Q 79: Cavity QED and QED III

Time: Friday 14:30–16:30 Location: P 4

Q 79.1 Fri 14:30 P 4

Heat transport between nonreciprocal media — Nico Strauss, •Omar Jesus Franca Santiago, and Stefan Yoshi Buhmann — Institute of Physics, University of Kassel, Germany

The second law of thermodynamics dictates that heat flows from warm to cold objects, thereby providing a direction of time [1]. In the optics of nonreciprocal media [2], an arrow of time is alternatively provided by the observation that optical paths cannot be reversed. How are these two notions compatible at the level of quantum electro- dynamics? In order to answer this question, we analyse the near-field heat transfer in a three-layer system constituted by nonreciprocal media with special focus on three-dimensional topological insulators, which break time-reversal symmetry. We investigate the impact of these materials on the heat transfer.

References

[1] Volokitin, A. I.; Persson, B. N. J. Rev. Mod. Phys. 4, 79 (2007).

[2] S. Y. Buhmann et al., New J. Phys. 14, 083034 (2012).

[3] Nico Strauß, Heat transfer in macroscopic electrodynamics. Doctoral Dissertation, University Kassel, 2025.

Q 79.2 Fri 14:45 P 4

Noise-protected state transfer between distant nodes in a quantum network — •Syeda Aliya Batool[1], Iñigo Arrazola[2], and Peter Rabl[1] — [1]Walther-Meißner-Institut, 85748 Garching, Germany — [2]Institute of Theoretical Physics-IFT, Madrid, Spain

Low-frequency noise represents a major source of decoherence in cavity QED systems, significantly limiting the fidelity of quantum state transfer and, consequently, the reliability of long-distance quantum communication protocols. To address this challenge, we investigate two complementary noise-mitigation strategies: continuous dynamical decoupling, which implements a continuous spin-echo effect through strong qubit driving, and pulsed dynamical decoupling, which applies sequences of control pulses to suppress low-frequency fluctuations. These techniques target different experimental regimes, and together they offer a universal solution for mitigating low-frequency noise across a wide range of system parameters. We analyze their effectiveness, demonstrating that they can significantly enhance the robustness of qubit-photon interfaces while preserving coherent photon-mediated state transfer. Our results provide practical guidance for implementing noise-resilient qubit-photon interfaces, laying a foundation for secure and high-fidelity quantum information transfer in long-distance quantum networks.

Q 79.3 Fri 15:00 P 4

Quantum metasurfaces as probes of vacuum particle content — •Germain Tobar[1], Joshua Foo[2], Sofia Qvarfort[3], Fabio Costa[3], Rivka Bekenstein[4], and Magdalena Zych[1] — [1]Department of Physics, Stockholm University, SE-106 91 Stockholm, Sweden — [2]Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1 — [3]Nordita, KTH Royal Institute of Technology and Stockholm University, Hannes Alfvens vag 12, SE-114 19 Stockholm, Sweden — [4]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

The quantum vacuum of the electromagnetic field contains spatially localised particle content. We propose to probe this content in the non-perturbative regime of boundary-condition changes using a quantum mirror - a two-dimensional sub-wavelength atomic array dividing a photonic cavity. Its reflectivity is quantum-controlled by a single Rydberg atom, creating coherent superpositions of transmissive and reflective states. Unlike parametric dynamical-Casimir approaches, this platform enables boundary changes that non-perturbatively alter the cavity-mode structure, directly coupling to the particle content of the vacuum. This opens an experimental route to observing superposed Dirchtlet boundary conditions, superpositions of particle creation effects and the dynamical casimir effect with highly non-perturbative boundary condition changes.

Q 79.4 Fri 15:15 P 4

Perfect Quantum State Transfer in a Dispersion-Engineered Waveguide — Zeyu Kuang, •Oliver Diekmann, Lorenz Fischer, Stefan Rotter, and Carlos Gonzalez-Ballestero — Institute for Theoretical Physics, TU Wien, Vienna A-1040, Austria

Faithful transfer of quantum states between distant nodes is a cornerstone of quantum networks, yet even the simplest setups such as two qubits weakly coupled to a waveguide suffer from fundamental efficiency limits related to the temporal shape of the emitted photon. I will present an approach that circumvents this limitation by directly engineering the waveguide dispersion. In particular, I will show how a tailored dispersion profile can reshape the photons wavepacket into the optimal time-reversed form, enabling faithful transfer without external control fields. I will discuss how to design the dispersion relation at different node distances and achieve robustness to variations of these distances.

Q 79.5 Fri 15:30 P 4

Casimir Control: A new Mechanism for Cavity Quantum Materials — Ola Carlsson[1,2], Sambuddha Chattopadhyay[1], Jonathan B. Curtis[1], •Frieder Lindel[1,3], Lorenzo Graziotto[3,4], Jerome Faist[3,4], and Eugene Demler[1] — [1]Institute for Theoretical Physics, ETH Zürich, Zürich 8093, Switzerland — [2]Department of Physics and Arnold Sommerfeld Center for Theoretical Physics (ASC), Ludwig-Maximilians-Universität München, Theresienstr. 37, D-80333 München, Germany — [3]Quantum Center, ETH Zürich, Zürich 8093, Switzerland — [4]Institute of Quantum Electronics, ETH Zürich, Zürich 8093, Switzerland

External classical radiation can control properties of quantum materials. Recently, an alternative has been proposed, in which the external driving is replaced by the quantized modes of a dark cavity.

In my talk, we will discuss Casimir control [1] as a new mechanism for cavity control of electronic nematic order in Fermi liquids, where different electronic order orientations are often energetically degenerate. We will find that the zero-point energy of the electromagnetic continuum, the Casimir energy, depends on the properties of the material system. This can be exploited to stabilize particular orientations of the nematic order. The experimental feasibility will be illustrated using the example of a quantum Hall stripe system [2].

[1] O. Carlsson et al., preprint at arXiv:2510.05088 (2025).

[2] L. Graziotto et al., preprint at arXiv:2502.15490 (2025).

Q 79.6 Fri 15:45 P 4

Casimir forces for nonreciprocal and chiral materials — •Aaron Laszlo Nyerges, Fabian Spallek, and Stefan Yoshi Buhmann — Universität Kassel

The Casimir effect, a manifestation of quantum vacuum fluctuations, remains a vibrant area of research since its prediction in 1948 [1]. Macroscopic Quantum Electrodynamics (QED) provides a foundational framework for studies of Casimir forces in systems with simple geometries and allows for the description of diverse magnetoelectric media with unique properties [2]. In this work, we extend the established solutions for planar multilayer systems of perfectly conducting plates to incorporate generalized material properties. We specifically investigate the Casimir forces generated between plates composed of nonreciprocal media [3], where the Onsager reciprocity relations are violated, and chiral materials with broken parity symmetry. We describe these different media properties on the level of the reflection and transmission coefficients of the material. Our goal is to find a generalized framework to unify these nontrivial electromagnetic properties and to study whether they introduce unique signatures into the Casimir force.

[1] Casimir, H. B. G.: On the attraction between two perfectly conducting plates, Proc. K. Ned. Akad. Wet. 51, 793 (1948). [2] Buhmann, S. Y.: Dispersion Forces I, (Springer, Berlin Heidelberg, 2012). [3] Rode, S., Bennett, R., and Buhmann, S. Y.: Casimir effect for perfect electromagnetic conductors (PEMCs), New. J. Phys. New J. Phys. 20, 043024 (2018).

Q 79.7 Fri 16:00 P 4

Entanglement and pair production in intense electromagnetic fields — Suo Tang[1], Barry Dillon[2], and •Ben King[3] — [1]College of Physics and Optoelectronic Engineering, Ocean University of China, Qingdao, Shandong 266100, China — [2]ISRC, Ulster University, Derry BT48 7JL, UK — [3]Centre for Mathematical Sciences, University of Plymouth, PL4 8AA, UK

We investigate the spin correlations between electron-positron pairs created from a photon when it scatters in a high-intensity laser pulse via the nonlinear Breit-Wheeler process. We find that the spin states of the generated electron-positron pair can exhibit strong entanglement, with the degree being sensitive to the photon energy, laser intensity, and the relative polarization of the photon and laser pulse. Photons with a high degree of polarisation can create strongly entangled pairs even in the intermediate intensity (non-perturbative) regime. We find that if the photons are provided by a Compton source, strongly spin-entangled electron-positron pairs can be generated with technology available today.

Q 79.8 Fri 16:15 P 4

The discovered adequate structure of space provides a foundation of quantum physics — •Hans-Otto Carmesin — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

The International Astronomical Union (IAU) proclaimed the problem to find an adequate coordinate system (ACS) of space and time in nature. This problem is solved here: For each point P in the universe, a measurement procedure for the ACS, the existence and the uniqueness of the velocity of the ACS, and the velocity zero of the ACS relative to the gravitational field are derived. As a consequence, the universal zero of the kinematic time difference and of the kinetic energy are derived. For homogeneous space, indivisible volume portions in nature are derived. Moreover, it is shown that homogeneous space is a stochastic average of indivisible volume portions in nature. Therefrom, the dynamics of these volume portions and the quantum postulates are derived. For the derived theory, successful tests are presented, predictions are derived, and experimental tests are proposed.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster. Carmesin, H.-O. (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin: Verlag Dr. Köster.