting quantum optical fields in integrated waveguide couplers, and for generating two-mode squeezed vacuum states were developed.

Topic 3: Ultrafast chirality

This topic focuses on attosecond electronic and vibronic response in chiral molecules. Molecules are called chiral when they cannot be superimposed on their mirror image, just like our left and right hands. These two mirror images, called enantiomers, play a critical role in living matter. Just like choosing between our left or right hand for a handshake, choosing one of the enantiomers to interact with another chiral entity will result in a very different outcome, making chirality a key property in drug design and medicine, among many other applications. In a series of recent papers, we have shown how electronic and vibronic currents generated in chiral molecules open new opportunities not only for sensing the molecular handedness, but also for dictating the fragmentation directions of chiral molecules during photolysis, thus enabling a new protocol for charge-directed chemistry.

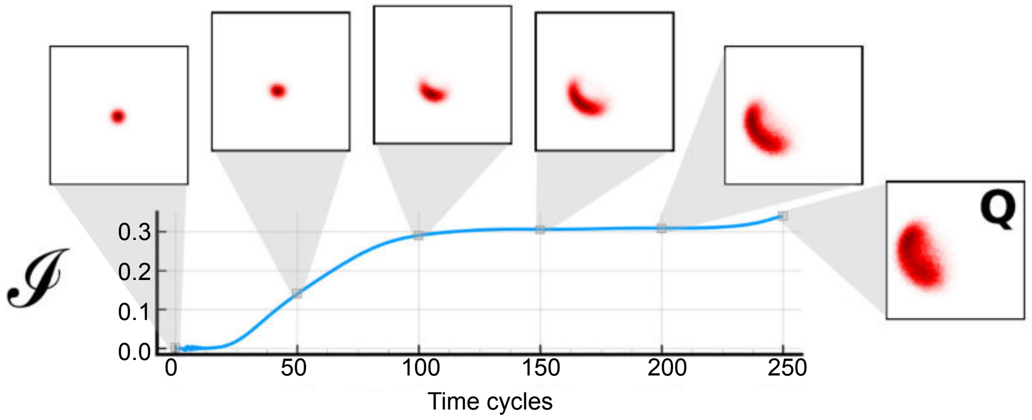

Fig. 1: The development of quantum correlations between 10 pseudospins placed inside a resonant cavity and driven by an external resonant classical field is illustrated by the parameter J, which would reach unity for a fully entangled state. The evolution of the Husimi representation of the generated light, shown in the insets, demonstrates clear deviations from the minimum uncertainty Glauber coherent state (round image at early times). Rapid growth of many body correlations is accompanied by the growth of the non-classical signatures in the generated light.

Topic 4: Optics and Photonics in structured media

This topic focuses on theoretical studies of light-matter interaction and light propagation in structured photonic environments. Tailored photonic environment, such as nano-structures and plasmonic systems, is used to enhance light-matter interaction, to control processing of information carried by light, or to improve sensing of molecules, among others. A comprehensive set of numerical codes developed in the project, which includes a discontinuous-Galerkin time-domain finite-element simulation approach, allows one to address design of nanostructures tools for enhanced molecular sensing, obtain a complete description of localized particle plasmon polaritons, and capture effects in the excitation of nanostructures by a penetrating beam of swift electrons.

The key component of the theoretical developments in this topic is the theory non-Hermitian quantum photonics, which rigorously accounts for gain and loss in structured photonic environments and shows how their interplay can be used for optimizing signal transmission, protection of desired modes against losses, coupling of modes inside and between the waveguides, and so on.

SHORT OUTLOOK

We plan to focus on the following questions:

- Using light to tailor the quantum properties of both quantum materials and the nonlinear response they generate.
- Application of attosecond-sculpted light for sensing molecular handedness in an efficient way.
- Tailoring nano-structured materials for enhanced photonic and quantum information applications.

HIGHLIGHTS

- Ultrafast valleytronics in inversion-symmetric multilayer MoS_2
- Ultrafast sensing and manipulation of chirality
- High harmonic generation of massively entangled bright states of light

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Ultrafast and Ultraprecise Laser Physics & Nonlinear Optics

Project 1.2 focuses on the development of ultrafast light sources for ultrafast and nonlinear optical spectroscopy. MBI advances the field through the creation of novel, non-commercial light sources with record-breaking performance, positioning ultrafast technology itself as a core research objective.

The project serves as MBI's central platform for research in nonlinear optics and laser physics, emphasizing the development of advanced light sources and time-resolved techniques. Its primary aim is to strengthen MBI's research on ultrafast and nonlinear light-matter interactions through state-of-the-art technologies emerging from original research activities. Depending on the intended application, development priorities include high pulse energy, ultrashort pulse duration, carrier-envelope phase stability, or high average power and repetition rates. A further objective is to provide few-cycle pulses across a broad spectral range, spanning from the THz to the soft X-ray regime. Accordingly, the project encompasses primary laser and parametric sources, as well as pulse compression and wavelength conversion, with these unique sources supporting research in Program Areas 2 and 3.

A new research direction within project 1.2 addresses the development of advanced optical frequency comb systems that extend well beyond the current state of the art. Emerging applications require access to spectral regions beyond the near-infrared and visible, including the ultraviolet below 200 nm and the mid-infrared between 5 and 20 µm, as well as comb line spacings not currently achievable. Long-term goals include low-noise ultraviolet frequency combs and high-power combs with low repetition frequencies for broadband precision spectroscopy. These developments pose stringent phase-noise requirements, with individual comb lines much narrower than 1 Hz, but remain compatible with amplifier-based architectures and efficient nonlinear frequency conversion. The project also explores integrated photonics approaches, including chip-based combs with repetition frequencies of hundreds of megahertz for gas-phase spectroscopy or with large line spacings for imaging and condensed-phase spectroscopy. Extending integrated platforms outside the telecom region is one of the main challenges. Finally, project 1.2 plans the use of quantum technologies for frequency combs suited to applications at low light levels.

As one part of our endeavours, we recently demonstrated self-compression of 2.5 mJ pulses at 5-µm wavelength exploiting spatial Townes solitons for the first time, which results in a reduction of pulse durations from 80 to 37 fs. The compression regime is situated slightly below the onset of small-scale filamentation, yielding two-cycle pulses with 2.0 mJ energy. Despite a high throughput of 80 %, this method is accompanied by a nearly undisturbed beam profile and excellent spectral homogeneity across the beam profile, which sets the scheme apart from other bulk compression schemes. The resulting peak power of 45 GW in a 1 kHz pulse train constitutes a new record value beyond 4 µm wavelength.

Another notable achievement is the recent demonstration of soliton and modulation-instability microcombs based on a low-loss 4H silicon carbide nanophotonic platform operating in the 110-240 THz (2.7-1.25 µm) region. Our dispersion-engineered microresonators are driven by a narrow-linewidth continuous-wave parametric oscillator. They exhibit quality factors of around 7x105 at 120 THz. The threshold for parametric oscillation is as low as 1 mW of on-chip power. We have demonstrated octave-spanning spectra, as well as the generation of perfect soliton crystals and dissipative Kerr solitons with a line spacing ranging from 90 GHz to 5.8 THz.

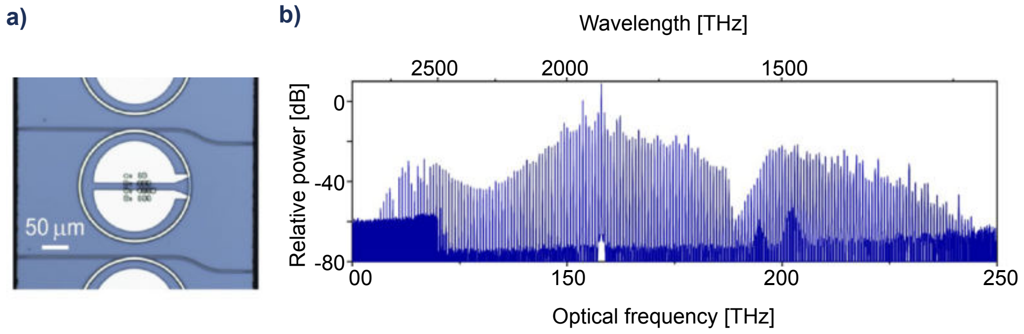
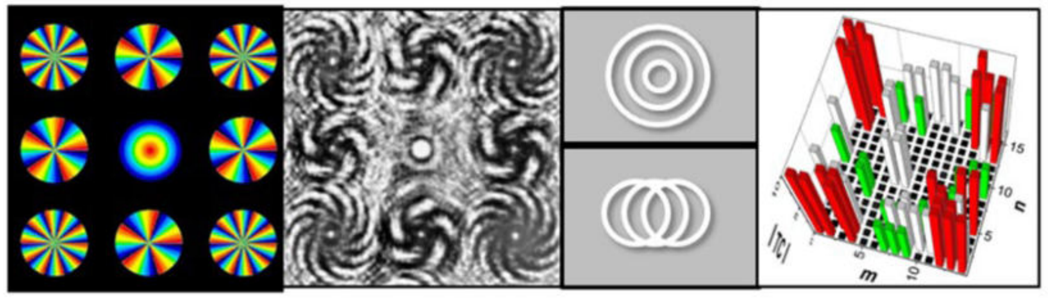


Fig. 1: Microcomb generation in high-quality factor SiC microresonators.
a) Optical microscope picture of a microresonator of a radius r = 110 µm.
b) Microcomb with a line spacing of 725 GHz.
More than 180 comb lines span over a range broader than 130 THz at -40 dB.

Fig. 2: Spiral-shaped interference patterns of orbital angular momentum (OAM) beams are analyzed by combining polar mapping and Fourier Transform algorithms. Single vortices are characterized by determining angular frequencies along concentric circular cuts (Fixed Circle Fourier Transform). To analyze beam arrays with unknown centroid positions, the procedure is performed for a matrix of origins sampling the field of interest (Scanning Circle Fourier Transform). The capability to recognize characteristic vortex features promises new



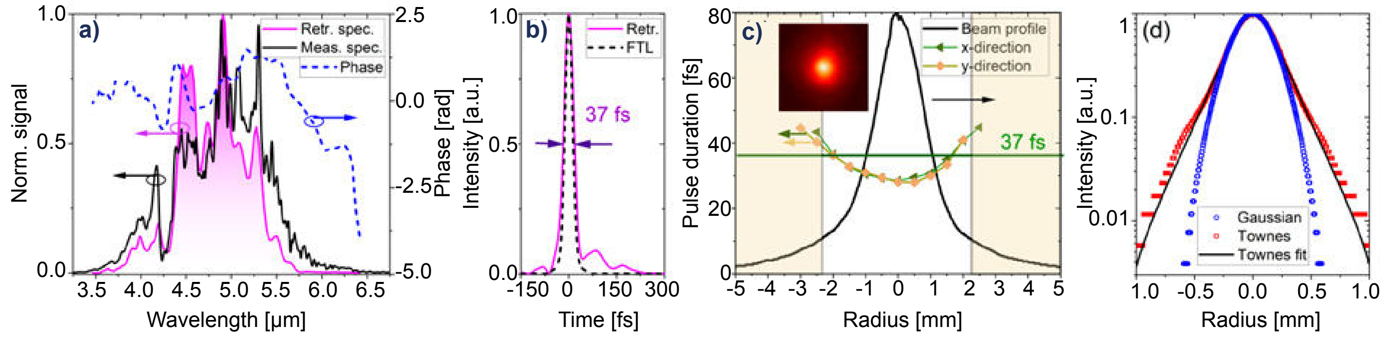


Fig. 3: Characterization of self-compressed 5-µm pulses in ZnS.
a) Optical spectrum,
b) temporal shape,
c) spatial-spectral homogeneity, beam profile,
(d) transition of Gaussian input beam into Townes profile behind ZnS.

HIGHLIGHTS

- Upscaling of 1 kHz Ho:YLF CPA emitting at 2.05 µm to deliver 75 mJ pulses with 2.2 ps duration
- Generation of two-cycle light bullets with 2.0 mJ energy via self-compression of 5-µm pulses in zinc sulfide
- Temporal characterization of tunable few-cycle vacuum ultraviolet pulses
- Soliton and modulation-instability microcombs in SiC at long wavelengths

SHORT OUTLOOK

The interplay between fundamental physics and advanced laser and photonic technologies continues to inspire inventions and discoveries in the fields of atomic and molecular physics. In the rapidly expanding field of frequency comb interferometry and its applications to spectroscopy, sensing and imaging, low-noise frequency combs provide a new set of tools for precision measurements, spectroscopy and dynamics. They cover broad spectral bandwidths across all phases of matter, opening up new territory where resolution and span are no longer limited by geometry.

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Ultrafast Electron Dynamics

When attosecond pulses were first demonstrated at the turn of the century – an achievement recognized with the 2023 Nobel Prize in Physics – there was a widespread expectation that attosecond pulses would soon be used to elucidate time-dependent electron dynamics in attosecond-pump attosecond-probe experiments, the way that femtosecond-pump femtosecond-probe spectroscopy had in the previous two decades been used to investigate molecular dynamics, as recognized by the 1999 Nobel Prize in Chemistry awarded to Ahmed Zewail.

However, despite extensive efforts using both laboratory light sources and large-scale free-electron lasers, only a very few such experiments have so far been carried out. In fact, as far as laboratory light sources are concerned, these have been abandoned in most laboratories, due to the significant experimental challenges involved. Recently, we have demonstrated all-attosecond transient absorption spectroscopy (AATAS), a technique that offers extremely high temporal resolution in both the pump and probe steps while maintaining excellent spectral resolution [M. Volkov, E. Svirplys, S. Carlström et al., arXiv:2512.09585]. As shown in Fig. 1, this capability has allowed us to observe valence-hole motion in xenon ions on a 3-femtosecond timescale. Due to the high information content of the spectrally resolved absorption signal, AATAS significantly goes beyond the limited number of previous demonstrations of attosecond-pump attosecond-probe spectroscopy. Moreover, the stability and reliability of our experimental approach have enabled us to collect high-quality data and to carry out systematic studies across multiple atomic species. We expect our table-top setup to be replicated in many laboratories worldwide.

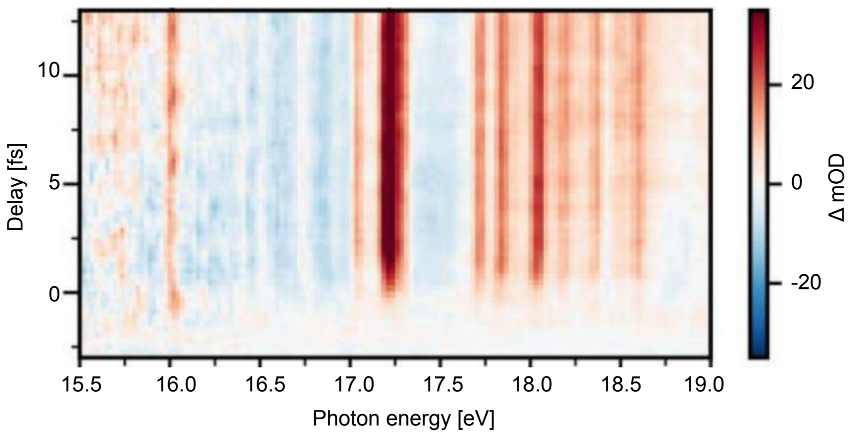

Fig. 1: AATAS map in Xe, showing the change in optical density (ΔmOD) as a function of the time delay and the photon energy. The blue regions indicate reduced absorption due the depletion of neutral Xe atoms. In addition, narrow absorption features are visible in red and are the result of additional absorption in the generated Xe+ ions. The absorption line at 16 eV exhibits an oscillatory behavior with a period of 3.1 fs, which is attributed to coherent hole wave packet motion initiated by the attosecond pump pulse and probed by the attosecond probe pulse.

SHORT OUTLOOK

In a next step, we will apply AATAS to a range of different molecules and solids to explore open questions in ultrafast science, including coupled electronic-nuclear dynamics in molecules and core-hole decay processes in solids.

HIGHLIGHTS

- Demonstration of all-attosecond transient absorption spectroscopy
- Development of an attosecond plasma lens
- First demonstration of attosecond-pump attosecond-probe spectroscopy based on an ytterbium laser

Fig. 2: PhD student Evaldas Svirplys in the laboratory where he performed his all-attosecond transient absorption spectroscopy experiments.

Stefanos Carlstroem, Kuo-Yang Chiang,
Lauren Drescher, Gabriel Emperauger,
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Marco Ruberti, Bernd Schuette, Olga Smirnova,
Evaldas Svirplys, Abhishek Verma, Tobias Witting

Ultrafast Molecular Dynamics

Nonadiabatic phenomena play a fundamental role in many photophysical and photochemical processes, including essential biochemical mechanisms such as visual perception, photosynthesis, and DNA photodamage, as well as technologically relevant applications such as light-energy conversion devices and molecular switches.

In molecular systems, nonadiabatic dynamics arise when nuclear motion is influenced by multiple electronic states, a situation commonly observed in electronically excited molecules. When electronic states are nearly degenerate and strongly coupled, population transfer can occur on ultrashort timescales, profoundly influencing nuclear motion and governing the fate of photoexcited molecules. Understanding the role of these nonadiabatic mechanisms constitutes the central aim of this project.

Recent advances in ultrafast laser science have enabled the observation of molecular dynamics on their intrinsic timescales. Few-cycle optical pulses are now routinely employed in the visible and infrared regions, while high-harmonic generation has extended access to the attosecond regime in the extreme-ultraviolet and soft-X-ray domains. However, the generation of broadly tunable few-femtosecond pulses in the deep- and vacuum-ultraviolet (DUV/VUV, 100-300 nm) has remained a major challenge. Recently, teams at the Max Born Institute developed a new ultrashort VUV source based on resonant dispersive-wave emission, enabling the generation of sub-4-fs pulses spanning 150-200 nm.

In a recent study, the team led by Arnaud Rouzée employed these sub-4-fs VUV pulses in combination with time-resolved photoelectron spectroscopy to investigate the excited-state dynamics of ethylene at 158 nm (see Fig. 2). As the smallest molecule containing a C=C bond, ethylene serves as a benchmark system for ultrafast $\pi\pi^*$ excitation dynamics. Despite extensive prior work, its sub-100-fs excited-state lifetime and strong nonadiabatic couplings have hindered a complete understanding of its early dynamics. The unprecedented temporal resolution achieved in this study revealed previously unobserved spectral features, motivating a revised theoretical interpretation. First-principles quantum dynamics simulations identified a previously overlooked $\sigma\pi^*$ electronic state, that strongly couples to the optically bright $\pi\pi^*$ state and initiates torsional motion about the C=C bond, providing new insight into ethylene's early photochemistry with broad implications for ultrafast photoisomerization in conjugated organic molecules.

While time-resolved spectroscopic techniques are indispensable for studying nonadiabatic dynamics in gas-phase molecules, they generally lack direct structural sensitivity. This limitation can be overcome using time-resolved diffractive imaging with ultrashort X-ray pulses available at large scale facilities such as the Linac Coherent Light Source (LCLS). In a joint collaboration between MBI researchers and physicists from the Max Planck Institute for Nuclear Physics, we recently succeeded to image the strong-laser-driven molecular dynamics in C60 using X-ray diffraction at LCLS.

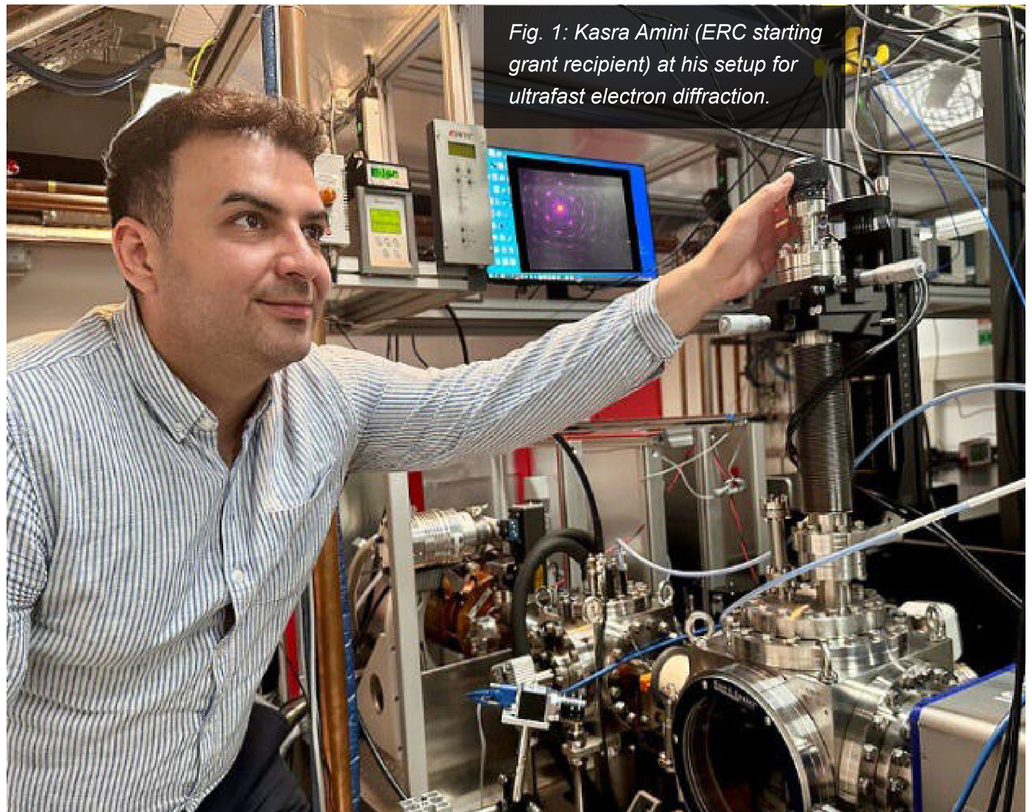

Fig. 1: Kasra Amini (ERC starting grant recipient) at his setup for ultrafast electron diffraction.

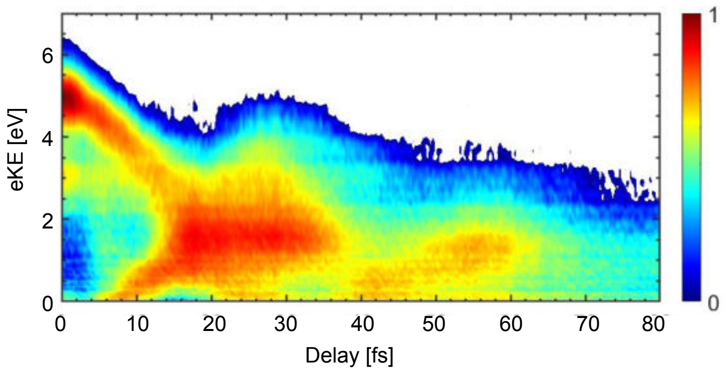

Fig. 2: Time-resolved photoelectron spectrum (TRPES) of C_2D_4 recorded as a function of the time delay between two sub-4-fs VUV (158 nm) pulse replicas generated via resonant dispersive-wave emission in a hollow-core fiber.

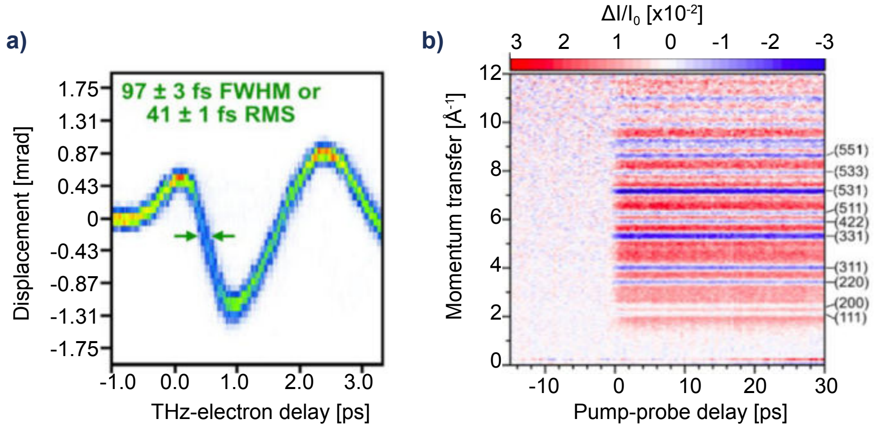

Fig. 3: a) THz electron deflectogram of radiofrequency-compressed 90 keV, 370-aC electrons; retrieval indicates a pulse duration of 68 fs (FWHM) with 75 fs (FWHM) total timing jitter.
b) Time-resolved UED measurements of non-thermal dynamics in aluminium thin film.

In recent years, we have also expanded our capabilities to perform diffractive imaging experiments in a laboratory-based environment using ultrashort electron pulses. Under the leadership of Kasra Amini (ERC Starting Grant recipient, Fig. 1), the Max Born Institute commissioned a state-of-the-art ultrafast electron diffraction (UED) beamline. Operating at repetition rates of 40-100 kHz, the beamline delivers sub-100 fs (FWHM) electron bunches enabled by radio-frequency (RF) compression and RF-laser timing jitter correction to 6 fs (FWHM) (see Fig. 3). In the high bunch charge mode, our UED setup has the highest throughput in the world. The UED instrument is currently being upgraded for gas-phase experiments, with an additional enhancement planned to enable simultaneous detection of elastic and energy-resolved inelastic scattering. This capability, enabled by an innovative THz streaking scheme, will provide simultaneous access to structural and electronic dynamics during ultrafast photochemical rearrangements. In parallel, efforts are ongoing to push ultrafast electron diffraction to the few-femtosecond timescale by exploiting the unique capabilities of the new instrument, combined with ultrashort VUV pulse generation based on resonant dispersive wave emission.

SHORT OUTLOOK

The developments described here open new perspectives for the real-time imaging of coupled electronic and nuclear dynamics in molecules. By combining few-femtosecond, infrared to ultraviolet, pulses with advanced methods such as time-resolved photoelectron spectroscopy, transient X-ray absorption spectroscopy, and ultrafast electron diffraction, these approaches pave the way toward a comprehensive understanding of ultrafast photochemical processes in complex molecular systems.

HIGHLIGHTS

- Few-femtosecond clocking of torsion-induced electronic state dynamics in Ethylene
- Ultrafast electronic relaxation pathways of the molecular photoswitch quadricyclane
- Visualizing the strong-field induced molecular break-up of C_{60} via X-ray diffraction
- Commissioning of high-repetition rate ultrafast electron diffraction beamline with single-electron capabilities, including radiofrequency compression down to 50 fs
- ERC Starting Grant "TERES", Kasra Amini

Kasra Amini, Filippo Aria, Rostyslav Danylo, Fernando R. Diaz, Miguel O. S. Guzmán, Mikhail Y. Ivanov, Oleg Kornilov, Martin Kretschmar, Sudhir Kumar, Felipe Morales Moreno, Tamas Nagy, Erik T. J. Nibbering, Arnaud Rouzée, Marco Ruberti, Aritha M. Santhosh, Claus P. Schulz, Arnab Sen, Olga Smirnova, Simone Stahl, Serguei Patchkovskii, Jyothsna Varghese, Marc J. J. Vrakking, Tobias Witting, Joanne Woodhouse, Zhuang-Yan Zhang, Mikalai Zhavarankau

Broadband Precision Spectroscopy of Molecules

Launched in autumn 2024, project 2.3 “Broadband Precision Spectroscopy of Molecules” includes a significant part of the activities of the Division of Precision Physics. Its mission is to push the frontiers of molecular physics by combining cutting edge laser science, nonlinear optics, and photonics, exploiting the transformative capabilities of laser frequency combs.

Building on laser technology from project 1.1, the project develops novel interferometric methods – particularly dual comb spectroscopy – to achieve unprecedented precision, expand broadband frequency metrology, and open new windows on fundamental physics. The program advances through three intertwined themes: precision spectroscopy in small molecules, comb based hyperspectral imaging and dimensional metrology, and quantum enhanced comb spectroscopy, each addressing a different scientific frontier.

The flagship effort, precision spectroscopy in small molecules, capitalizes on the unique attributes of dual comb interferometry, which performs direct time domain frequency measurements. Unlike dispersive or interferential instruments limited by path length and optical aberrations, dual comb interferometers attain resolving power limited only by the optical period, freeing them from geometric constraints and leaving the uncertainty principle as the ultimate bound. This conceptual breakthrough has recently been experimentally realized as a significant milestone of a long-term effort initiated at the Max Planck Institute of Quantum Optics: a self-referenced fibre laser dual comb interferometer captured spectra spanning more than 1 THz with 1 MHz comb line spacing – over one million resolved lines – in a single acquisition, exceeding the resolution of broadband spectrometers by more than two orders of magnitude (Fig. 1). This advance points to a long-term vision of transforming dual comb spectroscopy into a benchmark for ab initio quantum chemistry, refining fundamental constants such as the Rydberg constant, the proton electron mass ratio, and the proton charge radius, and testing their possible temporal variations. Instrumentally, the limits of accuracy and sensitivity – potentially down to single particle detection – are being explored, together with the use of dual comb methods as broadband optical frequency references.

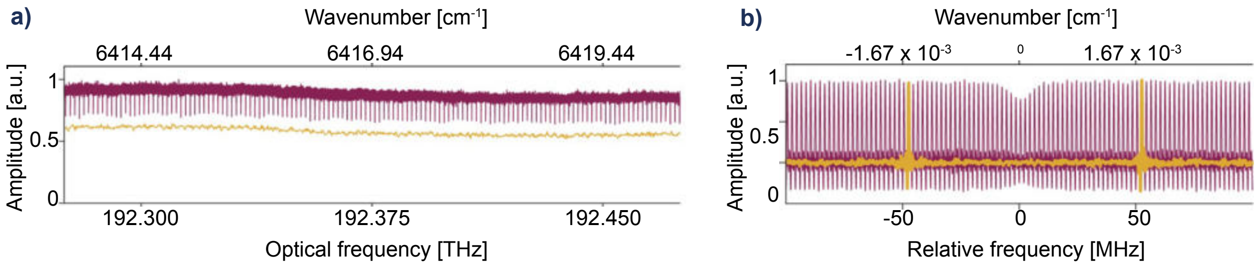

Fig. 1: Overcoming fundamental limits to resolution in broadband spectroscopy. The resolving power is 4 10^8.
a) A portion of the spectrum of a high-finesse Fabry-Pérot resonator, sampled at a resolution of 1 MHz with dual-comb spectroscopy (red) and at a resolution of 100 MHz (yellow), where the resonances are missing.
b) A portion of the same spectrum, with resolved comb lines. One million comb lines are resolved in the entire span. A resolution of 1 MHz would require a path difference of 300 metres using a grating spectrograph or Fourier transform spectrometer.

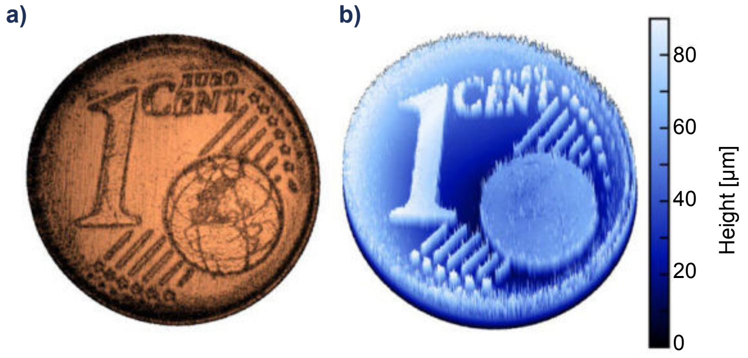

Fig. 2: High-throughput experimental height measurement using microcomb-based digital holography. The object, a 1 cent coin, is measured in a backward-scattering configuration in a single 0.96 second measurement at a sampling rate of 1.2 10^6 pixels s^{-1}.
a) Reconstructed amplitude of a single comb line.
b) A height map with a non-ambiguity range of 150 µm resulting from the reconstruction and combination of the phase information for 14 comb lines.

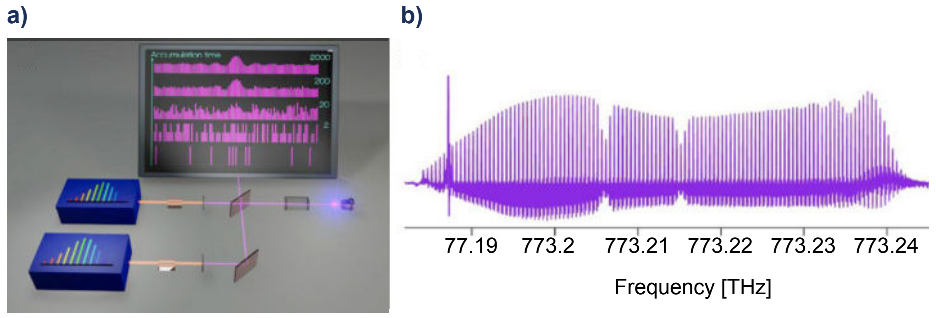

Fig. 3: Dual-comb spectroscopy in light-starved conditions.
a) An ultraviolet photon-counting dual-comb spectrometer.
b) Photon-counting near-ultraviolet dual-comb spectrum of weak transitions in ^{133}Cs at an optical power of 90 pW.

In parallel, comb based hyperspectral imaging and dimensional metrology explores the potential of dual-comb techniques for imaging. Recent experiments with microresonator-based frequency combs, whose large line spacings enable simultaneous retrieval of chemical composition and full 3D morphology – size, shape, depth, and position – of micro to millimetre scale particles across more than 10^5 pixels, achieving 1.2 megapixels/s throughput with micrometre scale precision (Fig. 2). The combination of amplitude and phase diagnostics promises nanometre level accuracy and has immediate applications in environmental sensing, such as microplastic characterization. Long term aims include pushing the accuracy of comb-based 3D imaging and including new diagnostic capabilities.

Quantum-enhanced comb spectroscopy explores whether quantum light and quantum technologies can enable fundamentally new performance regimes. We demonstrate experimentally, that dual-comb spectroscopy operates effectively under extreme low-light conditions, at power levels over a million times weaker than usual. Spectral information is retrieved from photon-counting statistics even when only one detector click occurs per 100 laser pulses, a regime where simultaneous photons from both lasers are exceedingly unlikely. This behavior cannot be explained by assuming photons exist prior to detection. These developments allow us to report the first near-ultraviolet dual-comb spectra with resolved comb lines, addressing the challenge of low ultraviolet comb power from nonlinear conversion (Fig. 3). Overall, our work extends dual-comb spectroscopy to starved-light regimes, enabling new applications in precision spectroscopy, biomedical sensing, and atmospheric measurements.

SHORT OUTLOOK

By combining the technological innovations developed in project 1.2 with a clear focus on fundamental discovery, project 2.3 is establishing MBI as a leading centre for precise interferometry and preparing the ground for transformative applications in physics and beyond.

HIGHLIGHTS

- Experimental demonstration of broadband spectroscopy and interferometry beyond geometrical limitations
- Microcomb-based hyperspectral 3D imaging of particulate matter
- Near-ultraviolet dual-comb spectroscopy in light-starved conditions

Stephan Amann, Quentin Bournet, Matei Crudu, Yuchen Gan, Alyssa Mayer, Jérémie Pilat, Marjan Shojaei, Brian Sinquin, Xuechen Wang, Bingxin Xu

Dynamics of Condensed Phase Molecular Systems

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).

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

The novel method of terahertz (THz) Stark spectroscopy gives insight in excited-state electric dipole moments and polarizabilities of molecular chromophores in liquids and proteins. The prototypical retinal in bacteriorhodopsin (BR), mutants of BR, and neorhodopsin, as well as the most abundant carotenoid β-carotene in a non-polar liquid environment were studied for an in-depth characterization of their transient electronic properties. Picosecond THz electric fields of up to 5.1 MV/cm induce a transient change of the electronic absorption spectra, which is mapped by 100 fs probe pulses. For BR and its mutants, a moderate electric dipole change of $\Delta\mu \approx 5$ Debye for the excited relative to the ground state is observed, while a smaller $\Delta\mu \approx 2.8$ Debye arises in neorhodopsin. In BR, $\Delta\mu$ is governed by the mixed S_1/S_2 charge-transfer character of the retinal excited state together with the early femtosecond evolution along the trans-cis isomerization coordinate. In neorhodopsin, the excited state has a mixed charge-transfer/covalent character, resulting in a smaller dipole change relative to the covalent ground state and the absence of isomerization. While changes of electric polarizability are negligible for retinal, they govern the THz Stark spectra of β-carotene. Very recent work reveals a polarizability difference between ground and excited state of 450 Å^3, which depends on the spectral position within the absorption band, in line with a theoretical analysis of electronic structure [ZSE24].

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

In previous years we have studied low-barrier superstrong hydrogen bonds in hydrated proton complexes and in protonated imidazole dimer using oxygen and nitrogen K-edge spectroscopy, where the spectral signatures of the so-called Zundel motif of shared protons have been elucidated. Following up on this, we have now studied of photoacid-imidazole bimolecular neutralization dynamics using ultrafast nitrogen K-edge spectroscopy with femtosecond time resolution. The experiments at the BESSYII synchrotron facility in 2021-2022 have been crucial in preparing for successful beamtimes in June 2025 at the EuXFEL (Schenefeld, Hamburg, Germany) and LCLS (Stanford, California, USA) free electron laser facilities.

Moreover, we have studied the role of reaction pairs and ion pairing in solution, for imidazole and the azide anion with different alkali and earth alkali counterions, using a combined experimental and theoretical approach. A first report on ion pairing using the asymmetric stretching mode of azide anion has been published with the Sebastiani group. These experiments are the right preparation for investigation of the role of ion pairing during ultrafast proton and electron transfer chemical reaction dynamics.

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

This is a joint effort with Project 2.2, 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 $\mathrm{Fe^{II}(bpy)_3^{2+}}$ in aqueous solution. For details see the highlight “Ultrafast photoinduced reaction dynamics using the nitrogen K-edge as a probe”.

Electronic excited state dynamics in molecular model systems (MSCA Doctoral Network “LUMIERE”)

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. Building upon static aqueous-phase XPS of organic biomimetic molecular switches, NAIP and p-HDIOP, we performed time-resolved investigation of one of them – NHIP (a protonated version of NAPI). The results demonstrate ballistic relaxation of the excited state towards the conical intersection with the rate of electronic energy change of 1 eV/100 fs. We further carry out tandem investigation by trXPS of the molecules from the nitroanilin family in water to investigate electronic relaxation in dependence of the conformer. The work performed in collaboration with the Complutense University of Madrid. Further work on novel biomimetic switches is carried out within the LUMIERE doctoral network.

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

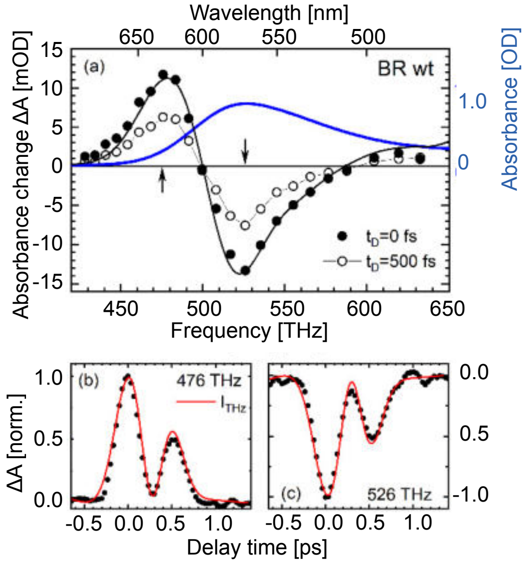

Fig. 1: THz Stark spectroscopy of bacteriorhodopsin. (a) Transient THz Stark spectra (symbols) for two different delay times, demonstrating a broadening of the steady-state absorption spectrum of retinal (blue line). The absorption changes ΔA were induced by a THz electric field transient with a local peak field of 5.1 MV/cm. (b, c) Time resolved absorption changes at fixed frequency positions (arrows in panel (a)), following the intensity envelope of the THz pulse (red lines).

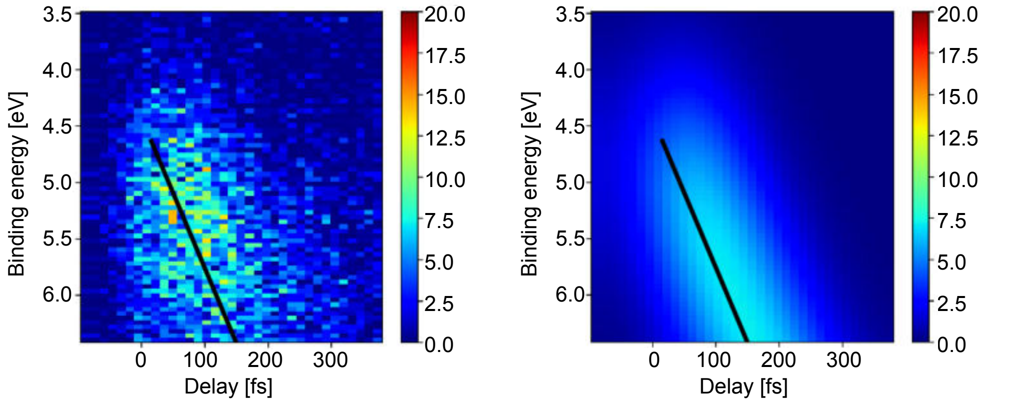

Fig. 2: Ballistic relaxation of NHIP photo switches in water measured by trXPS.

HIGHLIGHTS
- Excited-State Dipole Moments of microbial rhodopsins from terahertz Stark spectroscopy
- Azide Anion Interactions with Imidazole and 1-Methylimidazole in Dimethyl Sulfoxide
- Time-resolved photoelectron spectroscopy of the biomimetic photoswitch molecule NHIP

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Sanchayeeta Jana, Alina Khodko, Arkadi Kundik,
Máté Kurucz, Tifaine de Laubier, Debkumar Rana,
Poonam Singh, Arnaud Rouzée, Arnab Sen,
Gonca Ünder, Marc-Oliver Winghart, Jia Zhang,
Igor Zhuravlev

Solids and Nanostructures: Electrons, Spins, and Phonons

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 mid-infrared to soft x-ray frequencies.

The primary research topics focus on the following ultrafast phenomena. First, we probe light-driven, femtosecond processes in magnetic materials through time-dependent density-functional theory and complementary optical and soft-X-ray spectroscopy. Second, we investigate symmetry-broken systems with high-harmonic spectroscopy and interferometry and third, we explore ultrafast electron dynamics via all-attosecond spectroscopy. Leveraging our close collaboration with Project 3.3 “Structural Dynamics and Emergent Texture,” we further examine the structure-function relationships of these materials using diffraction, scattering, and coherent-imaging techniques.

Magnetism and transient electronic structure

A central question in ultrafast magnetism is whether magnetisation can be manipulated directly by ultrashort light pulses, bypassing the electron-mediated processes dominant in metallic systems. Using XUV T-MOKE spectroscopy, we simultaneously probed both sublattices of an FeNi alloy — a system for which direct light-spin coupling has been theoretically predicted and experimentally claimed. Comparing direct optical excitation with indirect excitation via hot electrons generated in an aluminium capping layer (cf. Fig. 2a,c), we found identical fingerprint behaviour in both cases: a delayed onset of Ni demagnetisation and increased asymmetry for photon energies below the Ni edge (cf. Fig. 2b,d). This strongly suggests that our results, and those previously reported, are attributable to secondary processes following electronic excitation, with no need to invoke direct light-spin interaction [KJZ24]. These findings will inform future experiments, which will also benefit from our progress towards achieving a time resolution of less than 10 femtoseconds and identifying materials with longer electron lifetimes. Another area of investigation involved exploring the all-optical switching of magnetisation at the nanoscale. This was studied using sources of synchrotron radiation [SSN25], free-electron lasers [SAY24], and high-harmonic radiation [HSS25].

Theory of dynamics in quantum materials

A cornerstone of femtomagnetism is that intense laser pulses drive ultrafast demagnetization in magnetic materials. Using tight-binding and time-dependent density functional theory, we have identified the opposite effect: a large, ultrafast laser-induced enhancement of magnetic moment. We demonstrate this in the two-dimensional magnet chromium(III) iodide (CrI_3), where spin moment increases of up to 2 μB are achievable. The mechanism is rooted in spin-orbit-induced valence band spin texture, which enables optical spin-flip transitions involving both intra- and inter-band excitations under intense pulsed illumination.

High-Harmonic Spectroscopy of transient electronic structure

This research topic aims to investigate transient changes in electronic structure and symmetry under strong-field, non-equilibrium conditions. To achieve this, we exploit the sub-cycle sensitivity inherent in high-harmonic generation (HHG) in solids. Using extreme ultraviolet (XUV) high-harmonic interferometry driven by few-cycle laser pulses, we have detected phase shifts induced by optical excitation in harmonic emission. These phase-resolved measurements correlate directly with transient bandgap renormalization, thus establishing XUV HHG interferometry as a sensitive probe of ultrafast electronic dynamics in solids [KJE2025].

Fig. 1: PhD student Pierre Gautier setting up a new beamline for ultrafast XUV reflectometry.

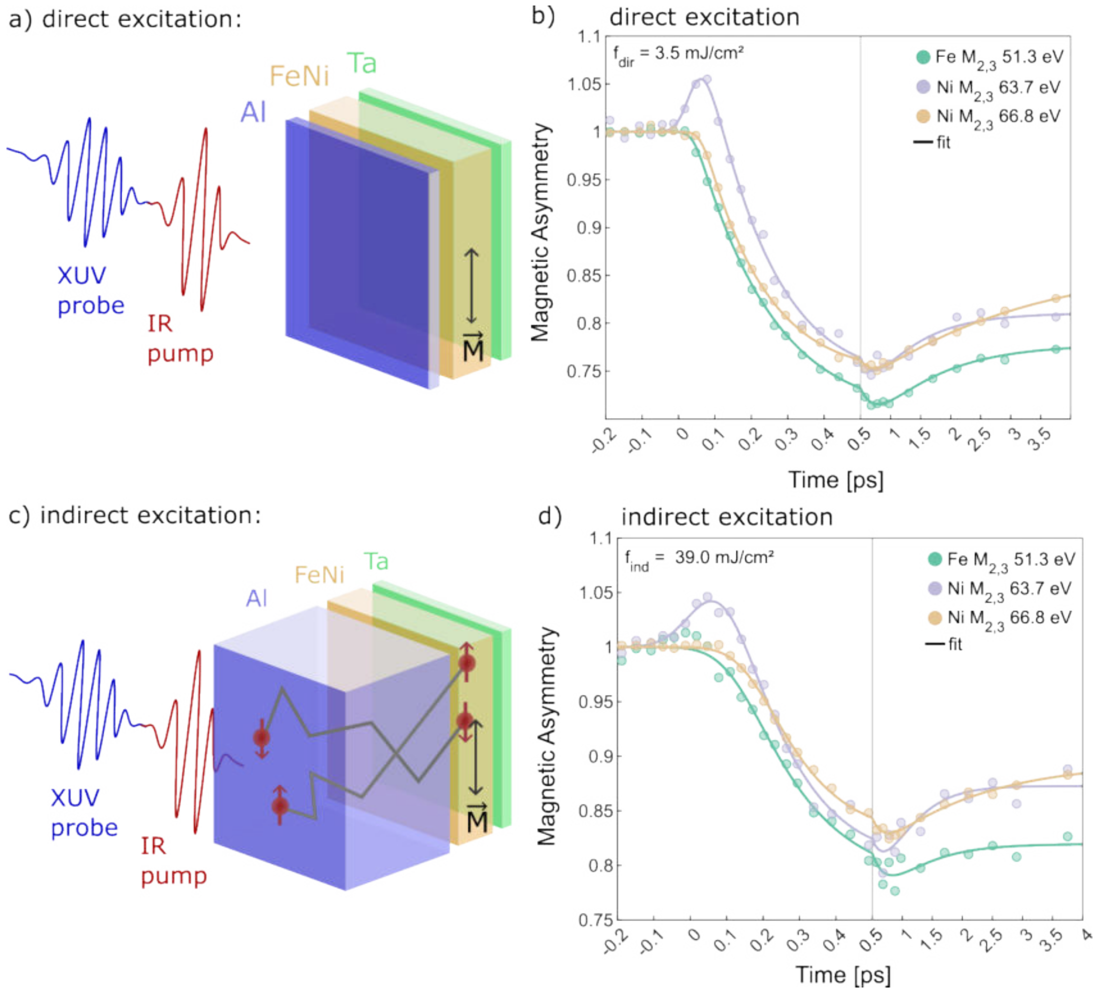

Fig. 2: Schematic of ultrafast XUV spectroscopy of a FeNi alloy with sample geometries for a) direct and c) indirect excitation. In both cases, we observe a delayed onset of Ni demagnetisation compared to Fe and an increased asymmetry for photons tuned to energies below the Ni edge (63.7 eV).

SHORT OUTLOOK

Looking ahead, we will focus on the following key research directions: (i) Building on our established expertise in ultrafast magnetic circular and linear dichroism spectroscopy, we will investigate the phenomenon of ultrafast spin reorientation in both ferromagnetic and antiferromagnetic materials, exploring its implications for magnetisation switching. (ii) Using time-resolved high-harmonic spectroscopy and interferometry, we will study photoinduced phase transitions and identify phase-resolved fingerprints of distinct high-harmonic generation mechanisms in solids. (iii) Complementing these efforts, we will use our unique all-attosecond transient reflectivity spectroscopy setup to investigate electron thermalisation processes in solids on atto-second to femtosecond timescales.

HIGHLIGHTS

- Fundamental spatial limits of all-optical magnetization switching [SAY24]
- Ultrafast Plasmon-Enhanced Magnetic Bit Switching at the Nanoscale [SSN25]
- Depth-profiling of magnetization: pushing boundaries in ultrafast magnetization switching [HSS25]
- Controlling magnetism with polarized light: giant helicity dependent effects in the XUV spectral range [HKY24]
- Watching bandgaps in motion - attosecond interferometry of solids [KJE2025]
- Correlating High-Harmonic Generation and Laser-Induced Excitation in Solids [JRM2024]
- Generation and control of collective vibrations in a liquid [RWE25], [MRW25]
- Optical control of phase and group velocities in everyday liquids [RWB25]

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Kurt Busch, Weidong Chen, Peter Elliott,
Lauren Drescher, Pierre Gautier, Deepika Gill,
Martin Hennecke, Jasmin Jarecki, Sanchayeeta Jana,
Peter Jürgens-Goltermann, Maximilian Mattern,
Niklas Mutz, Tino Noll, Bastian Pfau, Johanna Richter,
Daniel Schick, Bernd Schütte, Samuel Shallcross,
Puloma Singh, Nele Stetzuhn, Wenhua Zhao

Structural Dynamics and Emergent Texture

Project 3.3 investigates structure-function relationships in complex, often heterogeneous materials, with a focus on ultrafast dynamics under non-equilibrium conditions. Central to the project is the study of spatially and temporally evolving order and structure that arise from competing interactions, nanopatterning, and collective degrees of freedom.

The research builds on time- and space-resolved X-ray and XUV techniques, including diffraction, imaging, and absorption spectroscopy, which are complemented by electron diffraction and microscopy. Together, these methods provide access to atomic, electronic, and magnetic dynamics with high temporal and spatial resolution. Scientific topics range from magnetic nanostructures and topological textures to optically induced phase transitions and collective excitations such as lattice vibrations and spin waves. A further key activity is the development of advanced instrumentation, sources, and methods, enabling experiments both in laboratory environments and at large-scale research facilities.

The soft-X-ray laboratory is operated by the junior research group led by Daniel Schick and is built around a laser-driven plasma source that provides intense, pulsed soft-X-ray radiation for time-resolved scattering and spectroscopy experiments, optimized for resonant magnetic and structural studies. This instrumentation complements experiments at large-scale facilities by offering high flexibility in experimental design and rapid iteration. In 2024 and 2025, an advanced prototype hybrid-pixel detector from the Paul Scherrer Institute was integrated, enabling enhanced detection sensitivity through single-photon counting. In parallel, a femtosecond Ti:sapphire pump laser was installed and electronically synchronized to the plasma source driver, offering increased opportunities for photoexcitation into highly non-equilibrium regimes. Building on these upgrades, resonant soft-X-ray diffuse scattering from nanoscale magnetic domains in a ferrimagnetic Fe/Gd multilayer was demonstrated, revealing a complex reorganization of the domain pattern on picosecond to nanosecond timescales (Fig. 2) [LBS25]. The results showcase, that real-time dynamics of emergent magnetic textures can now be probed directly in the laboratory.

Fig. 1: Laboratory assistant Josefin Fuchs overseeing the installation of MBI's mobile soft-X-ray instrument MAXI at the MAX IV synchrotron-radiation facility in Lund, Sweden.

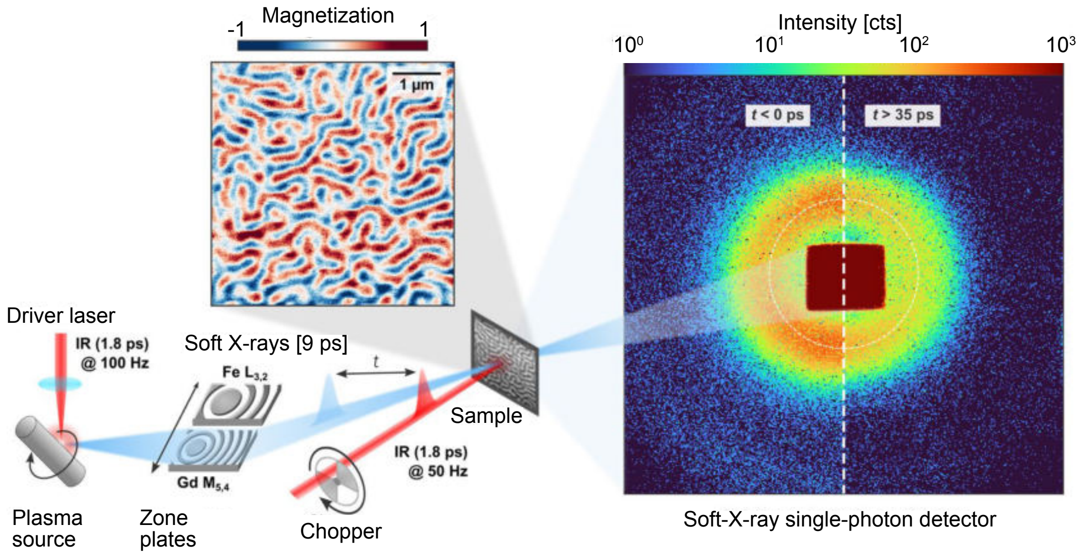


Fig. 2: Demonstration of diffuse scattering from maze-like domains in a thin magnetic film, obtained at a laboratory soft-X-ray source. Left: scattering pattern before photoexcitation of the sample; right: signal after excitation.

Coherent X-ray imaging and scattering experiments at large-scale photon sources form a central pillar of project 3.3. A key feature of these activities is that MBI operates its own instrumentation at these facilities, including the mobile holography instrument MAXI (Fig. 1), a permanent end station at PETRA III, and a picosecond laser system integrated at the X-ray microscope MAXYMUS at BESSY II. In 2024, a major methodological advance was achieved in coherent imaging, where the combination of holography and numerical phase retrieval enabled a record spatial resolution of 5 nm in soft-X-ray imaging of magnetic patterns [BMS24]. Scientifically, experiments focus on nanoscale emergent magnetic and electronic textures. The controlled formation of skyrmion bags was demonstrated [KKD25] (see highlight in this report). Further studies addressed the internal structure of magnetic domain walls [MLW25] and their nanoscale dynamics [BPL25], revealing how competing interactions govern transient and metastable magnetic states. Ptychography is increasingly employed in the soft-X-ray regime [HHG25], supported by dedicated instruments [BFH25] and recent advances in high-performance detectors [BBB25].

The ultrafast dynamics of materials is investigated at X-ray free-electron lasers such as the European XFEL and FERMI. Time-resolved scattering experiments targeted fundamental collective excitations in solids, including surface acoustic waves [CMB25], charge-density waves [LBG25], and spin waves [MBD24]. These studies provide direct access to ultrafast excitation dynamics in reciprocal space and establish XFELs as powerful tools for exploring non-equilibrium processes in quantum materials.

SHORT OUTLOOK

Research on ultrafast lattice and charge dynamics in polar and ionic materials using femtosecond X-ray diffraction has been completed and will be phased out after a series of pioneering contributions [GKF25]. Related questions on non-equilibrium structural dynamics will be pursued in the junior research group led by Kasra Amini, supported by an ERC grant and focusing on ultrafast electron diffraction. In 2025, substantial third-party funding was acquired for future projects on a new ptychography instrument, machine-learning methods for coherent diffraction, and spin-wave dynamics.

HIGHLIGHTS

- Detection of a magnetic diffuse resonant soft-X-ray scattering signal with a lab source
- Laser-induced control over the formation of magnetic skyrmion bags
- New record for spatial resolution in X-ray microscopy of magnetic domains

Tim Butcher, Thomas Elsaesser, Victor Deinhart,
Isabel Gonzalez Vallejo, Jasmin Jarecki,
Lisa-Marie Kern, Christopher Klose,
Maximilian Mattern, Daniel Metternich, Tino Noll,
Bastian Pfau, Daniel Schick, Clemens von Korff
Schmising, Michael Schneider, Holger Stiel,
Steffen Wittrock, Simon Wagner, Michael Woerner

Implementation of Lasers and Measuring Techniques

The general goal of this project is the development and engineering of laser-based sources and optical measurement systems tailored to applications specific to the MBI or laboratories of collaboration partners.

Project 4.1 has a strong connection to project 1.2. Some of the unique optical parametric chirped pulse amplification (OPCPA) systems and laser systems developed in the last few years at the institute are optimized and tailored to their application in experiments around the institute in the context of topical areas 2 and 3, or at the premises of collaboration partners, in order to enhance the experimental capabilities of these laboratories.

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 and beyond.

1. Lasers for particle accelerations

MBI operates a laser installation at 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. This laser has been significantly upgraded in 2025. In the current CPA, the recompressed pulses are transmitted by a hollow-core fiber to the vacuum chamber of the microscope. A new miniature focusing system illuminates the sample with laser pulses of 0.5 ps duration. Secondly, the control system has been improved significantly. It is now EPICS compatible and thus can be adapted by users of the laser to their specific needs. The Graphical User Interface (GUI) of the amplifier chain is displayed on several computer at the MAXYMUS lab simultaneously. This allows for convenient control of the laser parameters by the experimentalists, thereby significantly improving the usability of the laser system (Fig. 1).

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.

2. OPCPA engineering

Topic 1: 800 nm high repetition rate OPCPA

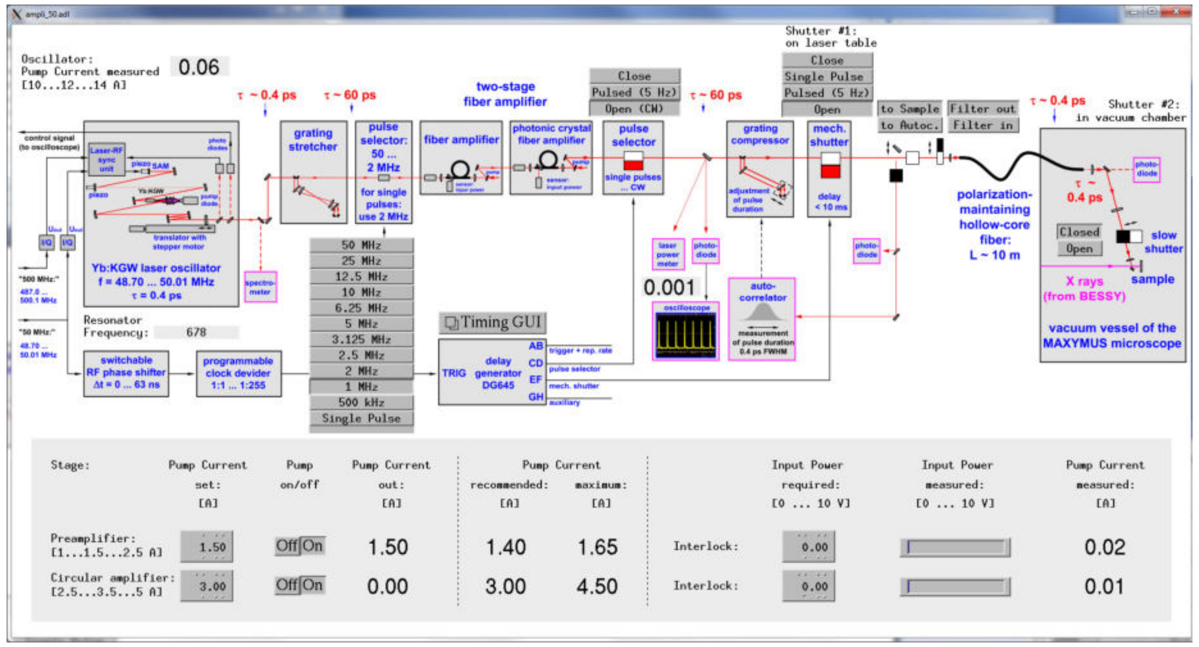
For advanced experiments with coincidence detection of ions and electrons from attosecond pulse induced photoionization we develop our own high repetition, high power laser systems based on OPCPA. In 2025 the 100 kHz OPCPA system providing 800 nm few-cycle pulses has been upgraded resulting in 10 fs pulses with a 2.5 fold increase in pulse energy, now providing 500 µJ pulses at 2100 kHz repetition rate for experiments. The OPCPA system is pumped by 900 fs pulses at 515 nm generated from second harmonic generation of 1 ps long pump pulses with 1030 nm wavelength from an Yb:YAG based pump laser chain. The second amplifier stage in the OPCPA system is pumped by a flat-top 515 nm beam, which is generated with an all reflective inline setup, which was developed in collaboration with the group of Stefan Petit from the Centre Lasers Intenses et Applications (CELIA) in Bordeaux, France. The spatial phase of the 1030 nm beam is shaped by a custom designed reflective phase mask. After second harmonic generation in BBO and propagation a flat top pump pulse is formed, which pumps the second OPCPA stage. Using flat top pumping results in a higher spatio-spectral uniformity due to reduced back-conversion in the OPCPA crystal as compared to Gaussian pump beams.

Topic 2: Midwave-IR OPCPA at 1 kHz repetition rate: 5-µm pulse shortening by self-compression in a hollow-core fiber

The midwave-IR OPCPA system operates at 1 kHz repetition rate and delivers 80 fs pulses with up to 3.2 mJ of energy at a central idler wavelength of 5.0 µm. The system is pumped at 2.0 µm by a Ho:YLF CPA developed in-house. This OPCPA serves as the driver laser for a Cu-Kα source utilized for time-resolved X-ray diffraction experiments.

Duration and energy of the driving laser pulses plays an important role particularly with regard to the associated efficiency in hard X-ray generation. Pulses should be as short as possible to efficiently drive these processes. Further shortening of the pulses was achieved by spectral broadening due to self-phase modulation (SPM) in a nonlinear medium with simultaneous temporal compression. We performed self-compression of the 5-µm idler pulses in a hollow-core fiber (HCF) due to solitonic effects. The HCF used is filled with 3.6 bar argon gas, has a diameter of 500 µm and is 0.5 m long. Uncoated CaF2 windows seal off the gas chamber. After mode-matching by an astigmatism-compensated mirror telescope pulses with 1.9 mJ energy are launched into the HCF. The transmitted beam exhibits an excellent quality, typical for HCFs, and the pulses contain 0.88 mJ energy. SPM in the HCF leads to a broadening of the spectrum by roughly a factor of two. The FROG retrieval delivered a smooth spectral phase between 4.0 µm and 5.5 µm, which proves that the output pulse is self-compressed with duration close to the Fourier-transform limit (FTL). This is confirmed by the retrieved pulse duration of 47 fs which corresponds to sub-three optical cycles.

In this initial HCF self-compression experiment, we have demonstrated 1.8-fold compression of millijoule 5 µm pulses in an Ar-filled HCF resulting in pulses with 47 fs duration and 17 GW peak power. In good agreement with the experiment, the simulation indicates the existence of the solitonic self-compression regime. The more advantageous shorter pulse duration for hard X-ray generation is accompanied by a loss of approximately 50 %, which is too much to generate hard X-rays efficiently. Therefore, in the next step, the HCF will be replaced with an anti-resonant HCF (AR-HCF). The expected loss of the AR-HCF is only 10 %.



Oscillator:
Pump Current measured
[10...12...14 A] 0.06

Resonator Frequency: 678

0.001

Stage:	Pump Current set: [A]	Pump on/off	Pump Current out: [A]	Pump Current recommended: [A]	Pump Current maximum: [A]		Input Power required: [0 ... 10 V]	Input Power measured: [0 ... 10 V]	Pump Current measured: [A]
Preamplifier: [1...1.5...2.5 A]	1.50	Off On	1.50	1.40	1.65	Interlock:	0.00		0.02
Circular amplifier: [2.5...3.5...5 A]	3.00	Off On	0.00	3.00	4.50	Interlock:	0.00		0.01

Fig. 1: EPICS compatible Graphical User Interface for controlling the laser and the pulse parameters.

3. Implementation of measuring techniques

The 800 nm OPCPA system developed in topic 2 emits few-cycle pulses which may inherently carry spatio-temporal couplings. For the generation of attosecond pulses via high harmonic generation it is of utmost importance to be able to quantify and also to control these pulse properties. For this we have employed the SEA-F-SPIDER technique. We have used this ultrafast pulse measurement technology to accurately characterize the pulses from the newly built OPCPA. Spatio-spectral and spatio-temporal measurements in vertical as well as horizontal beam planes have been made. Comparisons of gaussian and flat top pumping of the OPCPA power amplifier stage have been made, showing the superiour beam quality with flat top pumping.

SHORT OUTLOOK

- Towards fully automated, user friendly lasers for accelerators
- Attosecond pulse generation with upgraded 800 nm OPCPA - Single cycle self-compression of 5-µm-pulses in an anti-resonant hollow core fiber

HIGHLIGHTS

- New miniature focusing system for 0.5 ps pulses for MAXYMUS at BESSY II
- 0.5 mJ, 10 fs pulses at 100 kHz repetition rate with flat top pump pulses
- 0.88 mJ sub-50-fs pulses from hollow fiber compression at 5 µm wavelength

Martin Bock, Federico Furch, Uwe Griebner,
Hadil Kassab, Lars Opperman, Johannes Tuemmler,
Ingo Will, Tobias Witting

Application Laboratories and Technology Transfer

For time-resolved spectroscopy and imaging with soft X-rays, MBI operates application laboratories and develops infrastructure open for internal and external users. The focus is on stability and reliability for routine operation.

Since the experiments seek effects on ultrafast timescales and at short wavelengths where only low photon numbers are available, it is very important to have a highly stable and reproducible light source. Therefore, wherever possible, established methods and components with proven performances are implemented. This work is carried out within the two topics NanoMovie and BLiX.

NanoMovie
NanoMovie provides a laser infrastructure based on commercial components adapted to our needs. It consists of two MIR ultrafast OPCPA systems operating at 2 µm and 3 µm wavelength. Both systems are based on the same concept and technology platform, simplifying maintenance and optimizing uptime.

The 2 µm system gives excess to the 100-550 eV photon energy region (water window) by high harmonic generation. The 3 µm system (still under development) is expected to reach up to about 1000 eV. Each OPCPA system is pumped by a dedicated Yb:YAG thin-disk laser (Dira 500, Trumpf Scientific) with 500 W output power @10 kHz. Both 2 µm and 3 µm seeds are generated by a dedicated OPCPA front-end (FASTLITE). The seed pulse is amplified in successive OPCPA stages, developed in-house based on YCOB (2 µm) or LNO (3 µm) crystals.

The 2 µm system is in operation since 2019 with regular small upgrades. In 2024/25 larger upgrades were implemented. As requested by multiple users, the installation of a NIR-VIS-UV OPCPA pump source from Class5 will allow the selection of a required wavelength from a broad spectral range for resonant excitation in pump-probe experiments. During the installation the beam line was not operational for many weeks. In the next shut-down period we will make this pump source available for the experiments. The second upgrade focused on the experimental station, where additional beam stabilization and beam diagnostic (for both pump and probe beams) were implemented. Jointly with a new HHG cell and a new beam transport system, this allowed to greatly simplify the operations required to initiate a measurement.

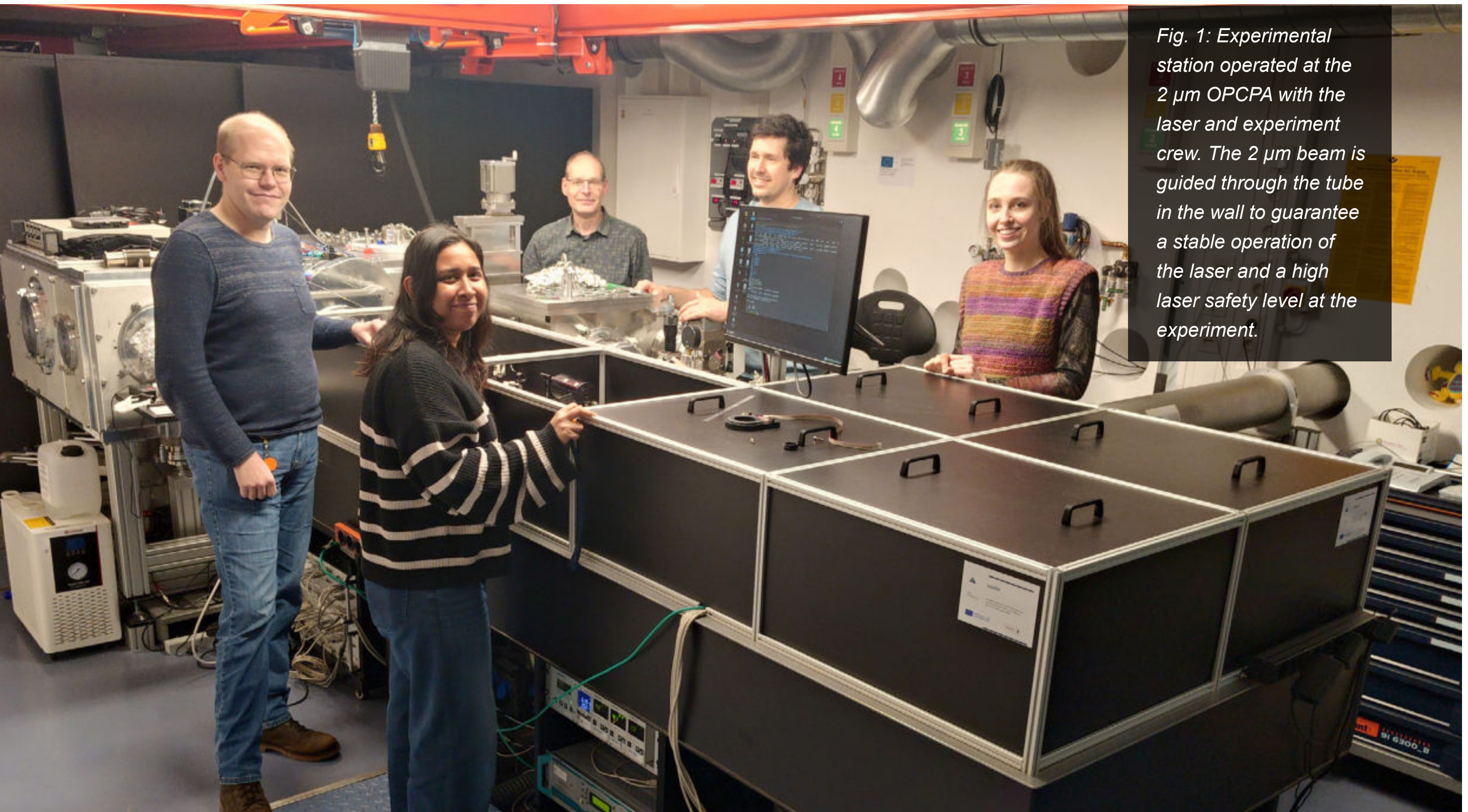


Fig. 1: Experimental station operated at the 2 µm OPCPA with the laser and experiment crew. The 2 µm beam is guided through the tube in the wall to guarantee a stable operation of the laser and a high laser safety level at the experiment.

The 3 µm system is close to commissioning. In 2024/25 we increased the output by applying a pulse front tilt to the pump pulse to match the pulse front of the seed. Due to the large non-collinear angle this had a strong influence on the beam quality the output pulse energy, that increased by 60 %, in agreement with simulations (Sisyfos, G. Arisholm; Chi2D, T. Lang). Our initially aimed output parameters (>15 W, < 60 fs) were almost reached (13 W, 62 fs). Our 3 µm OPCPA system is now one of the few systems in the world combining high peak power and high average power. The evaluation for its usability as a driver for HHG in the range up to 1 keV started at the end of 2025.

Berlin Laboratory for innovative X-ray Technologies (BLiX)
BLiX is a Leibniz-application laboratory of MBI and jointly operated with the TU Berlin. 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. The joint research group SyncLab (HZB and BLiX) will identify and promote advantages of combining laboratory methods developed at BLiX with capabilities offered by large scale facilities. MBI contributes to BLiX predominantly by a lab based Near-Edge X-ray Absorption Spectroscopy (NEXAFS) setup and a Laboratory Transmission X-ray Microscope (LTXM) including tomography option in the water window.

MBI's experience in lasers, soft X-ray optics and 2D detectors are the basis for these setups. Especially the LTXM has experienced a major upgrade during the last years on nearly all components – laser system, sample stage, liquid nitrogen jet, and operating and control software.
For further information see https://www.tu.berlin/axp/forschung/forschungsschwerpunkte

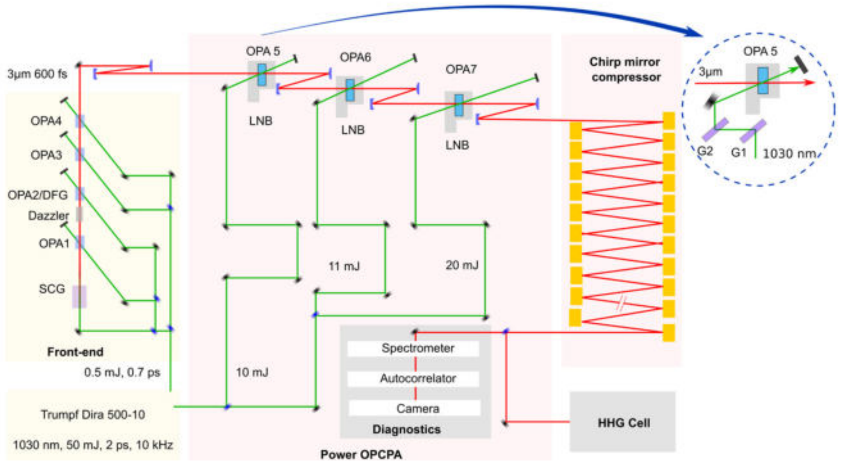


Fig. 2: Sketch of the 3 µm OPCPA system. In front of the OPA stages 5-7 the pulse front is tilted by two transmission gratings (G1, G2).

SHORT OUTLOOK

- Upgrade for higher long-term stability and simplified operation of the reflectometer end-station in connection with the implementation of the NIR-VIS-UV OPCPA for resonant pumping
- Commissioning of the 3 µm beam as HHG driver and first results on output power and stability
- Optimization of HHG source geometry to enable easier photon-flux optimization
- Operation of the LTXM for in vivo visualization of extracellular matrix pathology within CRC 1340 (coll.: Charité Berlin)
- Development of a new system for optical pump X-ray probe investigations in the liquid phase

HIGHLIGHTS

- Installation of the NIR-VIS-UV OPCPA pump source (Class5) at the 2 µm OPCPA system
- Tilted pump pulse front in the 3 µm OPCPA system for increased pulse energy and better beam profile
- Implementation of a computer-based control system at the LTXM, for user-friendly operation and higher long-term stability

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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)

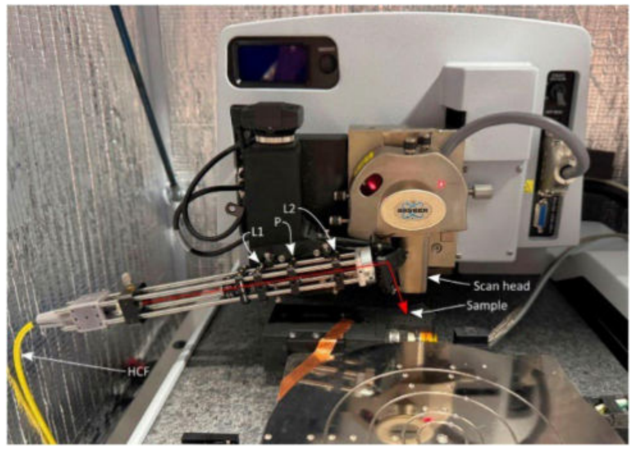
Nanoscale Samples and Integrated Optics

Our institute is engaged in a wide range of research activities that concentrate on dynamic processes occurring at the nanometer and femtosecond scale. These processes are governed by fundamental material properties, including the inelastic mean free path for electron and spin transport.

A number of experimental approaches using short-pulse excitations with light, XUV, or soft X-rays make these ultrafast dynamics accessible in various projects at our institute. For this purpose, we operate a thin-film laboratory with an expanded magnetron sputtering cluster and an electron-beam evaporator system. Our structuring capabilities include UV lithography, reactive ion etching, and precision back-thinning of single-crystal substrates. These capabilities are complemented by advanced nano-patterning through collaboration with TU Berlin on FIB and electron-beam lithography. In early 2025, the project was strengthened by adding a focus on femtosecond micro-processing. The mission of the femtosecond laser processing laboratory is to harness the unique properties of ultrashort laser pulses (down to sub-7-fs duration) to understand and exploit unconventional laser-matter interaction regimes. Various workstations with different laser setups are used to produce photonic integrated circuits and waveguide chips. These micro-optical systems can serve as platforms for surface plasmon resonance (SPR) sensing in a refractive index region highly relevant for biomedical applications.

A notable development in recent research has been the further development and optimization of an advanced sample environment, which was integrated with a conventional commercial magnetic force microscope (see Fig. 1 & 2: Bruker Dimension Icon). This innovation facilitates the precise manipulation and subsequent in-situ characterization of magnetic thin-film systems. The experimental setup facilitates the spatial resolution of magnetic characterization within a bipolar magnetic field (±380 mT) subsequent to the optical manipulation of magnetic states by 370 femtosecond short laser pulses at a central wavelength of 1030 nm (see Fig. 3). As well the generation and movement of magnetic domains can be induced by current pulses of nanosecond duration. This unique sample environment is thus optimized to image the generation and manipulation of magnetic domains in thin films, without the need of transferring the sample to another device, e.g., for optical or electrical excitation in suitable external fields. Consequently, measurement cycles are accelerated considerably. The fabrication of the entire sample environment was accomplished through the implementation of a three-dimensional printing process in conjunction with conventional optical components.

Fig. 1: Puloma Singh in front of the MFM preparing a sample within the advanced environment.



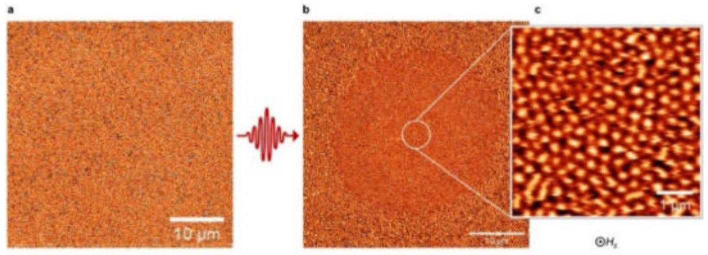


Fig. 2 Left: Inside view of the MFM chamber highlighting the opto-mechanical setup guiding the laser beam toward the sample. The HCF is connected to an optical cage system mounted on a 3D printed adapter for the MFM head. The light emitted from the fiber is collimated by lens (L1) and focused onto the sample by a second lens (L2). The polarization on the sample is controlled via half-wave plate (P). Right: Laser-induced skyrmion nucleation at MFM (a) initial state of the sample ($Co_{60}Fe_{25}B_{15}$ multilayer) and (b) at an external magnetic field of $\mu_0 H_z$ = 20 mT (following saturation at 180 mT).

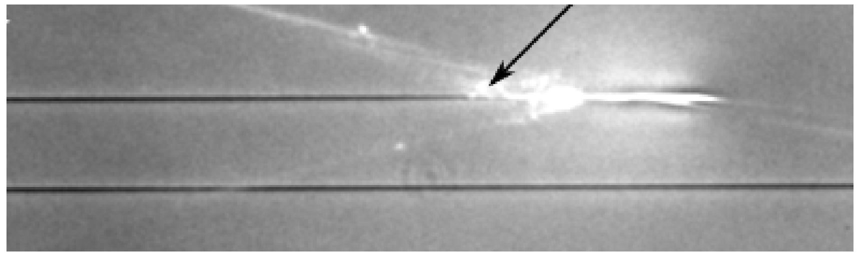


Fig. 3: Phase-contrast microscopy picture of the surface of a fused silica sample during the photo inscription of adjacent surface waveguides separated by a 50 µm distance.

Additionally, project 4.3 includes a topic dedicated to ultrashort microprocessing, with a special (but not exclusive) emphasis on microprocessing with few-cycle pulses. In the past years, MBI has accumulated a considerable deal of expertise in the generation, characterization, and manipulation of few-cycle pulses, i.e. typically with a sub-10 fs duration. Because of a unique combination of high intensity and low pulse energy, few-cycle light pulses enable novel microprocessing approaches for materials with low thermal shock resistance, such as thin dielectric layers. Because micro-integrated optical platforms inherently incorporate thin solid dielectrics, microprocessing with few-cycle pulses is highly suited to advancing production techniques for integrated-optics microdevices.

SHORT OUTLOOK

- Establishment of a commercial filter production
- Construction and production of optimized 1” and 2” sputtering sources
- Implementation of a solid-state laser beamline with pulse durations covering the 50-300 fs range

HIGHLIGHTS

- Preparing soft-X-ray-transparent single-crystalline substrates
- Combined sample environment with fs-laser pulses, ns-current pulses and bipolar magnet
- Single step photoinscription of optical waveguides on the surface of fused silica with few cycle pulses

Denny Sommer, Jannis Angenendt,
Michael Schneider, Christian Günther (TU Berlin),
Alexandre Mermillod-Blondin, Dieter Engel

Where Light Meets Matter: Insights from Attosecond Physics

Interview with Prof. Dr. Olga Smirnova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Olga Smirnova, internationally recognized theoretical physicist at the Max Born Institute, reflects on her path from Russia to Berlin as well as her work in ultrafast and strong-field physics. In this interview she talks early inspiration through a children's book, "closed doors" for female physicists in the past and the creative and collaborative process of doing research.

Prof. Dr. Smirnova: You are originally from Russia, studied and taught there. What brought you to Berlin and especially the Max Born Institute?

It is a long story that began more than twenty years ago. I originally studied and taught in Russia, and in 2003 I moved to Vienna as a Lise Meitner fellow. Shortly afterwards, at a workshop in Quebec, I met Wolfgang Sandner, the former founding director of the Max Born Institute. I was presenting a poster on time-resolved Auger decay, and he came by, asked very sharp and engaged questions, and showed genuine interest in my work. At the end of our discussion, he invited me to give a talk at MBI. I visited the institute in 2004 and was immediately impressed by the scientific atmosphere — the intensity of the discussions, the openness, and the intellectual energy. Wolfgang stayed in contact over the following years and encouraged me to consider Berlin more seriously.

A decisive step came, when I became one of the first recipients of a Leibniz Junior Research Group position. This opportunity allowed me to establish my own group at MBI. Wolfgang strongly supported this move and played a key role in bringing me to Berlin. So, my move to Berlin was shaped both by the scientific environment at MBI and by Wolfgang's support and vision at an important stage of my career.

What fascinates you most about physics? And how did you choose your field of ultrafast and strong-field physics?

What fascinates me most about physics is the possibility to describe extremely complex phenomena with elegant and powerful theoretical ideas. I have always been drawn to areas where deep conceptual thinking meets experimentally observable effects. My field is light-matter interaction, and I come from the strong multiphoton physics community in Russia that was created by Nikolai B. Delone. My very first interest was actually quantum field theory. However, at that time, in my institution, women were not-so-subtly discouraged from entering that field. I was told by a senior student that Leonid Keldysh had profoundly influenced quantum field theory by developing the non-equilibrium Green's function formalism — and that at his department the door was open to female students. So, I decided to join the department he was leading.

Later, I discovered that Keldysh had also written a seminal paper on intense-field ionization, in which he unified the tunneling and multiphoton regimes that had previously been treated separately. I found this work extraordinarily beautiful — conceptually deep, yet directly connected to experiment, albeit performed much later. That paper strongly influenced me and ultimately led me to work on related problems. Through this path, I became part of the Delone seminar and the multiphoton community, which shaped my scientific identity and naturally led me into ultrafast and strong-field physics.

You have significantly shaped the theoretical understanding of high-harmonic generation and attosecond science. What makes these phenomena so powerful as tools to study matter?

Attosecond physics allows us to observe and control electron dynamics triggered by light on their natural timescale. Since electrons are responsible for bonding, conductivity, and chemical reactivity, following their motion in real time gives us access to the very foundations of how matter functions.

What makes high-harmonic generation and attosecond techniques so powerful is their universality. The underlying strong-field interaction can occur in almost any medium. The field began with atoms — with electrons being ripped out by intense laser fields — but it quickly expanded to molecules, and later to solids and quantum materials. Today it connects atomic physics, chemistry, condensed matter physics, and materials science.

Your research often builds bridges between theory and experiment. What does successful collaboration between theorists and experimentalists look like to you?

I often quote the Russian film director Sergei Solovyov, who once said that films can only be made with friends, lovers, and family. I feel that truly successful collaborations in science are very similar. The best collaboration between theorists and experimentalists is built on trust, openness, and genuine intellectual curiosity. It is not a service relationship where one side merely "explains" data and the other "produces" it. It is a shared creative process.

In strong-field and attosecond physics especially, theory and experiment constantly push each other. Experiments reveal unexpected features that challenge our models; theory suggests new regimes, observables, and ways of interpreting what is measured. The most productive collaborations happen when both sides are willing to expose unfinished ideas, admit uncertainties, and think together from the very beginning of a project. In that sense, collaboration works best when it is based on mutual respect and long-term commitment — when people are not just colleagues, but intellectual partners.

Although your research is fundamentally driven, it underpins techniques with wide relevance. What potential applications do you see emerging from attosecond and ultrafast science?

There are several promising directions where attosecond and ultrafast science may lead to impactful applications. I will probably sound a bit biased, but let me focus on the one I am most excited about: enantio-discrimination — the ability to distinguish between left- and right-handed molecules.

This is a fundamentally important problem. Many biological molecules are chiral, and two mirror-image versions of the same molecule can have dramatically different chemical or pharmacological effects. For more than two centuries, chiral matter has been probed using spatially chiral structures such as circularly polarized light, but because molecule can be much smaller than the size of light's chiral structure these approaches often produce relatively weak signals. Ultrafast and strong-field physics offer a new route. Through nonlinear light-matter interaction and the ability to excite and probe ultrafast electron currents, we can create chiral temporal structures in light and in the electronic dynamics of matter. Because temporal chirality does not rely on spatial size, the usual geometric mismatch is no longer a fundamental limitation, potentially making enantio-sensitive detection more efficient and universal.

How does the interdisciplinary and international environment at MBI influence your research and the way you develop new ideas?

The interdisciplinary and international environment at MBI has a very direct impact on how new ideas emerge in my group. It constantly exposes us to concepts and techniques that are not originally part of our own field. Let me give you a recent example: I mentioned that I am excited about the idea that chiral electron currents can encode molecular chirality in time. For this encoding to be robust, however, one needs extremely precise phase relationships between different frequency components of the driving light field. Temporal chirality is a subtle effect — it lives in the relative phases.

At the same time, a different research direction at MBI — frequency comb technology, brought to the institute by our new director — focuses precisely on phase control and stability. Frequency combs are essentially the most precise "phase-keeping" tools we have in optics. Putting these ideas together led to a new concept: chiral frequency combs, which could provide a very sensitive and robust platform for chiral discrimination. This kind of cross-fertilization happens naturally in an environment like MBI, where different expertise areas coexist under one roof.

For readers outside academia, how would you describe the main differences between a scientific career and a more traditional office-based profession?

One of the main differences is that in many traditional office-based professions, work is expected to end when you leave the office. There are defined hours, defined tasks, and a clearer separation between professional and private time.

In science that boundary is much less strict. The creative process does not follow office hours. An idea may emerge during a discussion, on the way home, while cooking dinner, or even in the middle of the night. Questions continue to live in your mind long after you close your laptop. This does not mean that scientists work all the time in a formal sense, but rather that scientific thinking becomes part of how you experience the world. It is closer to an ongoing dialogue with a problem than to a set of scheduled tasks.

That is both the beauty and the challenge of a scientific career. It offers enormous intellectual freedom and creativity — but it also requires learning how to live with a mind that does not always "clock out."

Interview by: Julia Bill

Capturing the Invisible: Two Careers in Experimental Physics

Interview with Dr. Kasra Amini and Dr. Guilio Rossi


© Berit Kraushaar

Dr. Kasra Amini (left) and Dr. Giulio Rossi (right) are group leaders at the Max Born Institute, where they develop ultrafast experimental methods to investigate atomic and electronic dynamics in matter. In the interview, they discuss their scientific paths to MBI, the challenges of building cutting-edge experiments and the curiosity that drives their research into the fastest processes in physics.

Dr. Amini and Dr. Rossi, could you please briefly describe your academic path and what ultimately led you to join the Max Born Institute?

KASRA AMINI: In high school I was really interested in chemistry and mathematics. I studied at University College London and completed an integrated BSc/MSc degree in chemistry with mathematics. I then pursued a PhD in physical chemistry at the University of Oxford with Prof. Mark Brouard as my supervisor. Initially, I worked in ultra-cold chemistry, but became more interested in observing processes in real time and switched to ultrafast photochemistry and physics. During my postdoc at ICFO with Prof. Dr. Jens Biegert, I worked with femtosecond light sources and became interested in diffraction techniques. I then had the opportunity to come to the MBI to start a group and build an ultra-short electron diffraction source, and last year we received an ERC Starting Grant.

GIULIO ROSSI: I initially wanted to study physics or philosophy, but chose engineering and later specialized in physics engineering at Politecnico di Milano. There I worked in the group of Prof. Giulio Cerullo and learned about pulse lasers and nonlinear optics. I decided to pursue a PhD abroad, in Prof. Franz Kaertner's group at DESY in Hamburg, where I developed a highly innovative attosecond source. I stayed there for my PhD and postdoctoral work for more than ten years. After that, I moved to Berlin and the MBI, where I continue working with laser-based methods. At the MBI, my work has a stronger focus on solid-state physics.

Was there a particular moment or experience early in your careers that sparked your interest in your current research fields?

KASRA: During my first year in the laboratory of Henrik Stapelfeldt in Aarhus, I worked on time-resolved femtosecond measurements of molecular switches. It was the first time I was asked to take responsibility for leading parts of an experiment. While writing my PhD thesis, the more I learned about diffraction imaging the further my interest deepened. Performing time-resolved diffraction measurements at ICFO during my postdoc years to visualize the structure of matter at the atomic scale showed me how powerful time-resolved methods can be for understanding molecular dynamics. They shaped the direction of my later research. This fascination has stayed with me ever since.

GIULIO: My master's thesis at Politecnico di Milano sparked my interest in optics and nonlinear optics. Working in dark laboratories and directly observing light generation processes was very motivating. Nonlinear optics allows you to see physical effects with your own eyes, which made the experiments particularly engaging for me. This strong visual and hands-on component left a lasting impression. It convinced me to continue in laser-based research. The experience ultimately guided my decision to stay in this field.

How would you explain your main research focus at MBI to a scientifically interested but non-specialist audience?

KASRA: A key question is how electronic and nuclear degrees of freedom evolve together. Understanding this coupling is essential for describing photochemical reactions. We are studying these coupling effects in gases, liquids, and solids using 30-100 fs MeV and keV electrons. In the long-term, we aim to add the energy dimension to ultrafast electron diffraction through the ERC grant. This would allow us to observe not only structural changes but also how energy flows through excited systems, which is particularly relevant to real-world (e.g., optoelectronic) devices.

GIULIO: In our division we study ultrafast magnetism in solids. Many dynamical properties of magnetic materials are still not fully understood. I am currently working on developing laser sources that generate soft X-rays at energies relevant for magnetic elements such as iron. At present, there are few tabletop sources that can reach these energies with ultrashort pulses. Developing such sources would enable new experiments on magnetism. This could significantly advance our understanding of ultrafast magnetic processes.

What are some of the main challenges you face in your work?

KASRA: In experimental physics many things do not work as planned. Setbacks are part of everyday laboratory work. There is often no manual for building new experimental setups. Progress depends on systematic problem-solving and persistence. This constant troubleshooting is demanding but also highly motivating. For me, this hands-on aspect is one of the most fascinating parts of the work.

GIULIO: We face many technical challenges in developing and operating complex laser systems. Often, there is a trade-off between finding the optimal solution and finding a solution that is feasible within limited time. Not every technically perfect approach can be implemented in practice. This requires constant prioritization. At the same time, these challenges are intellectually rewarding. Overcoming them is an important part of experimental research.

How do you balance curiosity-driven fundamental research with an awareness of possible practical applications?

KASRA: My fundamental approach to science is curiosity-driven. At the heart of whatever I do is curiosity, and this is much more strongly weighted than considerations of applications. I am primarily motivated by understanding physical and chemical processes. Practical implications often emerge later and are not always foreseeable. Fundamental insights are, in my view, the basis for future applications. This is what drives most of my research.

GIULIO: Practical applications mainly become important when writing proposals. In that context, you need to connect fundamental research to short-term implications that are easier to communicate. However, science does not proceed in a straight line, and long-term implications are often unpredictable. Many outcomes cannot be planned in advance. Curiosity-driven research remains central to meaningful scientific progress. This tension is something we constantly navigate.

Looking ahead, what developments do you hope to see in your fields?

KASRA: I hope to regularly apply ultrafast electron diffraction to liquids. This would allow us to study chemical reactions in more realistic environments where chemical reactivity is influenced by the environment. In the longer term, applying these techniques to biological systems would be a major breakthrough. Of course, adding the energy dimension to ultrafast electron diffraction would revolutionize our understanding of energy dissipation in light-matter interactions.

GIULIO: I hope to see the development of laboratories that combine multiple spectroscopic techniques. This would allow different physical phenomena to be studied simultaneously on the same sample. At present, many experiments focus on only one energy range or probe. Combining approaches would provide a more complete picture of material dynamics. Although technically challenging, such integrated setups would be very powerful. They could help connect results from different fields more directly.

What advice would you give to young scientists considering a career in physics or laser-based research?

KASRA: Be driven, systematic, and persistent. Treat problems as challenges rather than obstacles. Accept constructive criticism and use it to improve your work. Manage your time carefully and work efficiently. Do not be discouraged by setbacks. Progress in experimental research often comes from learning through failure.

GIULIO: Be persistent and honest about your results. Do not focus only on producing a large number of publications. High-quality work is more valuable in the long term. Competition is part of an academic career, but integrity is essential. Take time to properly understand and report your findings. This approach will pay off over the course of a scientific career.

Interview by: Julia Bill

Lasers Without Borders: Past and future of Laserlab-Europe at MBI

Interview with Daniela Stozno and Neide Pedro

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Daniela Stozno (right), project manager of Laserlab-Europe since its foundation and head of the association's secretariat at the Max Born Institute, and Neide Pedro (left), project manager at MBI coordinating the Lasers4EU project. In the interview, they discuss the origins of Laserlab-Europe and MBI's key role as well as how Laserlab-Europe plans to expand its network in the future and develop new EU-funded initiatives.

Dear Ms. Stozno, dear Ms. Pedro, could you please introduce yourselves and your role regarding Laserlab-Europe at MBI.

DANIELA STOZNO: I have been project manager of Laserlab-Europe since its foundation more than 20 years ago, coordinating the successive projects from proposal preparation to implementation. I am also head of the secretariat of Laserlab-Europe AISBL, an international association founded by the members of Laserlab-Europe in 2018.

NEIDE PEDRO: Two years ago, I started as project manager at MBI. I am managing the Lasers4EU project where MBI has the role of coordinator, and I am involved in several other projects where I supervise work packages and tasks.

What exactly is Laserlab-Europe and what makes it so unique?

NEIDE: Today, Laserlab-Europe is an association of 48 leading laser research infrastructures in 22 European countries, going far beyond the membership in the joint projects. Most of the members, like MBI, provide open access to their facilities to scientists from all over the world to perform experiments in a large variety of advanced inter-disciplinary research from basic science to applications in many domains of research and technology. Under the umbrella of Laserlab-Europe, the members collaborate in EU-funded projects to provide access to their labs and to further promote cooperation on different topics.

When and why was it founded?

DANIELA: The association Laserlab-Europe AISBL was founded in 2018 to ensure continued collaboration of its members in view of changing EC funding priorities. The members highly valued the opportunities and synergies of their joint work that was made possible by the EC-funded projects. Therefore, they decided to create a legal entity, funded by themselves, that would allow for a basic level of collaboration and exchange even in the absence of major EC funds.

Which role did the MBI play in its founding and today?

DANIELA: MBI has organized the process of setting up the association and is one of the founding members. Since its approval as international non-profit association by the Belgian authorities, MBI is hosting the secretariat of the association. Over time, the secretariat's team has grown to seven staff members, managing projects and work packages in diverse EC projects.

Could you please tell us about Laserlab-Europe's various locations across Europe and international collaborations?

NEIDE: Currently, Laserlab-Europe has members in the majority of European countries, from Finland in the north to Portugal and Greece in the south, from the UK in the west to Lithuania and Romania in the east. Beyond this European coverage with an increasing number of members, Laserlab-Europe is active at an international level. In general, many scientists from all over the world have access to the labs. In addition, projects involve partners in Ukraine and the US, exchange with US labs in the X-lites consortium providing access to their facilities is promoted by a Memorandum of Understanding, and on a less formal level, collaboration with the Asian Intense Laser Network is pursued.

What are current (and upcoming) projects, for which Laserlab-Europe and MBI work together? Who is involved in those?

NEIDE: Most importantly, MBI is coordinating Lasers4EU, together with a scientific coordinator based at LULI in France. Lasers4EU is the most recent project in which laser laboratories all over Europe offer their labs to external scientists for conducting experiments. Several groups at MBI provide access to their labs under this project and benefit from further opportunities such as staff exchanges with consortium partners. Within the 360CARLA project, MBI works together with other Laserlab-Europe members to promote career opportunities in the field of optics and photonics.

Could you give us an outlook: What does the future hold for Laserlab-Europe? What's the vision?

DANIELA: Currently, Laserlab-Europe is strengthening the cooperation in the ARIE network, the Analytical Research Infrastructures in Europe, that includes synchrotrons, laser systems and free-electron lasers, sources of neutrons, ions and other particle beams, and facilities dedicated to advanced electron-microscopy and high magnetic fields. Two large-scale projects focus on synergies between these different science centers, one in the field of circular materials research (ReMade@ARI) and one in nanoscience and nanotechnology (RIANA). Together with ARIE partners, new proposals for EU funding are underway to ensure continued access to laboratories and collaboration. Within the Laserlab-Europe consortium, emphasis will be put on knowledge exchange through short-term visits and collaboration in the expert groups, focusing on diverse topics such as data analysis in imaging and spectroscopy, cultural heritage, clean energy and extreme intensity laser systems.

Laserlab-Europe connects 48 leading laser research infrastructures across 22 countries. Through this unique network, laboratories such as the Max Born Institute provide international researchers access to advanced laser facilities and collaborate on large-scale European research projects.

Interview by: Julia Bill

Interview Alumna Lisa-Marie Kern

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A little introduction: Who is Lisa-Marie Kern?

I am currently a postdoctoral researcher in the Spin Dynamics Group at MIT. Before that, I studied Physics in Germany, Luxembourg and France, and completed my PhD on the controlled manipulation of magnetic skyrmions in 2023 at MBI and TU Berlin. My research focuses on magnetism on ultrasmall length and ultrafast time scales, working at the intersection of magnetism, materials science and X-ray imaging.

How did you become interested in physics? And how did you later decide on your research focus?

With my father being a physicist too, I was exposed to and became fascinated by physics at a young age. At school, I loved both numbers and languages, which then drew me to the German-French double-degree programs. Studying Physics across Germany and France allowed me to explore physics from multiple perspectives while combining my passion for science and international experience – a path that shaped my approach to research today.

You already have various research positions behind you. How did you come to work at the MBI?

I completed my master’s thesis at the Laboratoire Albert Fert in Paris, where I worked on magnetism and spintronics. For my PhD, however, I wanted to return to Germany, and MBI quickly caught my attention for its outstanding research combining magnetism with X-ray imaging, a new direction I was eager to pursue. From my initial visit to MBI, I felt that both the project and the team were an excellent fit. After joining, I greatly appreciated the open and collaborative atmosphere, which became particularly evident during beamtime experiments and helped me grow both as a researcher and as a person.

As a woman, how were you perceived in a male-dominated scientific discipline and at the MBI? What advice would you give to girls/women interested in physics?

When I started, there were even fewer women than there are today. Efforts to attract more women clearly take time but are starting to pay off – I see it in the PhD offices now. At the same time, the network of women at MBI has grown stronger and has become an active voice.

Personally, and I can of course only speak for our group, I never noticed any difference in how male colleagues and I were treated or perceived in the lab or on beamtime - and that’s how it should be everywhere.

From my experience and belief, I am convinced that diverse and inclusive teams, beyond just gender, benefit from a variety of perspectives and simply work better.
My advice: stay curious, be confident, and find good mentors.

Is there anything that distinguishes MBI from other institutions you have encountered? What do you think is special about MBI?

MBI brings together diverse expertise under one roof, enabling interdisciplinary collaboration and the use of specialized skills and infrastructure. Working alongside experts in laser technology, nanofabrication, magnetism, X-ray imaging has enriched my research and inspired ideas that probably wouldn’t arise within a single discipline.

Was there a project or question at MBI that had a decisive influence on your future scientific direction?

My PhD research was on dynamics and control of complex magnetic textures of nanometer size and it was unique that I could pursue this with worldwide unique instruments, e.g. combining X-ray microscopy with laser pulse excitation. I was fortunate that my PhD project sparked a number of ideas and follow-up projects, many of which continue to inspire my research today and help shape new directions in the field.

Were there any mentors or colleagues at MBI who particularly encouraged or inspired you?

Many people at MBI and in its broader network have inspired me and continue to do so. I am especially grateful for the support of my advisors and now mentors, Bastian Pfau and Stefan Eisebitt. They gave me confidence and autonomy from the very beginning, and our discussions were always on equal terms - both of which I greatly appreciated.

To what extent did the MBI pave the way for you to now conduct research at MIT, among other places?

At MBI I have developed both professional and personal skills that are valuable in research and likely in industry as well: technical expertise in nanofabrication, characterization, (X-ray) microscopy, and data analysis, as well as soft skills in project management, proposal writing, presentations, and teamwork. The MBI environment allowed me to follow my curiosity and do excellent science which was published with high visibility - this was important to make the next step in my career. The first contact to the MIT team was established by a collaboration during my MBI time.

Are you still in contact with colleagues from the MBI?

Yes, we are still collaborating closely.

What advice would you give to young scientists who are joining the MBI today?

Be present, engage with your local network, and don’t hesitate to reach out for advice when you need it.

One sentence that would describe your experience at MBI:

Beamtimes were a central part of our group’s research, and what stayed with me most was the genuine teamwork - colleagues coming together, all driven by a shared curiosity and dedication to advancing cutting-edge physics.

Interview by: Julia Bill

Dr. Lisa-Marie Kern is the winner of the KlarText Award 2024. Learn more about her in this video:
https://www.youtube.com/watch?v=X-fIFC3wPcHQ

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6th Ultrafast Magnetism Conference

2-6 September 2024
Berlin, Germany

Prof. Dr. Stefan Eisebitt

The Ultrafast Magnetism Conference (UMC) series is the premier international event where researchers in the field of ultrafast spin and magnetization dynamics come together to discuss ultrafast dynamic processes in magnetic materials on picosecond, femtosecond and attosecond time scales. The series started 2013 in Strasbourg, continuing, Strasbourg (2013), Nijmegen (2015), Kaiserslautern (2017), York (2019), and Nancy (2022). The 2024 event took place in Berlin, jointly organized by the conference chairs Prof. Weinelt (Freie Universität Berlin) and Prof. Eisebitt (Max Born Institute). About 200 participants met to share their newest insight on spin dynamics and ultrafast magnetic switching, spin phononics, spin transport and devices, angular momentum transport beyond spin, as well as 2D and new materials enabling the observation and use of ultrafast magnetic phenomena. With 21 invited talks and tutorials and about 140 contributed presentations over the course of one week, the new developments in the field were discussed intensively, such as the transport of orbital moment or the exploitation of dynamics in antiferromagnets. UMC 2026 will take place at Eindhoven University, chaired by Prof. Koopmans.

HT-DYNA Workshop

Structural Dynamics of Elementary Proton Transport Processes
1-3 September 2025, Berlin, Germany

Dr. Erik T. J. Nibbering (MBI), and
Prof. Dr. Joachim Heberle (Physics Department, Free University Berlin)

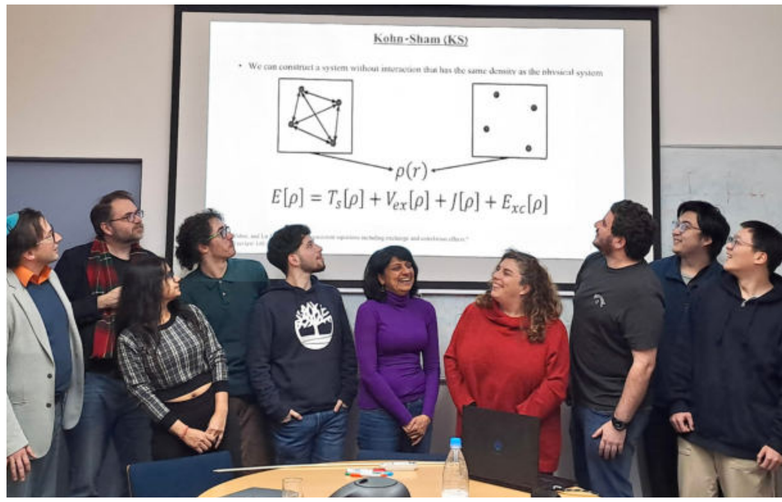
Proton transport is as ubiquitous as where acid and bases meet in real-world situations: from hydrogen fuel cell batteries to proton pumps in transmembrane proteins. Even though much progress has been achieved during the last three decades in the understanding of proton transport mechanisms either of the time scales involved – typically using experimental spectroscopic techniques – or at the microscopic level – using state-of-the-art ab initio quantum chemical simulations – only recently these two methodological approaches have started to touch common grounds. It is thus most timely to bring these communities from different backgrounds together in a workshop discussing the latest findings from which new insights and new activities are likely to be obtained. For this purpose, over 50 scientists, postdocs and Ph.D. students participated in the CCO Auditorium at the Charité in Berlin, an environment allowing for fruitful and lively discussions, and made HT-DYNA a successful event.

Workshop: Time-dependent exchange-correlation functionals for spin dynamics

8-10 December 2025,
Berlin, Germany

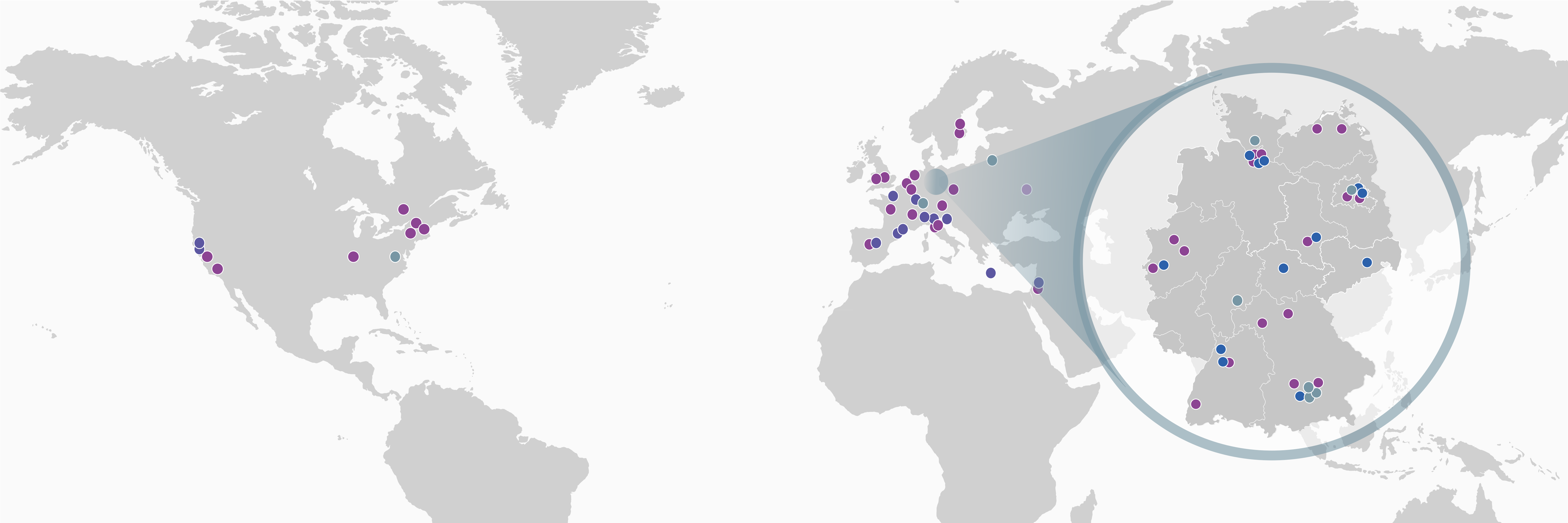
Prof. Dr. Sangeeta Sharma

An accurate theoretical description of materials' properties and physical and chemical processes they undergo requires a solution of the interacting many-electron problem. Such a solution in real materials is computationally formidable, with ~1015 GB of memory required just to store the wavefunction of an oxygen atom alone. However, in 1998 Walter Kohn was awarded Nobel Prize for developing an alternative to the direct wavefunction approach, namely, density functional theory (DFT) and Kohn-Sham method. Nowadays, Kohn-Sham allows for almost all ab-initio electronic structure calculations. Within DFT, a many-electron system can be treated using a system of non-interacting electrons, which are moving in a very complex potential. This potential is not known exactly, and it (or, more precisely, one of its ingredients, named the exchange-correlation (xc) potential), has to be approximated. In the workshop we discussed methods to improve these xc potentials for better description of laser pumped materials.



In December 2025, scientists form Hebrew University of Jerusalem, MPI-Halle and MBI met in Berlin to design better functionals within time-dependent density functional theory. These functionals are sculpted to better describe the physics of laser pumped strongly correlated and coupled materials. This would finally allow us to use the non-interacting Kohn-Sham system to study the dynamics of fully interacting strongly correlated materials.

Selected Cooperation Partners



Universities
- Autonoma University, Madrid, Spain
- Caltech, Pasadena, USA
- Complutensa University, Madrid, Spain
- École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
- École Polytechnique, Palaiseau, France
- FU University Berlin, Germany
- Harvard University, Cambridge, USA
- Imperial College London, UK
- Kansas State University, USA
- Leibniz-University Hanover, Germany
- Ludwig-Maximilian University of Munich, Germany
- Martin-Luther-University (MLU), Halle-Wittenberg, Germany
- Massachusetts Institute of Technology (MIT), Cambridge, USA
- Rostock University, Germany
- Ruhr-University Bochum, Germany
- RWTH Aachen, Germany
- Scuola Normale Superiore, Pisa, Italy
- Stanford University, USA
- Stockholm University, Sweden
- Technion, Haifa, Israel
- The Hebrew University of Jerusalem, Israel
- TU Berlin, Germany
- TU Dortmund, Germany
- University College London, UK
- University of Augsburg, Germany
- University of Berkeley, USA
- University of California at Santa Barbara, USA
- University of Chemistry and Technology, Prague, Czech Republic
- University of Freiburg, Germany
- University of Ghent, Belgium
- University of Graz, Austria
- University of Greifswald, Germany
- University of Hamburg, Faculty of Physics, Germany
- University of Hamburg, The Hamburg Centre for Ultrafast Imaging, Germany
- University of Konstanz, Germany
- University of Lorraine, Nancy, France
- University of Ottawa, National Research Council, Canada
- University of Padua, Italy
- University of Rochester, USA
- University of Siena, Italy
- University of Würzburg, Germany
- Uppsala University, Sweden
- Utrecht University, The Netherlands
- Yale University, New Haven, USA

- **Non-university research institutions**
- DESY Hamburg, Germany
- European XFEL, Hamburg u. Schenefeld, Germany
- Ferdinand-Braun-Institut, Berlin, Germany
- FERMI@Elettra, Italy
- Forschungszentrum Jülich, Germany
- FORTH Foundation for Research & Technology – Hellas, Greece
- Fritz Haber Institute, Berlin, Germany
- Helmholtz Institute Jena; Germany
- Helmholtz-Zentrum Berlin, Germany
- Helmholtz-Zentrum Dresden-Rossendorf, Germany
- ICFO, Barcelona, Spain
- ICMM Instituto de Ciencia de Materiales de Madrid, Spain
- IIT Delhi, India
- IMDEA Nanoscience, Madrid, Spain
- Institut für Kristallzüchtung, Berlin, Germany
- Institut Jean Lamour, France
- Instituto Polytechnico di Milano, Italy
- Lawrence Berkeley Lab, USA
- MPI for Intelligent Systems, Stuttgart, Germany
- MPI for Nuclear Physics, Heidelberg, Germany
- MPI for the Structure and Dynamics of Matter, Hamburg, Germany
- MPI of Microstructure Physics, Halle (Saale), Germany
- MPI of Quantum Optics, Garching, Germany
- Paul Scherrer Institute, Villigen, Switzerland
- Service de Physique de l'Etat Condensé SPEC, CEA, CNR, France
- SLAC Natl. Accelerator Lab, Linac Coherent Light Source, USA
- Strasbourg Institute of Material Physics and Chemistry, France
- The Weizmann Institute, Israel

Companies
- ASML Berlin GmbH, Germany
- Class 5 Photonics, Germany
- DECTRIS AG, Switzerland
- Light Conversion, Lithuania
- Menhir Photonics, Switzerland
- Menlo Systems, Germany
- Qlibri GmbH, Germany
- Thermo Fisher Scientific, USA
- Toptica Photonics SE, Germany

Appendices

Appendix 1

Publications 2024

AER24: O. Alexander, F. Egun, L. Rego, A. M. Gutierrez, D. Garratt, G. A. Cardenes, J. J. Nogueira, J. P. Lee, K. Zhao, R.-P. Wang, D. Ayuso, J. C. T. Barnard, S. Beauvarlet, P. H. Bucksbaum, D. Cesar, R. Coffee, J. Duris, L. J. Frasinski, N. Huse, K. M. Kowalczyk, K. A. Larsen, M. Matthews, S. Mukamel, J. T. O'Neal, T. Penfold, E. Thierstein, J. W. G. Tisch, J. R. Turner, J. Vogwell, T. Driver, N. Berrah, M.-F. Lin, G. L. Dakovski, S. P. Moeller, J. P. Cryan, A. Marinelli, A. Picón, and J. P. Marangos; Attosecond impulsive stimulated X-ray Raman scattering in liquid water; Sci. Adv. **10** (2024) eadp0841/1-8

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BJS24a: G. G. Brown, Á. Jiménez-Galán, R. E. F. Silva, and M. Y. Ivanov; Ultrafast dephasing in solid-state high harmonic generation: macroscopic origin revealed by real-space dynamics; J. Opt. Soc. Am. B **41** (2024) B40-B46

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BMS24: 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 **11** (2024) 234-237

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HZK: K. Heyne, X. Zhang, V. Kozich, A. Lindinger, T. Nagy, and M. J. J. Vrakking; Negatively chirped, self-compressing supercontinuum generation by ghost pulses; Nature portfolio

JKA: S. Jana, R. Knut, D. Afanasiev, N. Pontius, C. Schüßler-Langeheine, C. Tzschaschel, D. Schick, A. V. Kimel, O. Karis, C. v. K. Schmising, and S. Eisebitt; X-ray view of light-induced spin reorientation in TmFeO: Direct observation of a 90° Néel vector rotation

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LLC: K. Kato, K. Miyata, S. Wada, and V. Petrov; Thermo-optic dispersion formulas for AgGa1–xInxSe2; Opt. Mater. Express

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MRS: M. Mattern, A. Rodriguez-Fernandez, R. Shayduk, J. A. Arregi, V. Uhlíř, U. Boesenberg, J. Hallmann, W. Jo, A. Leonau, R. Rysov, J. Wrigley, A. Zozulya, S. Eisebitt, A. Madsen, D. Schick, and J.-E. Pudell; Ultrafast X-ray sonography reveals the spatial heterogeneity of the laser-induced magneto-structural phase transition in FeRh; Nat. Commun.

PDB: M. Piotrowski, S. Das, M. Bock, D. Ueberschaer, U. Griebner, and V. Petrov; Two-photon absorption of Germanium measured by z-scan at 2.05 µm; Opt. Mater. Express

RRF: Q. Remy, R. Rouzegar, O. Franke, G. Lemut, O. Gueckstock, J. Tong, W. D. Engel, X. Zhang, G. Woltersdorf, P. Brouwer, and T. Kampfrath; Femtosecond signatures of optically induced magnons before ultrafast demagnetization; Nat. Phys.

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SKK: N. Stetzuhn, A. M. Kumar, S. Kovalchuk, D. Yagodkin, L. Simon, S. Mañas-Valero, E. Coronado, T. Taniguchi, K. Watanabe, D. Gill, S. Sharma, P. Brouwer, C. v. K. Schmising, S. Eisebitt, and K. I. Bolotin; Tunable magnons in a dual-gated 2D antiferromagnet

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SSZ: M. A. Susner, P. Schunemann, K. Zawilski, J. Jesenovec, and V. Petrov; Thermal expansion of CdGeP2: a nonlinear chalcopyrite crystal for THz generation; Opt. Mater. Express

SZF: G. Steinmeyer, J. Zhang, J. Fan, C. Mei, and M. Hu; Efficient beam self-cleaning in a dissipative double-clad fibre; Opt. Lett.

TLJ: J. W. Tomm, J. Lang, and J. Jimenez; Catastrophic optical damage to edge-emitting diode lasers – new perspectives; Appl. Phys. Rev.

WKP: S. Wittrock, C. Klose, S. Perna, K. Baumgaertl, A. Mucchietto, M. Schneider, J. Fuchs, V. Deinhart, T. Karaman, D. Grundler, S. Eisebitt, B. Pfau, and D. Schick; Soft-X-ray momentum microscopy of nonlinear magnon interactions below 100-nm wave-length; Nat. Phys.

General Publications

BPi24: N. Bonod and N. Picqué; Interview with Nathalie Picqué; Photoniques **128** (2024) 21-23

WPi24: R. Won and N. Picqué; Dual-comb wonders; Nat. Photonics **18** (2024) 883-885

Bachelor, Master and PhD Theses

Bachelor Theses

Aue25: M. Auer; *Strominduzierte Erzeugung und Bewegung von H-Skyrmionen* (Supervisor: S. Eisebitt), Technische Universität Berlin

Hof24: J. Hofrichter; *Supercontinuum generation in bulk crystals at 2.4 µm wavelength* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

Iwa24: V. I. Iwanaga; *Neural networks for low-noise ultrashort pump-probe spectroscopy* (Supervisor: S. Eisebitt), Technische Universität Berlin

Roc24: R. E. Rochus; *Resonante magnetische Streuung von nicht kollinearen Antiferromagneten an einer Laser-getriebenen Plasma Röntgenquelle* (Supervisor: S. Eisebitt), Technische Universität Berlin

Sei25: L. Seidel; *Temperature and magnetic field dependence of ultrafast magnetization dynamics* (Supervisor: S. Eisebitt), Technische Universität Berlin

Master Theses

Hua25: W. Huang; *Chirped pulse fiber delivery of intense ultrashort pulses for THz spectroscopy* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

Kor25: K. Korell; *X-ray magnetic circular dichroism with a picosecond laser-driven plasma source* (Supervisor: S. Eisebitt), Technische Universität Berlin

Opp25: L. Oppermann; *Simulation and experimental analysis of an active pump seed delay stabilization and thermal properties of a high power, high repetition rate OPCPA system* (Supervisor: M. Y. Ivanov and F. Furch), Humboldt-Universität zu Berlin

Pra25: S. M. Pramod; *Post-compression and characterization of femtosecond laser pulses* (Supervisors: M. J. J. Vrakking, M. Wolf, and T. Nagy), Freie Universität Berlin

Sch24: N. Schneider; *Time-resolved magnetic small angle X-ray scattering using a laser-driven plasma source* (Supervisor: S. Eisebitt), Technische Universität Berlin

Uts25: F. Utsch; *Ultrafast Dynamics of an optically induced insulator-metal transition in NdNiO$_3$* (Supervisor: S. Eisebitt), Technische Universität Berlin

PhD Theses

Run24: M. Runge; *Nonlinear low-frequency excitations of condensed matter studied by two-dimensional terahertz spectroscopy* (Supervisor: T. Elsaesser), Humboldt-Universität zu Berlin

Sin24: P. Singh; *Real-time mapping of electric interactions in polar molecular environment using terahertz spectroscopy* (Supervisor: J. Kneipp and T. Elsaesser), Humboldt-Universität zu Berlin

Ste24: F. Steinbach; *Ultrafast and ultrasmall: exploring temporally and spatially the influence of heat diffusion on magnetic all-optical switching* (Supervisor: S. Eisebitt), Technische Universität Berlin

Appendix 2

External Talks, Teaching

Invited Lectures at Conferences

K. Busch; Optical Wave & Waveguide Theory and Numerical Modelling OWTNM24 (Kiel, Germany, 2024-05): *Theory and computation of atom-surface interactions*

K. Busch; Numerics, Dynamics & Physics of the CRC 1173 (Karlsruhe, Germany, 2024-06): *Atom-Surface Interactions: Theory and Computations*

T. A. Butcher; Seminar, Joint Meeting of PSRC Members and SOLARIS Centre Users (Krakau, Poland, 2024-09): *Development of ptychographic imaging with soft X-rays*

W. Chen with H.-Y. Nie, Z.-L. Lin, H.-J. Zeng, G. Zhang, P. Zhang, Z. Li, Z. Chen, P. Loiko, X. Mateos, V. Petrov; Optics Frontier - The 15th Int. Conference on Information Optics and Photonics (CIOP 2024) (Xi'an, China, 2024-08): *23-fs diode-pumped Kerr-lens mode-locked Yb,Gd:YAP laser*

L. Drescher; General Conference of the Condensed Matter Division of the European Physical Society (Braga, Portugal, 2024-09): *Ultrafast relaxation of carriers and spin in solids measured with attosecond transient absorption spectroscopy*

U. Eichmann; Science @ FELs 2024 (Paris, France, 2024-06): *Two-color stimulated Raman transitions in atomic systems from the XUV to the soft X-ray regime*

T. Elsaesser; BBAW - RSC Bilateral Meeting 'Expectations of Chemistry for a Sustainable World' (Berlin, Germany, 2024-10): *Charge densities and electric interactions in molecules and molecular materials*

F. J. Furch *together with* G. Arisholm; 32nd Annual Int. Laser Physics Workshop - LPHYS'24 (San Carlos, Brazil, 2024-07): *Few-cycle optical vortices from OPCPAs*

U. Griebner *together with* M. Bock, and G. Steinmeyer; XI Int. Conference "Ultrafast Dynamics & Ultrafast Bandgap Photonics" (Hersonissos, Crete, Greece, 2024-06): *Post-compression of few-cycle millijoule pulses beyond 4 µm wavelength*

U. Griebner *together with* M. Bock, and P. Fuertjes; 32nd Annual Int. Laser Physics Workshop - LPHYS'24 (San Carlos, Brazil, 2024-07): *Extension of a 1 kHz hard X-ray pump-probe setup by a few-cycle OPCPA pump at 11 µm*

A. Husakou *together with* I. Babushkin, O. Fedotova, R. Rusetsky, T. Smirnova, O. Khasanov, A. Fedotov, U. Sapaev, and T. Apostolova; XII Ultrafast Dynamics & Metastability and Ultrafast Bandgab Photonics Conference (University of Arizona, Tucson, USA, 2024-09): *Generation of ultrashort optical pulses by a transient plasmonic resonance, Keynote talk*

M. Y. Ivanov; PQE 2024 Physics of Quantum Electronics (Snowbird, Utah, USA, 2024-01): *Attosecond Science: Back to the Quantum Future, Plenary talk*

M. Y. Ivanov; Quantum light-matter interactions: Imaging and spectroscopy of ultrafast dynamics (GRC conference) (Bryant University, Smithfield, USA, 2024-06): *Attosecond science: Back to the quantum future*

M. Y. Ivanov; Quantum Frontiers in Molecular Science - Mexican Edition (Universidad Nacional Autonoma de Mexico, Mexico, 2024-07): *Lightwave driven topology for PHz valleytronics, tutorial lecture*

L.-M. Kern; DPG-Frühjahrstagung (Berlin, Germany, 2024-03): *Controlled manipulation of magnetic skyrmions: Generation, motion and dynamics*

L.-M. Kern; 9. ICSM 2024, Int. Conference on Superconductivity and Magnetism (Ölüdeniz-Fethiye, Turkey, 2024-05): *Controlling spin-orbit Torque driven dynamics for skyrmion generation*

L.-M. Kern; ICM 2024, Int. Conference on Magnetism (Bologna, Italy, 2024-07): *Controlling spin-orbit Torque driven dynamics for skyrmion generation*

L.-M. Kern; 16th BESSY@HZB User Meeting (Berlin, Germany, 2024-12): *Imaging nanometer scale spin textures and their picosecond dynamics*

K. Lamonova; 12. Int. Conference on Luminescent Detectors and Transformers of Ionizing Radiation (Riga, Latvia, 2024): *Modified crystal field theory: new possibilities for optical spectra analysis*

K. Lamonova; 12. Int. Conference on Luminescent Detectors and Transformers of Ionizing Radiation (Riga, Latvia, 2024): *Quantum dots as a precondition for the* $ZnCr_2Se_4$ *spinel formation in ZnSe:(Fe, Cr) laser crystal matrixes*

M. Mattern; 16th BESSY@HZB User Meeting (Berlin, Germany, 2024-12): *KMC-3 XPP accelerating the laser induced phase transition in nanostructured FeRh via plasmonic absorption*

E. T. J. Nibbering; 13th Ringberg Workshop on Science with FELs (Ringberg Castle, Tegernsee, Germany, 2024-02): *Ultrafast proton transfer in acid-base chemistry*

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, E. Ryland, K. Kunnus, J. Koralek, D. DePonte, M. Fondell, R. Mitzner, K. Gaffney, E. Pines, G. Dakovski, Ph. Wernet, and M. Odelius; Ultrafast Dynamic Imaging of Matter Conference (UFDIM) 2024 (Hamburg, Germany, 2024-11): *Ultrafast proton transport probed with soft-X-ray spectroscopy*

V. Petrov; Workshop IKZ Fellowship (Berlin, Germany, 2024-04): *Recent progress in non-oxide nonlinear crystals for the mid-IR*

V. Petrov with Y. Zhao, H. Yu; The 13th Advanced Lasers and Photon Sources (ALPS'24), (Yokohama, Japan, 2024-04): *Single crystal fibers for direct amplification of femtosecond optical vortices*

V. Petrov with X. Mateos, P. Loiko, M. Ceballos, A. Baillard, G. Brasse, R. M. Solé, A. Braud, W. Chen, M. Aguiló, C. Romero, V. Arroyo, J. R. Vázquez de Aldana, V. Llamas, J. M. Serres, P. Camy, F. Díaz; The 10th Tiny Integrated Laser and Laser Ignition Conference (TILA-LIC'24), (Yokohama, Japan, 2024-04): *Materials for waveguide lasers in the visible*

V. Petrov with G. Exner, A. Grigorov, E. Ivanova, V. L. Tassev; Conference on Advanced Topics in Photonics (CATP 2024) (Sofia, Bulgaria, 2024-07): *Nanomechanical properties of epitaxially grown GaAs1-xPx Layers for nonlinear optical applications*

V. Petrov; CLEO Pacific Rim 2024 (Incheon, South Korea, 2024-08): *Recent progress in the generation of sub-100-fs pulses from 2-micron Tm and Ho mode-locked solid-state lasers*

V. Petrov; CIOP 2024, 15th Int. Conference on Information Optics and Photonics (Xi'an, China, 2024-08): *Revival of the nonresonant optical parametric oscillator*

B. Pfau; Hauptvortrag, DPG-Frühjahrstagung (Berlin, Germany, 2024-03): *Imaging with coherent soft X-rays*

B. Pfau; XI Int. Conference "Ultrafast Dynamics & Ultrafast Bandgap Photonics" (Hersonissos, Crete, Greece, 2024-06): *Understanding the ultrafast emergence of a skyrmion phase in a ferromagnet*

N. Picqué; DPG Spring Meeting of the Atomic, Molecular, Quantum Optics and Photonics Section (SAMOP) (Freiburg, Germany, 2024-03): *Frequency comb interferometry (plenary)*

N. Picqué; SPIE Photonics Europe, Nanophotonics X (Strasbourg, France, 2024-04): *Integrated optics for frequency comb technology*

N. Picqué; CLEO 2024 (Charlotte, NC, USA, 2024-05): *Ultraviolet dual-comb spectroscopy*

N. Picqué; CLEO 2024 (Charlotte, NC, USA, 2024-05): *Dual-comb interferometry: principles and latest trends (tutorial)*

N. Picqué; 22nd GMA/ITG Symposium Sensors and Measurement Systems (Nürnberg, Germany, 2024-06): *Optical sensing with frequency combs (plenary)*

M. Richter; COFIL 2024, Int. Conference on Laser Filamentation (Nankai University, Tianjin, China, 2024-08): *Quantum optimal control of air lasing at ambient condition*

M. Richter; ISUILS 2024, Int. Symposium on Ultrafast Intense Laser Science (Jeju, South Korea, 2024-08): *Quantum optimal control of air lasing at ambient condition*

D. Schick; XI Int. Conference "Ultrafast Dynamics &Ultrafast Bandgap Photonics" (Hersonissos, Crete, Greece, 2024-06): *An ultrafast and depth-resolved view on all-optical switching of in-plane magnetization*

C. v. K. Schmising; Conference on Laser and Synchrotron Radiation Combination Experiment 2024 (LSC2024) (Yokohama, Japan, 2024-04): *Ultrafast and ultrasmall: all-optical switching of magnetization*

C. v. K. Schmising; UMC 2024, 6th Ultrafast Magnetism Conference (FU Berlin, Germany, 2024-09): *The fundamental spatial limit of ultrafast all-optical switching probed by transient grating spectroscopy*

M. Schneider; 36. MAX IV User Meeting (Lund, Sweden, 2024-01): *Holographic soft-X-ray imaging: spatial, temporal and spectroscopic resolution*

B. Schütte *together with* M. Kretschmar, E. Svirplys, M. Volkov, T. Witting, T. Nagy, and M. J. J. Vrakking; CLEO 2024 (Charlotte, NC, USA, 2024-05): *All-attosecond pump-probe spectroscopy at kHz repetition rate*

B. Schütte; Laserlab-Europe Conference (Lissbon, Portugal, 2024-05): *All-Attosecond transient absorption spectroscopy using HHG*

S. Sharma; NWO Physics 2024 (NH Koningshof, Veldhoven, The Netherlands, 2024-01): *Femto-phono-magnetism*

S. Sharma; Ultrafast Surface Dynamics (Göttingen (Uslar), Germany, 2024-05): *Ab-initio dynamics in quantum materials*

S. Sharma; UMC 2024, 6th Ultrafast Magnetism Conference (FU Berlin, Germany, 2024-09): *All about two dimensional materials - (invited tutorial)*

Appendix 2

O. Smirnova; The 53rd Winter Colloquium on the Physics of Quantum Electronics (Snowbird, UT, USA, 2024-01): *Enantio-sensitive spin-orientation locking and spin vortices induced by geometric fields in chiral molecules*

O. Smirnova; Attochem (Tenerife, Spain, 2024-03): *Ultrafast molecular chirality: a topological connection, plenary talk*

O. Smirnova; 8. Int. conference on photoinduced phase transitions (PIPT8) (Nijmegen, The Netherlands, 2024-06): *Sub-cycle multidimensional spectroscopy of strongly correlated materials*

O. Smirnova; GRC and GRS on Multiphoton Processes (Boston, USA, 2024-06): *Panel Discussion, Scientific carreers in academia and industry*

O. Smirnova; 23rd Int. Conference on Ultrafast Phenomena 2024 (Barcelona, Spain, 2024-07): *Ultrafast molecular chirality: A topological connection*

O. Smirnova; Quantum Frontiers in Molecular Science 2024 (Mexico City, Mexico, 2024-07): *Ultrafast molecular chirality: a topological connection*

O. Smirnova; CMD31, General Conference of the Condensed Matter Division (Braga, Portugal, 2024-09): *Sub-cycle multidimensional spectroscopy of strongly correlated materials*

O. Smirnova; The 54th Winter Colloquium on the Physics of Quantum Electronics (PQE) Snowbird (Snowbird, UT, USA, 2025-01): *Geometry of temporal chiral structures and photoinduced chirality-spin coupling*, plenary talk

O. Smirnova; Workshop “Theory meets XFELs 2025” (Hamburg, Germany, 2025-12): *Chirality-spin coupling without magnetic fields*

O. Smirnova; DPG Spring meeting CM division 2025 (Regensburg, Germany, 2025-03), *Geometry of temporal chiral structures and photoinduced chirality-spin coupling*, invited talk

N. Stetzuhn; 73rd Lindau Nobel Laureate Meeting (Lindau, Germany, 2024-07): *Ultrafast, ultrathin, ultratunable: Spintronics in 2D materials*

C. Tzschaschel; INTERMAG 2024, Int. Magnetics Conference (Rio de Janeiro, Brazil, 2024-05): *Optical control of antiferromagnetism*

M. J. J. Vrakking; WUFS2024, The 2024 Int. Workshop on Ultra-Fast Science (East China Normal University, Shanghai, China, 2024-04): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking; Int. School on Ultrafast X-Ray & Attosecond Science (University Paris-Saclay, Fance, 2024-05): *Quantum effects (I)*

S. Amann *together with* E. Vicentini, T. W. Haensch, and N. Picqué; 14th Advanced Lasers and Photon Sources Conference (ALPS2025) (Yokohama, Japan, 2025-04): *Three-dimensional imaging using optical frequency combs*

Q. Bournet *together with* S. Amann, and N. Picqué; Nonlinear Dynamics in Semiconductor Lasers 2025 (NDSL 2025) (Berlin, Germany, 2025-06): *Long-wavelength microresonator-based frequency combs*

K. Busch; AMPD 2025, 17th Annual Meeting Photonic Devices (Berlin, Germany, 2025-04): *Atom-Surface Interactions: Theory and Computations*

K. Busch; WE-Heraeus-Seminar “Non-Hermitian and Topological Photonics” (Berlin, Germany, 2025-06): *Multiphoton dynamics in tight-binding lattices*

T. A. Butcher; 13th Asia Pacific Microscopy Congress 2025 (APMC13) (Brisbane, Australia, 2025-02): *Imaging ferroic order in nanomaterials with soft X-ray ptychography*

T. A. Butcher; Joint European Magnetism Symposia 2025 (Frankfurt, Germany, 2025-08): *Probing multiferroic order with dichroic soft X-ray ptychography*

W. Chen *together with* H.-Y. Nie, Z.-L. Lin, P. Loiko, H.-J. Zeng, L. Zhang, Z. Lin, X. Mateos, V. Petrov; Optics Frontier - The 16th Int. Conference on Information Optics and Photonics (CIOP 2025), (Xi’an, China, 2025-08): *Kerr-lens mode-locked, diode-pumped Yb:MgWO4 laser generation 32 fs pulses at 1079 nm*

W. Chen; Spin, Waves, and Interactions 2025 (Greifswald, Germany, 2025-09): *Ultra long range physics*

S. Eisebitt; XIII Int. Symposium “Ultrafast Dynamics and Ultrafast Bandgap Photonics, Int. Symposium & The Summer School” (Hersonissos, Crete, Greece, 2025-06): *Dynamics and fundamental spatial limits in all-optical magnetic switching*

S. Eisebitt; FisMat 2025 (Venice, Italy, 2025-07): *How to get magnets small, fast*

T. Elsaesser; 54th Winter Colloquium on the Physics of Quantum Electronics (PQE) (Snowbird, UT, USA, 2025-01): *Electric interactions in liquids and proteins probed by ultrafast terahertz methods*

T. Elsaesser; 14th Ringberg Workshop on Science with FELs (Rottach-Egern, Germany, 2025-02): *Electric charge dynamics in liquids and proteins probed by ultrafast terahertz methods*

T. Elsaesser; HT-DYNA Workshop on Structural Dynamics of Elementary Proton Transport Processes (Berlin, Germany, 2025-09): *Ultrafast probes and electron dynamics in liquids and solids (plenary)*

T. Elsaesser; 19th Int. Conference on X-ray Lasers (Orford, QC, Canada, 2025-10): *Compact laser-driven hard X-ray sources for femtosecond diffraction experiments*

F. J. Furch; VII “Rio de la Plata” Workshop on Optics and Photonics (Punta del Este, Uruguay, 2025-12): *High average power OPCPA with minimized spatio-temporal distortions*

U. Griebner *together with* M. Bock, and P. Fuertjes; XIII Ultrafast Dynamics & Ultrafast Bandgap Photonics 2025 (Hersonissos, Crete, Greece, 2025-06): *Upgrade of an X-ray pump-probe arrangement by a high-energy few-cycle OPCPA pump at 11 µm*

U. Griebner *together with* M. Bock, D. Ueberschaer, and G. Steinmeyer; 33rd Annual Int. Laser Physics Workshop - LPHYS’25 (Szeged, Hungary, 2025-06): *Extension of a 1 kHz hard X-ray pump-probe setup by a few-cycle OPCPA pump at 11 µm*

U. Griebner together with M. Bock, and G. Steinmeyer; 3rd Int. Conference on UltrafastX 2025 (Xiamen, China, 2025-10): *Generation of two-cycle 5 µm pulses with high spatio-temporal homogeneity and multi-mJ energy via nonlinear compression in II-VI chalcogenides*

S. Hu; Workshop on Coherence, Dephasing, Dissipation, Switching (TU Graz, Austria, 2025-11): *Dynamics of coupled electrons and phonons*

M. Y. Ivanov *together with* N. Klimkin, and S. Yi; 54th Winter Colloquium on the Physics of Quantum Electronics (PQE) (Snowbird, UT, USA, 2025-01): *Quantum Optics of High Harmonic Generation: From Atoms to Solids and Waveguides, Plenary Talk*

M. Y. Ivanov *together with* N. Klimkin, and S. Yi; China-Israel symposium on strong-light quantum optics, Nan’ao conference series (Nan’ao Island, China, 2025): *Quantum Optics of High Harmonic Generation: From Atoms to Solids and Waveguides, Keynote talk*

M. Y. Ivanov; WUFXS2025, The Int.Workshop on Ultrafast & X-ray Science (Shanghai, China, 2025-05): *Attosecond approaches to the generation of quantum states of light from IR to XUV range*

M. Y. Ivanov; IOP Mini Symposium on ultrafast Science (Beijing University, China, 2025-05): *Attosecond approaches to the generation of quantum States of light from IR to XUV*

M. Y. Ivanov; SPEQED25, Strong-field Physics Encounters Quantum Electro Dynamics (MPI Dresden, Germany, 2025-08): *Quantum Light generation in strong laser fields: from atoms to solids*

M. Y. Ivanov; Strong-field attosecond and attosecond physics, Workshop (Aarhus University, Denmark, 2025-10): *From making quantum light to ultrafast quantum optical spectroscopy*

M. Kretschmar *together with* J. R.C. Andrade, R. Danylo, S. Carlström, T. Witting, A. Mermillod-Blondin, S. Patchkovskii, M. Y. Ivanov, M. J. J. Vrakking, A. Rouzée, and T. Nagy; CLEO Europe-EQEC 2025 Conference (München, Germany, 2025-06): *Full characterization of few-fs pulses tunable in the vacuum ultraviolet*

M. Kretschmar; 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden, 2025-07): *Characterization of sub-3-fs tunable VUV pulses*

A. Mermillod-Blondin; CLEO2025, Laser Science to Photonic Applications (Long Beach, USA, 2025-05): *Direct functionalization of amorphous fused silica with few-cycle laser pulses*

F. Morales and S. Carlström; Int. COST/ZCAM School on New Computational Methods for Attosecond Molecular Processes (Lausanne, Switzerland, 2025-05): *TDSE 1e simulation*

F. Morales and S. Patchkovskii; Int. COST/ZCAM School on New Computational Methods for Attosecond Molecular Processes (Lausanne, Switzerland, 2025-05): *Simulations on strong-field ionization*

T. Nagy *together with* J.R.C. Andrade, M. Kretschmar, R. Danylo, S. Carlström, T. Witting, A. Mermillod-Blondin, S. Patchkovskii, M. Y. Ivanov, M. J. J. Vrakking, and A. Rouzée; LPHYS’25, 33rd Annual Int.Laser Physics Conference (Szeged, Hungary, 2025-07): *In-situ characterization of few-fs tunable VUV pulses*

T. Nagy *together with* J.R.C. Andrade, M. Kretschmar, R. Danylo, S. Carlström, T. Witting, A. Mermillod-Blondin, S. Patchkovskii, M. Y. Ivanov, M. J. J. Vrakking, and A. Rouzée; UFO XIV, Ultrafast Optics XIV (Furnas, Azores, Portugal, 2025-10): *Full characterization of tunable few-fs vacuum ultraviolet pulses*

E. T. J. Nibbering *together with* M.-O. Winghart, S. Das, D. Rana, Z.-Y. Zhang, P. Han, M. Ekimova, C. Kleine, J. Ludwig, M. Ochmann, T. E. G. Agrenius, E. Kozari, D. Pines, M. Fondell, R. Mitzner, S. Eckert, E. Pines, N. Huse, Ph. Wernet, and M. Odelius; Int. Conference Celebrating the 220th Anniversary of the First Theory of Electrolysis by Theodor von Grotthuss (Vilnius, Lithuania, 2025-06): *On the nature of shared protons in water and in imidazole: Mid-infrared and soft-X-ray spectroscopy (keynote)*

E. T. J. Nibbering *together with* M.-O. Winghart, D. Rana, M. Kurucz, S. Jana, A.-L. Upterworth, S. Das, V. Kabanova, D. Garratt, A. Cordones, D. DePonte, K. Kunnus, E. Ryland, R. Jay, J. Koralek, M. Fondell, S. Eckert, K. Gaffney, E. Pines, G. Dakovski, D. Sebastiani, Ph. Wernet, and M. Odelius; The 16th Femtochemistry Conference (Trieste, Italy, 2025-06): *Ultrafast photoacid-base reactions in aqueous solution*

E. T. J. Nibbering *together with* M.-O. Winghart, Z.-Y. Zhang, D. Rana, M. Kurucz, P. Han, C. Kleine, A. Sen, A. Rouzée, M. Fondell, S. Eckert, D. Garrett, K. Gaffney, K. Kunnus, G. Dakovski, V. Kabanova, Ph. Wernet, S. Das, and M. Odelius; FisMat 2025 (Venice, Italy, 2025-07): *Ultrafast chemical reactions in aqueous solution: Probing the nitrogen K-edge with table-top X-treme high order harmonics sources and with free electron laser facilities*

V. Petrov *together with* X. Mateos, G. Z. Elabedine, R. M. Solé, S. Slimi, M. Aguiló, F. Díaz, and W. Chen; ALPS2025, The 14th Advanced Lasers and Photon Sources Conference (Yokohama, Japan, 2025-04): *Growth, spectroscopy and anisotropic properties of* Yb^{3+}*- and* Tm^{3+}*-doped* $MgWO_4$ *crystals*

V. Petrov *together with* X. Mateos, G. Z. Elabedine, R. M. Solé, S. Slimi, M. Aguiló, F. Díaz, and W. Chen; ALPS2025, The 14th Advanced Lasers and Photon Sources Conference (Yokohama, Japan, 2025-04): *Growth, spectroscopy and anisotropic properties of Yb^{3+}- and Tm^{3+}-doped MgWO$_4$ crystals*

V. Petrov; World Photonics Conference 2025, 14th Applied Optics and Photonics China (AOPC 2025) (Beijing, China; 2025-06): *Nonresonant optical parametric oscillators*

V. Petrov; 24th American Conference on Crystal Growth & Epitaxy (ACCGE-24) (Stevenson (WA), USA, 2025-07): *Acentric barium chalcogenides for mid-IR frequency conversion*

V. Petrov; The 21st Int. Conference on Crystal Growth and Epitaxy (ICCGE-21) (Xi'an, China, 2025-08): *Characterization of acentric barium chalcogenides for mid-IR nonlinear frequency conversion*

V. Petrov; Optics Frontier - The 16th Int. Conference on Information Optics and Photonics (CIOP 2025) (Xi'an, China, 2025-08): *Intracavity-pumped cascade optical parametric oscillators and difference-frequency generation*

B. Pfau; ICSM 2025, Int. Conference on Superconductivity and Magnetism (Ölüdeniz-Fethiye, Turkey, 2025-05): *Understanding and Controlling the Ultrafast Emergence of a Skyrmion Phase*

B. Pfau; DanScatt XFEL Workshop 2025 (Odense, Denmark, 2025-05): *Correlation-based single-shot X-ray imaging at a free-electron laser*

B. Pfau; Workshop Soft X-ray Science at PETRA (Odense, Denmark, 2025-11): *Imaging Thermal Motion of Nanoscale Skyrmions*

N. Picqué; SPIE Photonics West 2025 (San Francisco, CA, USA, 2025-01): *Optical frequency combs for interferometry from the mid-infrared to the ultraviolet range (plenary)*

N. Picqué; Int. Scientific Symposium on World Interferometry Day 2025 (Ilmenau, Germany, 2025-04): *Interferometry with optical frequency combs*

N. Picqué; 26th Int. Conference on Laser Spectroscopy ICOLS (Elba, Italy, 2025-06): *Interferometry with optical frequency combs (plenary)*

N. Picqué; GRC Laser Diagnostics in Energy and Reacting Flows (Les Diablerets, Switzerland, 2025-06): *Dual-comb spectroscopy and holography: New opportunities for characterizing energy and reacting flows*

N. Picqué; EOSAM 2025 - European Optical Society Annual Meeting (Delft, The Netherlands, 2025-08): *Frequency comb interferometry (plenary)*

J. Pilat *together with* B. Xu, T. W. Hänsch, and N. Picqué; DPG-Frühjahrstagung 2025 der Sektion Atome, Moleküle, Quantenoptik und Photonik (SAMOP) (Bonn, Germany, 2025-03): *Breaking the barrier of resolution in broadband spectroscopy*

A. Rouzée; CSC2025, Canadian Chemistry Conference and Exhibition 2025 (Ottawa, Canada, 2025-06): *Probing ultrafast molecular dynamics with ultrashort X-ray and VUV pulses*

D. Schick; Conference on Laser and Synchrotron Radiation Combination Experiment 2025 (LSC2025) (Yokohama, Japan, 2025-04): *Laser-driven soft-X-ray sources for studying ultrafast electron and spin dynamic*

D. Schick; Int. Conference on Resonant Elastic X-ray Scattering 2025 (REXS2025) (Almadraba, Spain, 2025-10): *Laser-driven resonant soft-X-ray scattering*

C. v. K. Schmising; XIII Int. Symposium "Ultrafast Dynamics and Ultrafast Bandgap Photonics XIII, Int. Symposium & The Summer School" (Hersonissos, Crete, Greece, 2025-06): *Interatomic spin transfer*

C. v. K. Schmising; FisMat 2025 (Venice, Italy, 2025-07): *Nanoscale magnetization switching probed by transient grating spectroscopy*

B. Schuette; ACS Spring 2025 (San Diego, CA, USA, 2025-03): *Table-top all-attosecond pump-probe spectroscopy*

B. Schuette; SPIE Optics + Optoelectronics 2025 (Prague, Czech Republic, 2025-04): *All-attosecond transient absorption spectroscopy using high-harmonic generation*

B. Schuette; IOQ-Kolloquium (Friedrich-Schiller-Universität, Jena, Germany, 2025-06): *All-attosecond pump-probe spectroscopy*

B. Schütte; ATTO X, 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden, 2025-07): *Table-top all-attosecond pump-probe spectroscopy*

A. Sen; 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden, 2025-07): *Probing the ultrafast vibronic wavepacket dynamics of ethylene with sub-4fs VUV pulses*

S. Shallcross; CECAM/ALC/CCP9 Spectroscopy Masterclass (CECAM-UK-DARESBURY, Rutherford Appleton Laboratory, Abingdon, UK, 2025-09): *Magnetism TD-DFT*

S. Shallcross *together with* S. Sharma; Magneto-Optics in Quantum Light and Matter Conference (National Physical Laboratory, Teddington, UK, 2025-11): *Femto- phono- magnetism*

S. Sharma; 10th Time-Dependent Density-Functional Theory: Prospects and Applications Workshop (Benasque, Spain, 2025-04): *Time-dependent density-functional theory for dynamics of excitons*

O. Smirnova; Workshop on Characterization and control of quantum materials with optical vortex beams (Ingelheim, Germany, 2025-06): *Enantio-sensitive spin-orientation locking and spin vortices induced by geometric fields in chiral molecules*

O. Smirnova; Topological Photonics 2025 (Donostia-San Sebastian, Spain, 2025-07): *Combining chirality and topology in ultrafast optical response of gas phase molecules, Keynote talk*

O. Smirnova; Int. Workshop "Strong-field Physics Encounters Quantum Electro Dynamics" (MPI für Physik komplexer Systeme, Dresden, Germany, 2025-08): *Enantio-sensitive spin-orientation locking and spin vortices induced by geometric fields in chiral molecules*

O. Smirnova; ELCH25 "Conference on Extreme Light and Chiral Molecular Systems" (Kassel, Germany, 2025-09): *Chirality-spin coupling without magnetic fields, invited talk*

O. Smirnova and S. Carlström; Int. COST/ZCAM School on New Computational Methods for Attosecond Molecular Processes (Lausanne, Switzerland, 2025-05): *Tutorial on strong-field physics 2*

O. Smirnova; Photonics Days Berlin Brandenburg (Berlin, Germany, 2025-10) *Chirality in the fast lane, plenary talk*

G. Steinmeyer *together with* W. Chen, H. Shi, Y. Lu, J. Fan, and M. Hu; Laser Physics Conference, LPHYS 25 (Szeged, Hungary, 2025-06): *Emergence of rogue waves in optical parametric generation*

G. Steinmeyer; Millennium Institute for Research in Optics (Miro) Workshop (Universidad de Santiago de Chile, Chile, 2025-12): *Townes solitons in guided and and unguided media*

M. J. J. Vrakking; ATTO X, 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden, 2025-07): *Attosecond science: from adolescence to adulthood - tutorial*

M. J. J. Vrakking; ICPEAC 2025 (Sapporo, Japan, 2025-07): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking; SPEQED25, Strong-field Physics Encounters Quantum Electro Dynamics (MPI Dresden, Germany, 2025-08): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking; UltrafastX 2025 (Xiamen, China, 2025-10): *Control of attosecond entanglement and coherence*

Invited External Talks at Seminars and Colloquia

K. Amini; Seminar (Max-Planck-Institut für Kernphysik, Heidelberg, Germany, 2024-08): *High repetition rate ultrafast electron diffraction with direct electron detection*

K. Amini; Seminar (Lund University, Lund, Sweden, 2024-09): *High repetition rate ultrafast electron diffraction with direct electron detection*

T. A. Butcher; Seminar, Jožef Stefan Institut (Ljubljana, Slowenien, 2024-11): *Soft X-ray ptychography: A microscopy technique for nanoscale imaging of ferroic order*

L. Drescher; Seminar, Sonderforschungsbereich 1319 ELCH (Universität Kassel, Germany, 2024-10): *Ultrafast relaxation of carriers and spin in solids measured with attosecond transient absorption spectroscopy*

Á. R. Echarri; Nano & Quantum Optics seminar (Friedrich-Schiller-Universität Jena, Germany, 2024-07): *Nonlinear plasmonic response in atomically thin metal films and generation of entangled photon pairs in optical waveguides*

Á. R. Echarri; Seminar (AMOLF, Amsterdam, The Netherlands, 2024-07): *Real-time surface plasmon polariton propagation in silver nanowires*

F. J. Furch; EEOF-TOPFOT, Encuentro de Estudiantes de Óptica y Fotónica Taller de Óptica y Fotónica (Balseiro Institute, Bariloche, Argentina, 2024-03): *High repetition rate OPCPAs for Attosecond Science*

U. Griebner, Lecture (Physics Department, University of Sao Paulo, Brazil, 2024-07): *High-energy few-cycle pulses generation beyond 4 µm wavelength*

E. T. J. Nibbering; Department Seminar (École Normale Supérieure, Paris, France, 2024-07): *Ultrafast soft X-ray spectroscopy: An element specific local probe of structural dynamics of elementary water-mediated proton transport processes*

V. Petrov; Seminar (Shandong University, Jinan, China, 2024-08)*: Revival of the nonresonant optical parametric oscillator*

V. Petrov; Seminar (Tianjin University, Tianjin, China, 2024-08*): Recent progress in non-oxide nonlinear crystals for the mid-IR*

N. Picqué, Colloquium (Collège de France, Paris, France, 2024-03): *Frequency combs and dual-comb interferometry*

M. Richter; Annual LiMatI Retreat 2024 (Gut Gremmelin, Germany, 2024-03): *Cavit-free lasing*

M. Ruberti; Atomic Physic Workshop (MPIPKS Dresden, Germany, 2024-11): *Bell test of quantum entanglement in attosecond photoionization*

M. Ruberti; Theory@XFELWorkshop (AIX-Marseille University, France, 2024-11): *Attosecond coherent electron dynamics triggered by XFEL pulses*

D. Schick; Kolloquium (TU Graz/Uni Graz, Austria, 2024-12):*Following complex spin structures in time & space*

B. Schütte; Atomic Physics Workshop (MPI Dresden, Germany, 2024-11): *Table-top all-attosecond transient absorption spectroscopy*

J. W. Tomm; Seminar (HPP PAS New Technologies building, Warsaw, Poland, 2024-05): *Non-equilibrium carrier dynamics in polar InGaN/GaN structures with “wide” quantum wells*

M. J. J. Vrakking; Seminar (University of Buenos Aires, Argentina, 2024-3): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking; Photon Science Seminar (SLAC Stanford, USA, 2024-05): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking; ELI Summer School 2024 (Szeged, Hungary, 2024-09): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking; RAC Int. Summer School 2024 (Krakow, Poland, 2024-09): *Attosecond science at small- and large-scale facilities*

M. J. J. Vrakking; Colloquium (University of Rostock, Germany, 2024-11): *Control of attosecond entanglement and coherence*

M. J. J. Vrakking and F. J. Furch, Course, 20 (University of Buenos Aires, Argentina, 2024-03): *Attosecond science: Principles and applications*

S. Amann, *together with* E. Vicentini, T. W. Haensch, and N. Picqué; Seminar (University of Electro-Communications, Chofu, Tokyo, Japan, 2025-04): *Three-dimensional imaging using optical frequency combs*

S. Amann; Seminar (Humboldt-Universität zu Berlin, Germany, 2025-06): *Microcombs for hyperspectral digital holography*

K. Busch; Colloquium of the Physics Department, Universität Graz (Graz, Austria, 2025-03): *Atom-surface interactions: Theory and computations*

K. Busch; Colloquium of the Physics Department, Universität Würzburg (Würzburg, Germany, 2025-05): *Atom-surface interactions: Theory and computations*

T. A. Butcher; Seminar, The Australian Synchrotron (Melbourne, Australien, 2025-02): *Development of soft X-ray ptychography and its application in studies of ferroic order at the nanoscale*

T. A. Butcher; Seminar, Helmholtz-Zentrum Jena (Jena, Germany, 2025-04): *Coherent Diffractive Imaging of Magnetic Materials*

T. A. Butcher; Condensed Matter Physics Seminars (University of Oxford, UK, 2025-05): *Uncovering multiferroic order at the nanoscale with soft X-ray ptychography*

T. A. Butcher; IKZ Kolloquium (Berlin, 2025-08): *Microspectroscopy of nano-oxides with soft X-rays*

S. Carlström *together with* O. Smirnova, M. Y. Ivanov, and S. Patchkovskii; Seminar (Lund University, Sweden, 2025): *Spin polarization and migration*

S. Carlström *together with* O. Smirnova, M. Y. Ivanov, and S. Patchkovskii; Seminar (University of Gothenburg, Sweden, 2025): *Spin polarization and migration*

S. Carlström *together with* O. Smirnova, M. Y. Ivanov, and S. Patchkovskii; Seminar (European XFEL, Hamburg, Germany, 2025): *Spin polarization and migration*

S. Carlström *together with* O. Smirnova, M. Y. Ivanov, and S. Patchkovskii; Int. Workshop on Atomic Physics (Dresden, Germany, 2025): *Spin polarization and migration*

L. Drescher *together with* N. Mayer, K. Gannan, J. Adelman, and S. Leone; DPG SAMOP (Bonn, Germany, 2025-03): *Circular dichroic attosecond transient absorption spectroscopy*

T. Elsaesser; Seminar (Padova, Italy, 2025-02): *Ultrafast charge dynamics and elec-tric interactions in molecules and molecular materials*

U. Griebner; Lecture (Fuzhou, China, 2025-10): *Multi-mJ, few-cycle midwave-IR OPCPA pumped by a Ho:YLF CPA and its applications*

M. Y. Ivanov *together with* N. Klimkin, and S. Yi; Distinguished Colloquium (Bejing University, China, 2025-03): *Intense Light Matter Interactions: from Quantum Optics to Topology*, keynote talk

M. Y. Ivanov; ZCAM/COST School on New Computational Methods for Attosecond Molecular Processes (Zaragoza, Spain, 2025-04): *Tutorial on strong-field physics1 Vol. 3*

O. Kornilov; Seminar (Lawrence Berkeley National Library, CA, USA, 2025): *Electronic structure and excited state reactions of molecules in aqueous solutions studied by time-resolved XUV photoelectron spectroscopy*

A. Loehr; Workshop on Light-Matter Interaction: Focusing on Polariton Chemistry and Physics (Vidin, Bulgaria, 2025-05): *Guiding synthetic chiral light*

S. Patchkovskii; ZCAM/COST School on New Computational Methods for Attosecond Molecular Processes (Zaragoza, Spain, 2025-04): *Tutorial on strong field ionization of molecules Vol. 5*

S. Patchkovskii *together with* F. Morales; ZCAM/COST School on New Computational Methods for Attosecond Molecular Processes (Zaragoza, Spain, 2025-04): *Simulations on strong-field ionization Vol. 3,5*

V. Petrov; Seminar (Institute of Physics (CAS), Beijing, China, 2025-11): *VUV light generation below 160 nm in nonlinear optical crystals*

V. Petrov; Seminar (Institute of Opto-Electronics, Shanxi University, Taiyuan, China, 2025-11): *VUV light generation below 160 nm in nonlinear optical crystals*

V. Petrov; Seminar (Harbin Institute of Technology, Harbin, China, 2025-08): *Acentric barium chalcogenides for the mid-IR: Characterization and ultrafast nonlinear frequency conversion*

V. Petrov; Seminar (Shandong University, Jinan, China, 2025-08): *Acentric barium chalcogenides for the mid-IR: Characterization and ultrafast nonlinear frequency conversion*

N. Picqué, Physics Colloquium, ETH Zürich (Zurich, Switzerland, 2025-03): *Frequency comb interferometry*

N. Picqué, Colloquium (Stuttgart, Germany, 2025-11): *Frequency comb interferometry*

D. Schick, Colloquium (LMU, TUM Garching, Germany, 2025-07): *Following complex spin structures in time & space*

D. Schick, Colloquium (University Duisburg-Essen, Germany, 2025-11): *Following complex spin structures in time & space*

O. Smirnova; Colloquim Erlangen University (Erlangen, Germany 2025-01): *Combining chirality and topology in ultrafast response of gas phase molecules*

O. Smirnova; Festkolloquium Hamburg University (Hamburg, Germany, 2025-05) *Hamburg’s hidden Saint and his miracles*

C. v. K. Schmising; (Helmholtz-Zentrum Jena, Germany, 2025-04): *Ultrafast magnetization dynamics probed by XUV spectroscopy*

G. Steinmeyer; Lecture (online) (Wrocław University of Science and Technology, Poland, 2025-10): *Mode-locking*

J. W. Tomm; Seminar (Ferdinand-Braun-Institut, Berlin, Germany, 2025-11): *Experimental analysis of thermal profiles in edge emitting high power diode laser*

M. J. J. Vrakking; HELIOS-PIER Graduate Week DESY (Hamburg, Germany 2025-10): *Velocity map imaging: a powerful diagnostic in ultrafast laser physics experiments*

M. J. J. Vrakking; HELIOS-PIER Graduate Week DESY (Hamburg, Germany 2025-10): *A hands-on tutorial on the analysis of velocity map imaging data*

M.-O. Winghart, Gruppenseminar DESY (Hamburg, Germany, 2025-10): *Ultrafast X-ray spectroscopy of proton transfer processes*

Academic Teaching 2024

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt Universität zu Berlin, SS 2024): *Statistische Physik*

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt Universität zu Berlin, SS 2024): *Computerorientierte Photonik*

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 2024): *Optik/Photonik: Projekt und Seminar*

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 2024/2025): *Optik/Photonik: Projekt und Seminar*

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, WS 2024/2025): *Nicht-Hermitesche Photonik*

K. Busch, *together with* A. Rauschenbeutel; Vorlesung, 6 SWS (Humboldt-Universität zu Berlin, WS 2024/2025): *Fundamentals of optical sciences*

K. Busch, *together with* O. Benson; Vorlesung, 4 SWS (Humboldt-Universität zu Berlin, WS 2024/2025): *Laserphysics*

S. Carlström, Vorlesung (Technische Universität Wien, WS 2023/2024): *Quasirelativistic corrections to the Schrödinger equation*

S. Carlström, Vorlesung und Übung (University of Zaragoza, Spain, SS 2024): *Strong-field theory*

S. Eisebitt, *together with* B. Kanngießer; Vorlesung und Übungen, 4 SWS (Technische Universität Berlin, Institut für Optik und Atomare Physik, SS 2024): *Röntgenphysik II*

S. Eisebitt, *together with* B. Kanngießer, B. Pfau, and C. von K. Schmising; Vorlesung und Übungen, 4 SWS (Technische Universität Berlin, Institut für Optik und Atomare Physik, WS 2024/25): *Röntgenphysik I*

F. Furch, *together with* M. J. J. Vrakking; Intensivkurs, WS 2024 (University of Buenos Aires, Argentina): *Attosecond science: Principles and applications*

M. Y. Ivanov, Vorlesung und Übungen, 6 SWS (Humboldt-Universität zu Berlin, WS 2024/2025): *Quantum dynamics in strong laser fields*

V. Petrov, Vorlesung (FJIRSM, Fuzhou, China, 2025-08): Ultrafast Laser Physics 1

V. Petrov, Vorlesung (Institute of Opto-Electronics, Shanxi University, China, 2025-12): Polarization and laser crystals

V. Petrov, Vorlesung (FJIRSM, Fuzhou, China, 2025-12): Polarization and laser crystals

N. Picqué and G. Steinmeyer, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, SS 2024): *Physik ultraschneller Prozesse (Kurzzeitspektroskopie)*

S. Sharma, Vorlesung und Übungen, 4 SWS (Freie Universität Berlin, SS 2024): *Computational electronic structure*

O. Smirnova, Vorlesung und Übungen (Technische Universität Berlin, Institut für Optik und Atomare Physik, SS 2025): *Attosecond Physics*

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*

G. Steinmeyer, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, WS 2024/25): *Nichtlineare Optik*

M. J. J. Vrakking, Vorlesungen und Übungen, 3 SWS (Freie Universität Berlin, WS 2024/2025): *Ultrafast Laserphysics*

Academic Teaching 2025

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt Universität zu Berlin, SS 2025): *Computerorientierte Photonik*

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 2025): *Optik/Photonik: Projekt und Seminar*

K. Busch, *together with* A. Rauschenbeutel; Vorlesung, 6 SWS (Humboldt Universität zu Berlin, WS 2025): *Fundamentals of optical sciences*

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 2025): *Seminar zur Numerik der Maxwell-Gleichungen*

K. Busch, *together with* O. Benson; Vorlesung, 4 SWS (Humboldt Universität zu Berlin, WS 2025): *Laserphysik*

K. Busch, Vorlesung und Übung, 4 SWS (Humboldt Universität zu Berlin, WS 2025): *Nicht-Hermitesche Photonik*

S. Carlström, Vorlesung und Übung, (University of Zaragoza, Spain, SS 2025): *Strongfield Theory*

S. Eisebitt, *together with* B. Kanngießer; Vorlesung und Übungen, 4 SWS (Technische Universität Berlin, Institut für Optik und Atomare Physik, SS 2025): *Röntgenphysik II*

S. Eisebitt, *together with* B. Kanngießer, and R. van der Veen; Vorlesung und Übungen, 4 SWS (Technische Universität Berlin, Institut für Optik und Atomare Physik, WS 2025/26): *Röntgenphysik I*

M. Y. Ivanov, Int. School of Attosecond Physics, (Erice, Italy, 2025-04): *Fundamentals of Strong Field Physics*

V. Petrov, Vorlesung (FJIRSM, Fuzhou, China, 2025-08): *Ultrafast Laser Physics 1*

V. Petrov, Vorlesung (FJIRSM, Fuzhou, China, 2025-12): *Polarization and laser crystals*

V. Petrov, Vorlesung (Institute of Opto-Electronics, Shanxi University, China, 2025-12): *Polarization and laser crystals*

N. Picqué, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, SS 2025): *Präzisionsphysik mit Licht*

O. Smirnova, Vorlesung und Übungen, (Technische Universität Berlin, Institut für Optik und Atomare Physik, SS 2025): *Attosecond Physics*

G. Steinmeyer, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, WS 2024/25): *Nichtlineare Optik*

G. Steinmeyer, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, SS 2025): *Physik ultraschneller Prozesse (Kurzzeitspektroskopie)*

G. Steinmeyer, Vorlesung und Übung, 4 SWS (Humboldt-Universität zu Berlin, WS 2025/26): *Nichtlineare Optik*

General Talks (Popular, Science Politics etc.)

T. Elsaesser, Vortrag: *Die Messung der Zeit – eine physikalische Herausforderung*
Goethe-Gymnasium Pritzwalk, 01.02.24, 29.01.25

T. Elsaesser, Vortrag: *Licht und Materie – Kann man Atome sichtbar machen?*
Paul-Fahlisch Gymnasium Lübbenau, 13.02.24

T. Elsaesser, Vortrag: *Was ist Quantentechnologie? Die physikalische Sicht*
Goethe-Schiller-Gymnasium Jüterbog, 28.02.2024
Gottfried-Arnold-Gymnasium Perleberg, 05.03.2024

T. Elsaesser, Vortrag: *Kommunizieren mit Licht – die Physik des Internets*
Friedrich-Wilhelm-Gymnasium Königs Wusterhausen, 26.02.24
Weinberg-Gymnasium Kleinmachnow, 01.03.24
Marie-Curie-Gymnasium Ludwigsfelde, 14.11.24
Kurt-Tucholsky-Oberschule, Berlin-Pankow, 06.12.24
Leibniz-Gymnasium Potsdam, 17.01.25
Goethe-Schiller-Gymnasium Jüterbog, 19.03.25
Oberstufenzentrum Lausitz, Schwarzheide, 26.03.25

A. Penk *together with* N. Pedro; Photonics Days Berlin-Brandenburg (Berlin, Germany, 2025-10): *Women in quantum tech & photonics*

Appendix 3

Ongoing Master and PhD Theses

Master Theses

F. Aria; *Influence of pump beam polarisation on multiphoton background and excited-state signal in liquid jet TRPES* (Supervisor: M. J. J. Vrakking), Freie Universität Berlin

Y. Gan; *Single-pixel imaging with dual-comb diagnostic* (Supervisor: N. Picqué), Humboldt-Universität zu Berlin

J. Hofrichter, *Supercontinuum generation in silicon-on-sapphire (SOS) waveguides* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

S. Kumar; *Gas-phase ultrafast electron diffraction imaging of inertia and potential effects in aldehydes* (Supervisors: H. Seiler, and K. Amini), Freie Universität Berlin

S. D. Lara; *Construction of a velocity map imaging spectrometer beamline for attosecond pump probe experiments with a 100 kHz OPCPA laser system* (Supervisors: T. Witting and R. Kienberger), TU München

Y. Lu; *Simulation of optical parametric generation* (Supervisor: G. Steinmeyer), Humboldt-Universität zu Berlin

M. Moussa; *Optical Control of High-Order Harmonic Generation in Solids* (Supervisors: M. J. J. Vrakking, P. Jürgens, and A. Rouzée), Freie Universität Berlin

S. M. Pramod; *Post-compression and characterization of femtosecond laser pulses* (Supervisors: M. J. J. Vrakking, M. Wolf, and T. Nagy), Freie Universität Berlin

S. Schuelzky; *Geometric approach to enantio-senstive population dynamics in chiral molecules* (Supervisor: O. Smirnova), Technische Universität Berlin

M. Shojaei; *Three-dimensional imaging with frequency combs* (Supervisor: N. Picqué), Humboldt-Universität zu Berlin

S. Stahl; *Ultrafast electron diffraction imaging of gas-phase and liquid-phase photochemistry (Supervisors*: R. van der Veen and K. Amini), Technische Universität Berlin

H. Sun; *Optimierung der Klassifikation von Beugungsmustern in der kohärenten Bildgebung zur Röntgenabbildung magnetischer Materialien* (Supervisor: S. Eisebitt), Humboldt Universität zu Berlin

C. Ünder; *Quantum-Correlated Biphotons for Two-Photon Absorption in Biomimetic Photoswitches* (Supervisor: O. Kornilov), Freie Universität Berlin

J. Varghese; *Generation and characterization of a THz source for electron compression* (Supervisors: A. Trabbatoni, and K. Amini), Leibniz Universität Hannover

PhD Theses

S. Amann; *Three-dimensional imaging with frequency combs* (Supervisor: T. W. Hänsch and N. Picqué), Ludwig-Maximilians-Universität München

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

E. A. Christou; *Ultrafast chirality with conformer specificity* (Supervisor: O. Smirnova), Technische Universität Berlin

M. Crudu; *Photonic system engineering with microcombs* (Supervisor: N. Picqué), Humboldt-Universität zu Berlin

V. Deinhart; *Nanometer-scale control of ultrafast magnetization dynamics using ion-based magnetic patterning* (Supervisor: S. Eisebitt), Technische Universität Berlin

F. A. R. Diaz; *A high-repetition-rate ultrafast electron diffraction setup with direct detection for solid-state samples* (Supervisor: K. Amini, and M. Weinelt), Freie Universität Berlin

M. O. S. Guzman; *Ultrafast charge carrier dynamics in oxide semiconductors by time-resolved soft X-ray absorption spectroscopy* (Supervisors: M. J. J. Vrakking, and M. Weinelt), Freie Universität Berlin

Hei: R. Heilemann; *Enantio-senstive quantum electronics* (Supervisor: O. Smirnova), Technische Universität Berlin

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

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

C. Klose; *Stochastic nanoscale dynamics in magnetic materials probed by coherent X-rays* (Supervisor: S. Eisebitt), Technische Universität Berlin

A. Loehr; *Syntetich chiral light for control of rotational chiral dynamics and microfluidic chiral sensors* (Supervisor: O. Smirnova), Technische Universität Berlin

P. Maier; *Topological response in gas phase chiral molecules* (Supervisor: O. Smirnova), Technische Universität Berlin

A. V. Mayer; *Precision nonlinear Raman spectroscopy in molecular hydrogen with optical frequency combs* (Supervisor: N. Picqué), Humboldt-Universität zu Berlin

A. M. Santhosh; *Ultrafast electron diffraction imaging of gas-phase photochemical reactions* (Supervisors: K. Amini, and H. Seiler), Freie Universität Berlin

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

J. Petkovic; *Entanglement and decoherence in small molecules upon photoionization using isolated attosecond pulses* (Supervisor: M. J. J. Vrakking, and B. Schütte), Freie Universität Berlin

J. Pilat; *Doppler-free spectroscopy over broad spectral bandwidth* (Supervisors: T. W. Hänsch, and N. Picqué), Ludwig-Maximilians-Universität München

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

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

A. Roos; *Geometry of temporal chiral structures* (Supervisor: O. Smirnova), Technische Universität Berlin

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

N. Stetzuhn; *Ultrafast Magnetization Dynamics in van der Waals Ferromagnets* (Supervisor: 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. Wagner; *Time-resolved imaging of magnetic skyrmion dynamics* (Supervisor: S. Eisebitt), Technische Universität Berlin

X. Wang; *Ultraviolet frequency combs for dual-comb spectroscopy* (Supervisor: N. Picqué), Humboldt-Universität zu Berlin

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

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

E. Ikonnikov; *Time-resolved photoelectron spectroscopy of solvated molecules with phase-locked pulse pairs* (Supervisor: M. J. J. Vrakking, and K. Heyne), Freie Universität Berlin

Appendix 4

Colloquia and Guest Lectures at MBI

G. M. Rossi, CFEL at DESY, Hamburg, Germany; Seminar B (Seminar room A, 2024-01-08): *OP(CP)A-based pulse synthesis and its applications in attosecond science*

G. Malinowski, Institut Jean Lamour, UMR CNRS – Université de Lorraine, Nancy, France; Seminar B (Max Born Hall, 2024-01-31): *Ultrafast spin dynamics: How to generate and use spin currents to manipulate magnetization on the femtosecond timescale*

P. Tzallas, Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, Greece; Institute colloquium (Max Born Hall, 2024-02-14): *Generation of intense optical Schrödinger “cat” states and applications in non-linear optics*

M. Seidel, DESY Deutsches Elektronen-Synchrotron, Hamburg, Germany; Seminar B (Max Born Hall, 2024-03-11): *Speeding up high-power short-pulse infrared lasers*

G. M. Rossi, CFEL at DESY, Hamburg, Germany; Seminar B (Max Born Hall, 2024-03-13): *Ultrashort pulses with (ultra)short wavelengths: novel schemes for few-femtosecond/attosecond pulse generation in the ultraviolet to soft X-ray region*

B. Manschwetus, DESY Deutsches Elektronen-Synchrotron, Hamburg, Germany; Seminar B (Max Born Hall, 2024-03-19): *Advanced femtosecond laser systems for pump probe spectroscopy*

A. N. I. L’Huillier, Lund University, Sweden; Institute colloquium (Max Born Hall, 2024-03-25): *The route to attosecond pulses*

A. Bragas, University of Buenos Aires, Argentina; Seminar A (Seminar room A, 2024-04-05): *Nanomechanics with nanoantennas*

J. Chaiken, Syracuse University, Syracuse, NY, USA; Seminar A (Seminar room A, 2024-04-12): *From quantum beat spectroscopy to multiphoton processes involving organometallic molecules: the central role of the density of states in the interaction of matter and energy*

T. Laarmann, DESY Deutsches Elektronen-Synchrotron, Hamburg, Germany; Institute colloquium (Max Born Hall, 2024-04-17): *Interferometry on extreme time and wavelength scales*

K.-Y. Chiang, Max-Planck-Institute for Polymer Research, Mainz, Germany; Seminar A (Max Born Hall, 2024-05-21): *Dielectric properties of interfacial water and distribution of ions at the air/water interface*

C. Gutt, University of Siegen, Germany; Institute colloquium (Max Born Hall, 2024-05-22): *Dynamics of magnetic structures on picosecond time scales probed via resonant magnetic scattering at FERMI*

T. Satoh, Department of Physics, Tokyo Institute of Technology, Japan; Seminar B (Max Born Hall, 2024-05-23): *Truly chiral phonons in chiral materials*

S. K. Kim, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea; Seminar A (Max Born Hall, 2024-06-18): *Nonadiabatic reaction dynamics of polyatomic molecules (or anions): Role of the electron in the (non)valence orbitals*

L. Bruder, University of Freiburg, Germany; Seminar A (Max Born Hall, 2024-08-13): *Nonlinear spectroscopy and coherent control: from the visible to the XUV spectral domain*

A. Saha, Indian Institute of Science Education and Research, Kolkata, India; Seminar A (Max Born Hall, 2024-08-27): *Controlling resonant absorption in helium using intense XUV FEL pulses in combination with HHG transient-absorption spectroscopy*

R. Kosloff, Institute of Chemistry, The Hebrew University, Jerusalem, Israel; Institute colloquium (Max Born Hall, 2024-09-04): *Deciphering the mechanism of animal magnetic navigation: Geometric phase*

J. Tavers, Heriot-Watt University, Edinburgh, United Kingdom; Institute colloquium (Max Born Hall, 2024-09-18): *Ultrafast nonlinear optics in gas-filled hollow-core fibres: From supercontinuum to attosecond X-ray pulses*

P. Smorenburg, ASML Research, The Netherlands; Seminar A (Seminar room A, 2024-10-01): *Soft X-ray scatterometry for semiconductor metrology*

M. Voncken, ASML Research, The Netherlands; Institute colloquium (Max Born Hall, 2024-10-01): *ASML introduction and recent developments in measurement and metrology*

Appendix 4

F. Calegari, Center for Free-Electron Laser Science (CFEL), DESY Hamburg, Germany; Seminar A (Max Born Hall, 2024-10-02): *Controlling chemistry at extreme time scales*

M. Gühr, DESY and University of Hamburg, Germany; Institute colloquium (Max Born Hall, 2024-10-16): *Observing ultrafast molecular energy-conversion using free-electron lasers*

P. Yzombard, Laboratoire Kastler Brossel, Paris, France; Institute colloquium (Max Born Hall, 2024-10-23): *Hydrogen/Deuterium 1S-3S spectroscopy and beyond*

T. Fennel, University of Rostock, Germany; Institute colloquium (Max Born Hall, 2024-10-30): *Electronic quantum dynamics in helium droplets traced by coherent diffractive imaging*

H. Jani, University of Oxford, UK; Seminar C (Seminar room C, 2024-11-04): *Tailoring topological antiferromagnetic solitons*

C. Arnold, Lund University, Sweden; Seminar A (Seminar room A, 2024-11-11): *Two-color HHG revisited*

C. Tserkezis, University of Southern Denmark; Seminar A (Seminar room A, 2024-11-14): *Nanophotonic environments for Purcell enhancement and strong coupling*

R. Sharma, FU Berlin, Germany; Seminar A (Seminar room A, 2024-11-13): *Probing Dzyaloshinskii-Moriya interaction in FM thin films*

S. Kumar, FU Berlin, Germany; Seminar A (Max Born Hall, 2024-11-19): *My physics journey so far*

D. Gajera, FU Berlin, Germany; Seminar A (Seminar room A, 2024-11-21): *Area of research interest in ultrafast optics and dynamics*

N. Mutz, HU Berlin, Germany; Seminar A (Seminar room A, 2024-11-21): *Energy and charge transfer at hybrid interfaces probed by optical spectroscopy*

S. Wall, Aarhus University, Denmark; Institute colloquium (Max Born Hall, 2024-11-21): *Heterogeneity and disorder in ultrafast phase transitions*

K. Ishikawa, University of Tokyo, Japan; Institute colloquium (Max Born Hall, 2024-11-22): *Control of ion-photoelectron entanglement and coherence via Rabi oscillations*

T. Sato, University of Tokyo, Japan; Seminar A (Seminar room A, 2024-11-24): *Simulations of intense laser-driven multielectron dynamics using classical and quantum computers*

W. Eschen, University Jena, Germany; Seminar B (Max Born Hall, 2024-11-26): *Material-specific and high-resolution imaging using extreme ultraviolet ptychography*

J. Sarkar, Fritz Haber Institute Berlin, Germany; Seminar C (Seminar room C, 2024-12-10): *Coherent light control of the metastable hidden phase in* TaS_2

F. Kärtner, DESY Hamburg, Germany; Institute colloquium (Max Born Hall, 2024-12-11): *THz acceleration for compact electron and X-ray sources*

W. van der Zande, ARCNL Amsterdam, The Netherlands; Institute colloquium (Max Born Hall, 2024-12-17): *The Advanced Research Center for NanoLithography: better chips-making-tools using fundamental physics research*

B. Koopmans, University of Eindhoven, The Netherlands; Institute colloquium (Max Born Hall, 2025-01-08): *Applications of all-optical switching of magnetization: Photonic memory, magnetic sensors and writing skyrmions*

A. Manjavacas, Instituto de Química Física “Blas Cabrera”, Madrid, Spain; Seminar B (Seminar room B, 2025-01-21): *Transfer of energy and momentum mediated by the fluctuations of the electromagnetic field*

A. Stolow, University of Ottawa and National Research Council Canada; Institute colloquium (Max Born Hall, 2025-01-21): *Heuristic notions of the Born-Oppenheimer approximation and its failures in molecules*

J. Bredenbeck, University of Frankfurt, Germany; Institute colloquium (Max Born Hall, 2025-01-22): *Mixed IR/UV-VIS multidimensional spectroscopies for (Bio-)molecular dynamics*

A. Stolow, University of Ottawa and National Research Council Canada; Institute colloquium (Max Born Hall, 2025-01-29): *Probing complex molecular wave packets via time-resolved photoelectron and X-Ray absorption spectroscopy*

A. Stolow, University of Ottawa and National Research Council Canada; Institute colloquium (Max Born Hall, 2025-02-04): *Quantum interference and dynamic Stark control of molecular reaction dynamics*

A. Stolow, University of Ottawa and National Research Council Canada; Institute colloquium (Max Born Hall, 2025-02-12): *Polyatomic molecules in strong fields: Beyond the simple models*

L. Polling, FU Berlin, Germany; Seminar A (Seminar room A, 2025-02-12): *Introductory presentation*

A. Stolow, University of Ottawa and National research Council Canada; Institute colloquium (Max Born Hall, 2025-02-19): *Chirp modulation stimulated Raman scattering microscopy: Background-free chemical-specific imaging*

E. Goulielmakis, University of Rostock, Germany; Institute colloquium (Max-Born-Hall, 2025-02-25): *Nonlinear optics with synthesized light transients*

L. Niggli, Radboud University, Nijmegen, The Netherlands; Seminar B (Seminar room A, 2025-02-26): *Real-space investigation of the self-induced spin glass state and its aging dynamics in elemental neodymium*

E. Orhan, FU Berlin, Germany; Seminar A (Seminar room A, 2025-02-28): *Introductory presentation*

D. Ventura, Politecnico Di Milano, Milan, Italy; Seminar A (Max Born Hall, 2025-03-04): *Time-resolved photoelectron spectroscopy of neutral molecules: UV pump – XUV probe approaches in attochemistry*

L. Nahon, Synchrotron SOLEIL, Saint Aubin, France; Institute colloquium (Max Born Hall, 2025-03-05): *Recent results on Photoelectron Circular Dichroism (PECD): from static measurements to time-resolved site-specific explorations*

U. Staub, Paul Scherrer Institute, Villigen, Switzerland; Institute colloquium (Max Born Hall, 2025-03-19): *Coupling magnons and phonons*

P. Wernet, Uppsala University, Sweden; Institute colloquium (Max Born Hall, 2025-04-02): *Orbital control of catalysis enabled by ultrafast X-rays*

L. B. Madsen, Aarhus University, Department of Physics and Astronomy, Aarhus, Denmark; Seminar Theory department (Seminar room A, 2025-04-10): *Quantum optical generation of quantum light by high-harmonic generation: Correlated materials, an accurate approximation and excitonic enhancement*

G. Paulus, University of Jena, Germany; Institute colloquium (Max Born Hall, 2025-04-30): *XUV coherence tomography*

H. Ning, Imperial College London, UK; Seminar A (Seminar room A, 2025-05-07): *Ultrafast broadband nanoscopy on asymmetric nanogaps*

F. Lépine, Institut Lumière Matière, Lyon, France; Institute colloquium (Max Born Hall, 2025-05-14): *First instants following the ultrafast ionization of proteins*

L. Bennenraedts, University of Liège, Belgium; Seminar A (Seminar room A, 2025-05-15): *Master thesis presentation*

J. Petković, University of Belgrade, Serbia; Seminar A (Seminar room A, 2025-05-19): *High harmonic generation in gases and its properties*

A. Verma, Sorbonne University and Synchrotron SOLEIL, France; Seminar A (Seminar room A, 2025-05-22): *Electronic relaxation on the attosecond scale in post-collision interaction dynamics*

J. B. Khurgin, Johns Hopkins University, Baltimore, MD, USA; Seminar A (Seminar room A, 2025-05-22): *Photonic Time Crystals and Parametric Amplification: similarity and distinction*

C. Saraceno, Ruhr University Bochum, Germany; Institute colloquium (Max Born Hall, 2025-05-28): *High-power, laser-driven Terahertz sources*

S. Stahl, TU Berlin, Germany; Seminar A (Seminar room A, 2025-06-11): *Photoelectron and photodissociation spectra of diamondoids and their dervatives*

G. Emperauger, Laboratoire Charles Fabry, Palaiseau, France; Seminar A (Seminar room A, 2025-06-13): *A study of dipolar quantum magnets using Rydberg atoms*

G. Ünder, Freie Universität Berlin, Germany; Seminar A (Seminar room A, 2025-06-18): *From heavy atom effects to ultrafast relaxation: computational insights onto photoinduced molecular dynamics*

K. Oguri, NTT Basic Research Laboratories, Kanagawa, Japan; Seminar A (Seminar room A, 2025-07-04): *Attosecond technologies towards PHz-scale solid state physics at NTT Basic Research Laboratories*

A. Boyer, Institut de Physique et Chimie des Matériaux de Strasbourg, France; Seminar A (Seminar room A, 2025-07-18): *Investigating ultrafast internal conversion using extreme ultraviolet (XUV) time-resolved photoelectron spectroscopy*

V. Mujica, Arizona State University, School of Molecular Sciences, USA; Seminar A (Seminar room A, 2025-07-22): *On the connection between chiro-optical activity and spin polarization*

M. Fermann, IMRA America Inc. Ann Arbor, MI, USA; Seminar C (Seminar room C, 2025-07-24): *Frequency control research at IMRA America*

D. Bossini, University of Konstanz, Germany; Seminar B (Max Born Hall, 2025-07-24): *Dynamical renormalization of the spectrum of coherent magnons*

Y. He, Max Planck Institute for Nuclear Physics, Heidelberg, Germany; Seminar A (Seminar room A, 2025-08-22): *Measuring and modifying the electronic response in optically thick helium with intense laser fields*

M. Reduzzi, Politecnico di Milano, Italy; Seminar A (Seminar room A, 2025-09-17): *Time-resolved photoelectron spectroscopy with high-harmonic generation sources: From femtochemistry to attochemistry applications*

R. Huber, Regensburg University, Germany; Institute colloquium (Max Born Hall, 2025-09-24): *Quantum trajectories of Bloch electrons driven by lightwaves*

L. Vilčiauskas, Vilnius University, Institute of Chemistry, Lithuania; Seminar C (seminar room C, 2025-09-26): *Protonic defects, hydrogen-bond networks and long-range charge transport in phosphorus oxoacid systems*

S. Poelman, Ghent University, Belgium; Seminar C (Seminar room C, 2025-10-01): *Heterogeneously integrated III/V-on-SiN mode-locked lasers*

H. Gießen, University of Stuttgart, Germany; Institute colloquium (Max Born Hall, 2025-10-08): *Topological plasmonics and twistronics: Ultrafast vector movies of plasmonic skyrmions, merons, quasicrystalline structures and skyrmion bags on the nanoscale*

K. Vahala, California Institute of Technology, California, USA; Institute colloquium (Max Born Hall, 2025-10-13): *High-Q photonics: harnessing nonlinear optics on chip*

A. Leitenstorfer, University of Konstanz, Germany; Institute colloquium (Max Born Hall, 2025-10-22): *Fluctuations at elementary scales of time and space: Photons, charges and spins*

S. Nolte, Jena University, Germany; Institute colloquium (Max Born Hall, 2025-11-05): *Ultrashort pulse laser volume processing*

O. Vendrell, Heidelberg University, Germany; Institute colloquium (Max Born Hall, 2025-11-19): *Ultrafast molecular dynamics driven by electrons and nuclei*

R. Sri Vatsa, FU Berlin; Seminar (Seminar room A, 2025-12-12): *Exploring matter with femtosecond lasers and X-ray spectroscopy*

S. Urashima, Japan Atomic Energy Agency (JAEA), Ibaraki, Japan; Seminar C (Seminar room C, 2025-12-12): *Non-invasive cation composition analysis of natural carbonate minerals with Raman spectroscopy*

C. Ropers, Max Planck Institute for Multidisciplinary Sciences & University of Göttingen, Germany; Institute colloquium (Max Born Hall, 2025-12-17): *Free-electron quantum optics*

Appendix 5

Activities in Scientific Organisations

W. Becker

Member of the Advisory and Program Committee, 30th Int. Laser Physics Workshop - LPHYS'24, (Sao Carlos, Brazil)

Member of the Advisory and Program Committee, 30th Int. Laser Physics Workshop - LPHYS'25, (Szeged, Hungary)

K. Busch

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

S. Eisebitt

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

Chairman, DESY Photon Science Committee

Conference Chair, 6th Ultrafast Magnetism Conference

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

Sprecher des Vorstandes, Forschungsverbund Berlin e.V.

Vorsitzender PGzB (Physikalische Gesellschaft zu Berlin)

Stellvertretender Vorsitzender PGzB (Physikalische Gesellschaft zu Berlin)

T. Elsaesser

Associate Editor, Science Advances (AAAS)

Associate Editor, Struct. Dyn., AIP

Member, Editorial Board, Chem. Phys. Lett.

Chair, TELOTA steering group, Berlin Brandenburg Academy of Sciences

Member of the Board, Berlin Brandenburg Academy of Sciences

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

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

Member, Advisory Board, Ultrafast Phenomena Conference Series

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

Member, Proposal Review Panel for the Ultrafast Electron Diffraction (UED) Facility SLAC (Menlo Park, USA)

U. Griebner

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

R. Grunwald

Associate Editor, Opt. Express

Programm Committee, Photonics West, OPTO, Complex light and optical forces XVIII

Member, SPIE Fellows Committee

Associate Editor, Sci. Rep.

M. Y. Ivanov

Chair of Nobel Session, "Life in Science", ATTO X, 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden)

Chair of Session, Attosecond Physics II, PQE 2024, Physics of Quantum Electronics (Snowbird, Utha, USA)

T. Nagy

Editor, Opt. Express

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

Program chair, Optica Laser Congress and Exhibition (Vilnius, Lithuania)

Program chair, Optica Laser Congress and Exhibition (Prague, Czech Republic)

Program Committee Member, Photonics West (San Francisco, USA): LASE Symposium, Conference “Nonlinear Frequency Generation and Conversion: Materials and Devices”

Program Committee Member, Advanced Lasers and Photon Sources (ALPS) (Yokohama, Japan)

Program Committee Member, Conference on Lasers and Electro-Optics (Charlotte, USA)

Program Committee Member, Solid State, Fibre, and Other Laser Sources Committee of CLEO Pacific Rim (Beijing, China)

Programme Committee Member, Pacific RIM Laser Damage SPIE Conference (Hangzhou, China)

Programme Committee Member, CIOP (Int. Conference on Information Optics and Photonics), (Nanjing, China)

Feature Issue Topical Editor Optics Express/Optical Materials Express

N. Picqué

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

Chair, EPS-QEOD Prize for research in laser science and applications

Deputy Editor, Optica

Member, Committee on Atomic, Molecular, and Optical Sciences (CAMOS) (Washington, D.C., USA), The National Academies of Sciences, Engineering, and Medicine

Member, Scientific Advisory Board on Quantum Technology, German National Metrology Institute PTB (Braunschweig, Germany)

Member, Steering Committee, CLEO/EQEC Europe

A. Rouzée

Editor, Adv. Phys. X

S. Sharma

Chair, Workshop on Coherence, Dephasing, Dissipation, Switching (TU Graz, Austria)

Local Organizer, UMC 2024, 6th Ultrafast Magnetism Conference, FU Berlin, Germany

Int. Advisory Committee, FMAP-2024, 3. Int. Conference on Functional Material and Applied Physics, (Dept. of Physics, Sardar Vallabhbhai National Inst. of Technology, Surat, India)

O. Smirnova

Member, Int. Program Committee, 10th Int. Conference on Attosecond Science and Technology, ATTO X 2025

Member, Evaluation panel, Dept. of Physics and Astronomy at Aarhus University

Member, Scientific Advisory Committee, EUXFEL

Member, SQS Review Board, EUXFEL

Member, Editorial Board, Physical Review X

Member, Trilogy Network Supervisory Board

G. Steinmeyer

Associate Editor, Optica

Member, Editorial Board, Phys. Lett. A

J. W. Tomm

Associate Editor, Journal of Electronic Materials (JEMS)

Member Editorial Board, Communications in Physics (CIP)

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

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

M. J. J. Vrakking

Chair of session, MPS2024, Int. Conference on many-particle spectroscopy of atoms, molecules, clusters and surfaces (Fudan University, Shanghai, China)

Editor-in-chief, Journal of Physics B

Member of QU-ATTO supervisory board, University of Freiburg, Germany

Vice chair, GRC, Gordon Research Conference (Bryant University, Rhode Island, USA)

Honors and Awards

T. A. Butcher, “Ferroic Young Researcher Awards” E-MRS, The European Materials Research Society, Spring Meeting, (Strasbourg, France, 05/2025)

L. Drescher: The Best Poster Distinction, ATTO X 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden)

L.-M. Kern: KlarText Award for Science Communication, Dr. Klaus Tschira Foundation (Heidelberg, Germany, 2024)

L.-M. Kern: Dissertation Prize of the Condensed Matter Section (SKM), Deutsche Physikalische Gesellschaft (Berlin, Germany, 2024)

M. Mirahmadi: Best poster award in ELCH 2025 Int. Conference “Extreme light and chiral molecular systems”, 2025 (University of Kassel, Germany)

N. Picqué: William F. Meggers Award (Optica), (Charlotte, NC, USA)

E. Svirplys: The Best Poster Distinction, ATTO X 10th Int. Conference on Attosecond Science and Technology (Lund, Sweden)

W. Zhao: The Best Poster Award, Polariton Science Conference 2024 (Odense, University of Southern Denmark)

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The Divisions of the Max Born Institute

Division A: Attosecond Physics
Prof. Dr. M. J. J. Vrakking

Division B: Transient Electronic Structure and Nanoscience
Prof. Dr. S. Eisebitt

Division C: Precision Physics
Prof. Dr. N. Picqué

Address and Directions

City district: Berlin Treptow-Koepenick
Subdistrict: Berlin-Adlershof

Site: Berlin-Adlershof
Street: Max-Born-Straße 2 A

S-Bahn: S45, S46, S85, S8, and S9
Station: Berlin-Adlershof
from there:
Bus 162, 164 to Magnusstraße
Tram: M17, 63 to Karl-Ziegler-Straße

Subway: U7
Station: Rudow
from there:
Bus 162 to Magnusstraße

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