MP 10: Strong Fields

Time: Thursday 13:45–15:30 Location: KH 02.013

MP 10.1 Thu 13:45 KH 02.013

Dynamically assisted nuclear fusion — Daniil Ryndyk[1,3], Christian Kohlfürst[1], Friedemann Queisser[1], and •Ralf Schützhold[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [3]Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Straße, 52428 Jülich, Germany

We study the enhancement of tunneling through a potential barrier, such as the Coulomb potential in nuclear fusion, by an additional electromagnetic field, such as an x-ray free electron laser (XFEL). In addition to the known effects of pre-acceleration and potential deformation already present in the adiabatic regime, as well as energy mixing in analogy to the Franz-Keldysh effect in the non-adiabatic regime, the field can enhance tunneling by pushing part of the wave function out of the rear end of the barrier. We find that the XFEL field strengths required for these dynamical assistance mechanisms are challenging, but still well below the Schwinger critical field.

[1] F. Queisser and R. Schützhold, *Dynamically assisted nuclear fusion*, Phys. Rev. C **100**, 041601(R) (2019)

[2] C. Kohlfürst, F. Queisser and R. Schützhold, *Dynamically assisted tunneling in the impulse regime*, Phys. Rev. Research **3**, 033153 (2021)

[3] D. Ryndyk, C. Kohlfürst, F. Queisser, and R. Schützhold, *Dynamically assisted tunneling in the Floquet picture*, Phys. Rev. Research **6**, 023056 (2024)

MP 10.2 Thu 14:00 KH 02.013

Towards a vacuum birefringence experiment at the Helmholtz International Beamline for Extreme Fields — •Felix Karbstein — Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Quantum field theory predicts a nonlinear response of the vacuum to strong electromagnetic fields of macroscopic extent. This fundamental tenet has remained experimentally challenging and is yet to be tested in the laboratory. A particularly distinct signature of the resulting optical activity of the quantum vacuum is vacuum birefringence manifesting itself in a polarization-flipped signal component. This offers an excellent opportunity for a precision test of nonlinear quantum electrodynamics (QED) in an uncharted parameter regime. In this talk I will provide an update on the status of the dark-field approach devised to measure the leading (both polarization-flipped and unflipped) quantum vacuum signals in a dedicated experiment at the European X-ray Free Electron Laser (EuXFEL) within the Helmholtz International Beamline for Extreme Fields (HIBEF) User Consortium.

MP 10.3 Thu 14:15 KH 02.013

Detection schemes for quantum vacuum birefringence — •Naser Ahmadiniaz[1], Thomas Cowan[1,2], Christian Kohlfürst[1], Roland Sauerbrey[1], Michal Smid[1], Toma Toncian[1], and Ralf Schützhold[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Institut für Kern und Teilchenphysik, Technische Universität Dresden, 01062 Dresden, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Strong electromagnetic fields can not only create matter but also turn the quantum vacuum into an anisotropic medium. This effect is called vacuum birefringenc. Motivated by recent experimental initiatives of the BIREF@HIBEF collaboration at the Helmholtz International Beamline for Extreme Fields (HIBEF) of the HED instrument at the European XFEL, we study birefringent scattering of x-rays in the strong field of high-intensity optical lasers and compare several beam geometries. Special emphasis is placed on scenarios where signal and background photons differ in polarization, propagation direction, and possibly energy, in order to enhance detectability.

[1] N. Ahmadiniaz, C. Bähtz et al. (BIREF@HIBEF Collaboration), High Power Laser Science and Engineering 13 (2025).

[2] N. Ahmadiniaz, T.E. Cowan et al. Phys. Rev. D 108, 076005 (2023).

MP 10.4 Thu 14:30 KH 02.013

Matter from light: The Sauter-Schwinger effect — •Christian Kohlfürst[1], Naser Ahmadiniaz[1], Sebastian M. Schmidt[1,2], and Ralf Schützhold[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Strong electromagnetic fields can push even the quantum vacuum itself to its limits, forcing it out of equilibrium and triggering the creation of pairs of electrons and positrons. In this talk, we focus on the most extreme form of matter creation through light: the non-perturbative Sauter-Schwinger effect. In particular, we consider characteristic signatures in the particle distributions of the created electron-positron pairs and provide further context in terms of Relativistic Quantum Transport Theory.

[1] J. P. Edwards et al., Phys. Rev. D 112, L031901 (2025).

[2] C. Kohlfürst, Phys. Rev. D 110, L111903 (2024).

[3] C. Kohlfürst et al., Phys. Rev. Lett. 129, 241801 (2022).

MP 10.5 Thu 14:45 KH 02.013

Essential Nonlocality of Spin and Polarization Distributions in Strong-Field Quantum Electrodynamics — Samuele Montefiori[1], Antonino Di Piazza[2,3,1], Tobias Podszus[1], Christoph H. Keitel[1], and •Matteo Tamburini[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]University of Rochester, Rochester, USA — [3]Laboratory for Laser Energetics, Rochester, USA

Lepton spin and photon polarization are fundamental quantum degrees of freedom that govern scattering amplitudes and observable asymmetries. Advances in high-power lasers have opened the strong-field quantum electrodynamics (QED) regime, where modeling of nonlinear Compton scattering (NCS) typically relies on the collinear, locally constant field approximation (LCFA). We show that constructing angle- and polarization-resolved NCS distributions from local, instantaneous lepton states in a uniform constant crossed field can yield unphysical spin and polarization vectors with magnitudes exceeding unity, while accounting for the full photon formation length eliminates these pathologies. We introduce a new LCFA method that integrates over the entire formation region and, when applied to electron-laser interactions and to emission in strong magnetic fields, predicts qualitative and quantitative polarization differences relative to the commonly used local, collinear-emission model.

MP 10.6 Thu 15:00 KH 02.013

Comparative analysis of laser chirping schemes for compensation of ponderomotive broadening in high-intensity Compton sources — •Nikita Larin[1,2] and Daniel Seipt[1,2] — [1]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Inverse Compton scattering (ICS) is a well-established source of X-ray and γ-ray radiation with broad applications in medicine, biology, nuclear, and material sciences. A key advantage of ICS sources is their ability to generate photon beams with high spectral brightness.

However, achieving the necessary large photon yield requires operation at relativistic laser intensities, which introduces ponderomotive broadening. This effect directly limits the desired spectral brightness. To mitigate this constraint and enhance the performance of ICS sources, the use of chirped laser pulses has been proposed as a compensation strategy [1-4].

We present a comparative study of various chirping prescriptions by applying a novel time-frequency analysis method to the nonlinear Compton emission process. This approach provides deeper insights into the effectiveness of the different chirping prescriptions and guides further refinements toward creating narrowband X-ray and γ-ray sources based on ICS.

[1] I. Ghebregziabher et al., PRSTAB 16, 030705 (2013). [2] B. Terzić et al., PRL 112, 074801 (2014). [3] V. Kharin et al., PRL 120, 044802 (2018). [4] D. Seipt et al., PRL 122, 204802 (2019).

MP 10.7 Thu 15:15 KH 02.013

Status report of the photon photon scattering experiment at

CALA — •Timo Pohle[1], Leonard Doyle[1], Fabian Schütze[2,3], Pooyan Khademi[2,3], Felix Karbstein[2,3], Matt Zepf[2,3], and Jörg Schreiber[1] — [1]CALA/LMU, Am Coulombwall 1, 85748 Garching — [2]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena — [3]Faculty of Physics and Astronomy, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

In the Centre for Advanced Laser Applications (CALA) near Munich, an experiment is being set up with the aim of measuring photon-photon scattering in the all-optical regime. We expect tens of photon scattering when colliding two petawatt pulses from the ATLAS-3000 Laser head on. Measuring this weak signal in the environment of ultra-intense laser pulses consisting of $\mathcal{O}(10^{20})$ photons each is one of the main challenges of the experiment, which we want to overcome using the darkfield approach and a time-gated detection scheme. The quantification of this signal will help to verify the predictions made by the current theory about the quantum vacuum in a strong field environment. In my talk, I will give an overview of our planned experimental setup in combination with the expected signal yield predicted by analytical and numerical work [1] as well as report on the current progress of the implementation. Furthermore, I will show our approach to the detection of the weak signal and highlight other challenges in the realization of the experiment.

[1] Schütze et al. *Phys. Rev. D* **2024**, *109* (9), 096009.