Q 53: Quantum Optics and Photonics III

Time: Thursday 14:00–16:00 Location: S Gr. HS Maschb.

Q 53.1 Thu 14:00 S Gr. HS Maschb.

Fermionic time-reversal symmetry in a photonic topological insulator: Theory — •Bastian Höckendorf[1], Lukas Maczewsky[2], Mark Kremer[2], Tobias Biesenthal[2], Matthias Heinrich[2], Andreas Alvermann[1], Holger Fehske[1], and Alexander Szameit[2] — [1]Institut für Physik, Universität Greifswald, Greifswald, Germany — [2]Institut für Physik, Universität Rostock, Rostock, Germany

Much of the recent enthusiasm directed towards topological insulators is motivated by their hallmark feature of protected chiral edge states. In fermionic systems, these entities occur in the presence of time-reversal symmetry. In contrast, bosonic systems obeying time-reversal symmetry are generally assumed to be fundamentally precluded from supporting edge states. We challenge this belief by applying a new twist to the interpretation of $\mathbb{Z}_2$ topological insulators as two inverse Chern insulators which are related by time-reversal symmetry. Specifically, we adapt this concept to Floquet systems, and implement two inversely driven anomalous topological insulators on the sublattices of a face centered quadratic lattice. The resulting time-reversal symmetric driving protocol hosts counter-propagating edge states and is characterized by a $\mathbb{Z}_2$ invariant. The sublattices encode the spin degree of freedom of fermionic particles as an effective pseudo-spin degree of freedom, which makes implementation in bosonic systems possible. Photonic waveguide lattices are a natural platform for the experimental realization of our driving protocol, the results of which will be discussed in a related presentation by L. Maczewsky.

Q 53.2 Thu 14:15 S Gr. HS Maschb.

Fermionic time-reversal symmetry in a photonic topological insulator: Experiments — •Lukas Maczewsky[1], Bastian Höckendorf[2], Mark Kremer[2], Tobias Biesenthal[1], Matthias Heinrich[1], Andreas Alvermann[2], Holger Fehske[2], and Alexander Szameit[1] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, 18059 Rostock — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

In the recent years the field of topological insulators established a new phase of matter which is marked by the hallmark feature of protected chiral edge states. In fermionic systems these states occur together with time-reversal symmetry (TRS). In contrast, bosonic systems obeying TRS are generally assumed to be fundamentally precluded from supporting topological edge states. We dispel this perception in this work and experimentally demonstrate counter-propagating chiral states at the edge of a bosonic system with TRS for the first time. The core idea of our approach is to encode the effective spin of the propagating states as a degree of freedom of the underlying waveguide lattice. The proposed protocol is implemented by using the femtosecond laser writing technique. We experimentally observe the counter-propagating edge modes by excitation of single lattice sites. Additional to that we confirm the underlying fermionic TRS of the structure by light propagation through the structure in forward and backward direction. Our findings allow fermionic features in bosonic systems, thereby opening new avenues for topological physics in photonics as well as acoustics, mechanics and even matter waves.

Q 53.3 Thu 14:30 S Gr. HS Maschb.

Engineering Photon Delocalization in a Rabi Dimer with a Dissipative Bath — •Fulu Zheng — Max Planck Institute for the Physics of Complex Systems, Germany

A Rabi dimer is used to model a recently reported circuit quantum electrodynamics system composed of two coupled transmission-line resonators with each coupled to one qubit. In this study, a phonon bath is adopted to mimic the multimode micromechanical resonators and is coupled to the qubits in the Rabi dimer. The dynamical behavior of the composite system is studied by the Dirac-Frenkel time-dependent variational principle combined with the multiple Davydov D_2 ansätze. Initially all the photons are pumped into the left resonator, and the two qubits are in the down state coupled with the phonon vacuum. In the strong qubit-photon coupling regime, the photon dynamics can be engineered by tuning the qubit-bath coupling strength α and photon delocalization is achieved by increasing α. In the absence of dissipation, photons are localized in the initial resonator. Nevertheless, with moderate qubit-bath coupling, photons are delocalized with quasiequilibration of the photon population in two resonators at long times. In this case, high frequency bath modes are activated by interacting with depolarized qubits. For strong dissipation, photon delocalization is achieved via frequent photon-hopping within two resonators and the qubits are suppressed in their initial down state. This work has been published in [F. Zheng, Y. Zhang, L. Wang, Y. Wei, and Y. Zhao, *Ann. Phys.* 1800351 (2018)].

Q 53.4 Thu 14:45 S Gr. HS Maschb.

Effective dynamics of strongly coupled spin-boson systems with disorder and dissipation — •Eliana Fiorelli[1,2], Matteo Marcuzzi[1,2], Pietro Rotondo[1,2], Federico Carollo[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham

We are exploring the dynamics of an ensemble of spins that interact strongly with dissipative bosonic modes. Such scenario can be achieved experimentally in trapped ion systems, but it is also of relevance for the description of superconducting circuits and atom-cavity systems. By integrating out the bosonic modes we obtain an effective equation of motion for the spin dynamics. For disordered spin-boson interactions this reduces to a set of classical rate equations that describe a non-thermal, i.e. non-equilibrium, evolution. For uniform coupling strengths the system may feature decoherence-free subspaces which allow to preserve quantum coherence and pairwise entanglement of spins over long times even in the presence of strong coupling to the bosons.

Q 53.5 Thu 15:00 S Gr. HS Maschb.

Bose condensation of squeezed light — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics-UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

Light with an effective chemical potential and no mass is shown to possess a general phase-transition curve to Bose-Einstein condensation. This limiting density and temperature range is found by the diverging in-medium potential range of effective interaction. While usually the absorption and emission with Dye molecules is considered, here it is proposed that squeezing can create also such an effective chemical potential. The equivalence of squeezed light with a complex Bogoliubov transformation of interacting Bose system with finite lifetime is established with the help of which an effective gap is deduced. This gap phase creates a finite condensate in agreement with the general limiting density and temperature range. The phase diagram for condensation is presented due to squeezing and the appearance of two gaps is discussed. arXiv:1809.09525

Q 53.6 Thu 15:15 S Gr. HS Maschb.

Tracing ultrashort squeezed states — •Matthias Kizmann[1], Thiago Lucena de M. Guedes[1], Denis V. Seletskiy[2], Andrey S. Moskalenko[1], Alfred Leitenstorfer[1], and Guido Burkard[1] — [1]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz, Germany — [2]Department of Engineering Physics, Polytechnique Montréal, H3T 1J4, Canada

The quantum nature of light possesses many astonishing properties rendering it a promising candidate for novel spectroscopy methods of complex many body phenomena, quantum information processing and subwavelength lithography. Usually its quantum nature is described in the frequency domain and for broadband quantum states of light a quasi continuous wave picture with a well-defined carrier frequency is still applicable. Recent access to subcycle quantum features of electromagnetic radiation [1-3] promises a new class of time-dependent quantum states of light. In view of these developments we formulate a consistent time domain theory of the generation and time resolved detection of few-cycle and subcycle pulsed squeezed states, where the quasi monochromatic picture is not valid anymore and provide a relativistic interpretation of the squeezing process in terms of induced changes in the local flow of time [4]. Our theory enables the use of such states as a resource for novel ultrafast applications in quantum optics and quantum information. [1] C. Riek et al., Science 350, 420 (2015). [2] A.S. Moskalenko et al., Phys. Rev. Lett. 115, 263601 (2015). [3] C. Riek et al., Nature 541, 376 (2017). [4] M. Kizmann et al., arXiv:1807.10519 (2018).

Q 53.7 Thu 15:30 S Gr. HS Maschb.

Spectra of ultrabroadband squeezed pulses and the finite-time Unruh-Davies effect — •Thiago Lucena de M. Guedes, Matthias Kizmann, Guido Burkard, and Andrey S. Moskalenko — University of Konstanz, Konstanz, Germany

We study the spectral properties of quantum radiation of ultrashort duration. In particular, we introduce a continuous multimode squeezing operator for the description of subcycle pulses of entangled photons generated by a coherent-field driving in a thin nonlinear crystal with second order susceptibility. We find the ultrabroadband spectra of the emitted quantum radiation perturbatively in the strength of the driving field [1]. These spectra can be related to the spectra expected in an Unruh-Davies experiment with a finite time of acceleration [2]. We discuss the possibility of transition between finite-time and usual Unruh-Davies effects by increasing the intensity of the driving field. In the time domain, we describe the corresponding behavior of the normally ordered electric field variance, which can be compared to the recent results obtained in quantum electro-optic experiments [3].

[1] T. L. M. Guedes et al., arXiv:1810.08273v1.

[2] P. Martinetti and C. Rovelli, Class. and Quantum Gravity 20, 4919 (2003).

[3] C. Riek et al., Nature 541, 376 (2017).

Q 53.8 Thu 15:45 S Gr. HS Maschb.

Analogue of cosmological particle creation in electromagnetic waveguides — •Sascha Lang[1,2] and Ralf Schützhold[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Quantum field theory in curved space-time predicts a mechanism of pair-wise particle creation to occur in expanding universes. However, an analogous phenomenon emerging in waveguide structures with fixed spatial dimensions but a time-dependent speed of light $v(t)$ is more accessible in actual laboratory experiments.

In this talk, we discuss the dynamics of an electromagnetic waveguide that can be described as an effective arrray of identical LC-circuits. Changing the characteristic inductivity L for all loops under consideration alters the effective speed of light $v(t)$ inside the sample and triggers a creation of photon pairs.

The number of particles produced by this mechanism is of second order in the perturbation $\Delta v(t)$. The two-point correlation for the effective field inside the waveguide shows a characteristic imprint that clearly reflects the occurrence of pair creation. Since the expected pattern has an amplitude proportional to $\Delta v(t)$, we propose to study two-point correlations in future experiments on analogue cosmological particle creation.