Photon Science

THIS SESSION HAS BEEN ORGANISED IN COLLABORATION WITH THE SWISS SOCIETY FOR PHOTON SCIENCE.

Friday, 13.09.2024, Room ETF E 1

Time	ID	PHOTON SCIENCE *Chair: Lukas Gallmann, ETH Zürich*
13:30	801	**Hard X-ray scattering in the millikelvin domain at the SwissFEL Cristallina-Quantum endstation** *Jakub Vonka, Alexander Steppke, Maël Clémence, Maria Szola, Gabriel Aeppli, Simon Gerber, Bill Pedrini, Paul Scherrer Institut* Quantum fluctuations dominate over thermal fluctuations at low temperatures, as manifested by the emergence of quantum many-body ground states and new phases of matter. One of the goals of the new Cristallina-Quantum endstation at SwissFEL is to image these states with hard X-ray pulses, outrunning the beam heating thanks to femtosecond pulse duration. In this talk I will review our commissioning progress on a new dilution refrigerator instrument that has recently entered early pilot user program. I will describe some of the results demonstrating resonant X-ray scattering from magnetic orders down to sub-100 mK temperatures, and elaborate on the path towards full scientific exploitation of this unique experimental environment.
13:45	802	**Imaging Ultrafast Electronic Domain Fluctuations in a Nonequilibrium X-Ray Speckle Visibility Experiment** *Nelson Nientsu Hua [1], Surya Teja Botu [2], Maël Clémence [1], Vincent Esposito [3], Eric E. Fullerton [4], Simon Gerber [1], Shih-Wen Huang [1], Spencer Jeppson [2], Patrick Kramer [3], Roopali Kukreja [2], Erik Lamb [4], Henrik Lemke [1], Meera Madhavi [2], Roman Mankowsky [1], Aidan Mcconnell [1], Pooja Rao [2], Mathias Sander [1], Takahiro Sato [3], Oleg G. Shpyrko [4], Sanghoon Song [3], Boyan Stoychev [4], Yanwen Sun [3], Serhane Zerdane [1], Nanna Zhou Hagström [2], Diling Zhu [3]* *[1] Paul Scherrer Institut, [2] University of California Davis,* *[3] SLAC National Accelerator Laboratory, [4] University of California San Diego* We employed a novel coherent X-ray technique that uses a split-and-delay line in a pump-double-probe experimental scheme to measure ultrafast domain fluctuations for the first time at an X-ray free electron laser. By accessing the speckle pattern of a resonant charge order peak in Fe_3O_4, we imaged electronic domain fluctuations with sub-picosecond temporal resolution. Here we also demonstrate how a standard time-resolved x-ray diffraction experiment in a pump-probe setup complements the coherent X-ray experiment by revealing how the average and local domain structures evolve in Fe_3O_4, offering a unique perspective on the ultrafast dynamics of the lattice structure and electronic heterogeneities.
14:00	803	**Two-Color Diffractive Imaging of Helium Nanodroplets** *Linos Hecht [1], Jakob Asmussen [2], Björn Bastian [2], Thomas Baumann [3], Ltaief Ben Ltaief [2], Alessandro Colombo [1], Alberto Defanis [3], Simon Dold [3], Robert Hartmann [4], Sivarama Krishnan [5], Asbjorn Laegdsmand [2], Suddhasattwa Mandal [5], Christian Medina [6], Michael Meyer [3], Robert Moshammer [3], Marcel Mudrich [2], Yevheniy Ovcharenko [3], Thomas Pfeiffer [7], Daniela Rupp [1], Björn Senfftleben [3], Keshav Sishodia [5], Frank Stienkemeier [6], Rico Tanyag [2], Sergey Usenko [3]* *[1] ETH Zürich, [2] Aarhus University, [3] European XFEL, [4] Fa. PN Sensor, [5] IIT Madras* *[6] Universität Freiburg, [7] MPI für Kernphysik* A recent feature of X-ray free electron lasers is the ability to produce two ultrashort pulses at different photon energies with a controlled time delay. We utilize these capabilities for X-ray pump X-ray probe coherent diffraction imaging to investigate ultrafast dynamics in nanoscale matter. This simultaneously yields information on the pristine sample and its evolved state with high spatial and temporal resolution.

		Still, the challenge is to separate the two superimposed images on the detector. We developed algorithms for separating images of individual helium nanodroplets taken at the EuXFEL by analyzing single photon events in combination with two-color Mie modeling.
14:15	**804**	**Coherent diffraction imaging with micrometer-sized liquid helium droplets** *Katharina Kolatzki [1], David Carey [1], Alessandro Colombo [1], José Gómez Torres [1], Linos Hecht [1], Joshua Laux [1], Jannis Lehmann [1], Carole Michellod [1], Mario Sauppe [1], Björn Senfftleben [2], Frederic Ussling [1], Daniela Rupp [1]* *[1] ETH Zürich, [2] SQS, European XFEL, Germany* Coherent diffraction imaging (CDI) allows to track a single nanoparticle's shape and ultrafast laser-induced dynamics. In our experiments, we illuminate liquid helium droplets of sizes ranging between hundreds of nanometers and a few micrometers with intense XUV pulses created by our lab-based high-harmonic generation (HHG) source. Simultaneous to recording the CDI pattern, our setup allows us to monitor the spectrum and profile of the transmitted XUV beam after the interaction. I will present results from our recent experiments and discuss possibilities for ultrafast absorption spectroscopy and simultaneous scattering on free-flying single particles towards spatiotemporally resolving ultrafast electron dynamics.
14:30	**805**	**Combined electron and ion spectroscopy of atomic and molecular clusters** *Frederic Ussling, Yves Marc Acremann, David Carey, Alessandro Colombo, Moritz Heinemann, Linos Hecht, Katharina Kolatzki, Jannis Lehmann, Changji Pan, Mario Sauppe, José Gómez Torres, Angela Vidoni, Michael Wenger, Daniela Rupp, ETH Zürich* Understanding the interaction of high-intensity extreme ultraviolet and soft X-ray pulses with matter is essential to fully utilize the novel experimental capabilities of short-wavelength free-electron lasers and high-harmonic generation (HHG) sources. However, the complex and intertwined dynamics of ionization, plasma formation, and relaxation in condensed matter are not yet fully understood. We investigate clusters in the gas phase as ideal model systems by combining the measurement of electrons and ions from individual clusters interacting with single intense HHG pulses. This provides unprecedented insight into all relevant light-induced processes on femtosecond to nanosecond time scales.
14:45	**806**	**High average power SESAM modelocked laser oscillator exceeding 500 W** *Moritz Seidel, Ursula Keller, Lukas Lang, Christopher R. Phillips* *Department of Physics, ETH Zürich, 8093 Zürich* We present an ultrafast SESAM modelocked thin-disk laser oscillator providing 550 W of average output power with 100-μJ, 852-fs-long pulses at a repetition rate of 5.5 MHz. This presents a record for average output power and pulse energy from a modelocked oscillator. Key developments are a new cavity design and high-power ion-implanted sapphire-bonded SESAMs. This oscillator can enable new frontiers in nonlinear optics. For example, using it to drive high-harmonic generation at megahertz repetition rates offers a route to enhanced sensitivity in attosecond pump-probe studies. The laser is also well suited for industrial micromachining of metals, glasses and semiconductors.
15:00	**807**	**Single-cavity dual-comb lasers and applications** *Benjamin Willenberg, Justinas Pupeikis, Lukas Lang, Sandro Camenzind, Carolin Bauer, Alexander Nussbaum-Lapping, Christopher R. Phillips, Ursula Keller* *Department of Physics, ETH Zürich* Dual-comb laser sources are of high interest for many scientific and industrial applications. During the presentation we will highlight the latest advances in high performance single-cavity dual-comb modelocking, critically examining the potential challenges of single-cavity designs and exploring their prospective impact. The high mutual coherence and average powers directly obtainable from carefully designed laser oscillators provide the capability for coherent averaging in Fourier transform spectroscopy, ultra-low noise supercontinuum generation and efficient wavelength conversion via nonlinear processes. This renders these simple and compact sources highly interesting for practical dual-comb applications. We will discuss some latest experimental demonstrations involving precision ranging, pump-probe spectroscopy, and gas sensing.

15:15 | **808**

Shot-Noise Limited Dual-Comb Supercontinuum Source

Alexander M. Heidt [1], Sandro L. Camenzind [2], Benoît Sierro [1], Benjamin Willenberg [2], Alexander Nussbaum-Lapping [2], Anupamaa Rampur [1], Ursula Keller [2], Christopher R. Phillips [2]
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Dual frequency comb systems offer unique capabilities for spectroscopy, hyperspectral imaging, and ultrafast photonics, combining high temporal and spectral resolution with rapid electronic measurements. Despite their potential, challenges in simultaneously achieving broad spectral bandwidth, low noise, and high power have limited their applications. In this work we overcome these issues and introduce the first shot-noise limited, coherently averaged dual-comb interferometry from a supercontinuum source, featuring 450 nm bandwidth, gigahertz pulse repetition rate, and output power exceeding 1 W. Both combs are generated in a compact setup using a single free-running solid-state laser cavity and a single polarization-multiplexed photonic crystal fiber, making the system well-suited for field applications.

15:30 | **809**

High-sensitivity cross-comb spectroscopy enabled by a single-cavity dual-comb optical parametric oscillator

Carolin Bauer, Zofia Bejm, Michelle Bollier, Ursula Keller, Christopher R. Phillips, Justinas Pupeikis, Benjamin Willenberg, Department of Physics, ETH Zürich, 8093 Zürich

We present a novel configuration of a light source and a detection scheme optimized for high-sensitivity dual-optical frequency comb gas absorption spectroscopy in the mid-infrared. Using our free-running wavelength-tunable single-cavity dual-comb optical parametric oscillator and our simple intra-cavity upconversion-based detection scheme, we demonstrate heterodyne measurements with a signal-to-noise ratio of 50 dB $Hz^{1/2}$ and a figure of merit of 3.5 x 10^8 $Hz^{1/2}$. These results are enabled by a low-noise laser source, high-power per comb line, the usage of low-noise InGaAs-detectors, and a time-gating effect in the up-conversion process limiting the instantaneous shot-noise. In a 10-ms long proof-of-concept measurement, we detect 2 ppm of ambient methane over a 3-m path length.

15:45 | **810**

SWIR optically pumped semiconductor lasers

Marco Gaulke [1], Maximilian C. Schuchter [1,2], Nicolas Huwyler [1], Matthias Golling [1], Ursula Keller [1]
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Vertical-emitting, optically pumped semiconductor lasers (OPSL) are known for their high-power performance and excellent beam quality, primarily developed using the GaAs material system which restricts emission to the near-infrared. Our research focuses on extending OPSL into the short-wave-infrared (SWIR) region by employing the GaSb material system through molecular beam epitaxy. We achieved significant advancements in continuous wave operation through enhanced backside-cooling, refined gain characterization, and the first GaSb-based membrane-external cavity surface emitting laser. Additionally, we investigated SESAM modelocked emitters, integrated gain and absorber on single chips, and demonstrated dual-comb operation through spatial multiplexing. These developments mark substantial progress in the field of OPSL, expanding their utility in broader spectral applications.

16:00 | | ***END***

ID	Photon Science Poster

821

Enhancement of single-shot THz detection using a small bias detection scheme

Seyyed Jabbar Mousavi, Jan Sauter, Elnaz Zyaee, Vivek Unikandanunni, Thomas Feurer
Institute of Applied Physics, University of Bern, Sidlerstrasse 5, 3012 Bern

This work presents a single-shot THz detection technique utilizing optically chirped probe pulses combined with a small bias detection scheme to enhance the detected THz signals. By measuring the THz signals at opposite optical biases $\pm\theta$, where θ is a small angle of the quarter waveplate (QWP) near zero, an 18-fold enhancement factor is achieved compared to the standard electro-optic sampling (EOS) scheme.

822	**Small footprint integrated optical parametric oscillator with a Fabry-Perot resonator** *Alessandra Sabatti, Jost Kellner, Rachel Grange, ETH Zürich* Optical parametric oscillators (OPOs) are key components for applications like squeezing and random number generation. Their dense integration on-chip would allow the realization of computational networks such as Ising machines. However, integrated OPOs to date feature millimeters long quasi-phase matching regions that are located inside racetrack resonators, resulting in large footprint devices. Here we present a thin film lithium niobate on insulator OPO for which the nonlinear region is placed in a linear Fabry-Perot cavity formed by two Bragg reflectors, which is more compact and greatly reduces the occupied area. The device features a 30 mW threshold power and a 30 nm bandwidth, limited by the mirrors reflection band.
823	**Integrated lithium niobate on insulator high purity spontaneous parametric downconversion source** *Tristan Kuttner, Rachel Grange, Robert J. Chapman, ETH Zürich* Integrated quantum photonics poses some essential requirements a material needs to fulfil to be able to provide a fully integrated platform, among those is the ability of creating and interfering single photons. Given its second order non-linearity lithium niobate on insulator (LNOI) stands out among the contenders in integrated quantum photonics since it enables spontaneous parametric down-conversion (SPDC) as a process of creating pairs of single photons and allows for fast electro-optical tunability of integrated interferometric networks. We engineer the dispersion relations inside integrated periodically poled LNOI waveguides, thereby tuning the SPDC phase-matching to create pure photons which can be used as a resource for bosonic quantum experiments.