HL 34: Focus Session: Quantum Emission from Chaotic Microcavities (joint session HL/DY)

In this joint focused session of the divisions DY, HL, and TT, we bring together two dynamic areas of research: semiconductor quantum emitters and chaotic cavities. While quantum emitters in cavities represent an established building block for quantum information technologies, chaotic microcavities may promise novel design routes towards optimized cavity performance parameters. Experts from both fields will provide an overview of the current state of research, exploring the potential of chaotic and unconventional microcavities to enhance the emission of quantum states.

Organized by Sonja Barkhofen (University of Paderborn) and Christian Schneider (University of Oldenburg).

Time: Wednesday 9:30–12:15 Location: H17

Invited Talk HL 34.1 Wed 9:30 H17

From complex internal dynamics to emission characteristics control in quantum billiards — •Martina Hentschel — 1 Institute of Physics, Technische Universität Chemnitz, D-09107 Chemnitz, Germany

The field of mesoscopic physics has given access to new classes of fascinating model systems ranging from ballistic quantum dots via microcavity lasers to graphene billiards over the past decades. Their rich internal dynamics, subject to quantum chaos and often successfully accessed employing wave-particle correspondence in real and phase space, is directly related to their emission properties. Here, we illustrate this close connection for various examples and system classes. For optical microcavities, we vary the internal dynamics by changing the geometric shape of the resonator and explain how the far-field emission characteristics is determined by the underlying steady probability distribution and a possibility to achieve directional emission required for microlasing devices with the Limaçon geometry. Placing sources into the cavity will affect the internal dynamics of the cavity by, taking the particle point-of-view, effectively changing the set of initial conditions, as observed for optical cavities as well as for graphene billiards in the form of Dirac fermion optics. A further way to change the dynamics of a system is the existence of anisotropies that can either be intrinsically present such as in bilayer graphene in the form of trigonal warping [1], or can be induced to a given system by, for example, applying a mechanical strain. [1] L. Seemann, A. Knothe, and M. Hentschel, New J. Phys. 26, 103045 (2024).

Invited Talk HL 34.2 Wed 10:00 H17

Positioning of microcavities around single emitters — •Tobias Huber-Loyola — Technische Physik, Physikalisches Institut, Julius-Maximilians-Universität Würzburg, 97074 Würzburg, Germany

Single emitters in solids are great sources of single and entangled photons for usage in quantum information technologies. Many emitters possess high internal quantum efficiency, majority of the emission into the zero-phonon line and controllable single charge spins that can be used as quantum memories or as resource to generate chains of entangled photons. However, due to their solid-state host, which usually comes with a high refractive index, the outcoupling of photons requires the use of nanophotonic structures such as waveguides or microcavities. In this talk, I will show how we place microcavities around pre-registered quantum dots using hyperspectral imaging and e-beam lithography and I will give an overview of how placement accuracy has different effects on the emitted photons' properties based on the type of cavity.

Invited Talk HL 34.3 Wed 10:30 H17

Exploring Wave Chaos and Non-Hermitian Physics: Future Prospects for Quantum Emission from Chaotic Microcavities — •Jan Wiersig — Otto-von-Guericke-Universität Magdeburg, Germany

Optical microcavities play a fundamental role in many fields of basic and applied research in physics. A chaotic microcavity is a type of cavity where the light ray dynamics is (partially) chaotic [1]. This can occur in a microdisk cavity with a deformed boundary shape. Chaotic microcavities are ideal for studying ray-wave correspondence, or wave chaos, in open systems, allowing direct comparisons with experiments [2]. These cavities can also exhibit non-Hermitian phenomena such as reflectionless scattering modes [3] and exceptional points [4].

The light emission from chaotic microcavities has been studied exclusively within the classical domain. The effects of electromagnetic field quantization, including phenomena like entanglement, single-photon states, and squeezed light, remain unexplored in this context. In this talk, I will review my group's recent efforts to investigate classical emission from chaotic microcavities and quantum emission from semiconductor quantum dots embedded in conventional microcavities. Additionally, I will discuss the prospects for achieving genuine quantum emission from chaotic microcavities.

[1] H. Cao and J. Wiersig, Rev. Mod. Phys. 87, 61 (2015)
[2] X. Jiang et al., Science 358, 344 (2017)
[3] X. Jiang et al., Nat. Phys. 20, 109 (2023)
[4] C.-H. Yi et al., Phys. Rev. Lett. 120, 093902 (2018)

15 min. break

Invited Talk HL 34.4 Wed 11:15 H17

Correlations and statistics in cavity embedded quantum dot sources of quantum light — •Ana Predojevic — Stockholm University, Stockholm, Sweden

Single quantum dots coupled to photonic cavities are established emitters of single photons and entangled photon pairs. The cascaded generation of photon pairs intrinsically contains temporal correlations that negatively affect the ability of such sources to perform two-photon interference, hindering applications. I will show how such correlation interacts with decoherence and temporal postselection, and under what conditions temporal postselection could improve two-photon interference visibility. Our study identifies crucial parameters of the source and shows the way to achieve optimal performance. The single photons emitted by a quantum dot exhibit quantum statistics, which is usually verified in an autocorrelation measurement. Single photons can be subjected to more extensive tests of quantum nature, such as non-Gaussianity. However, there is little evidence that such a measurement can be made on pairs of photons. I will show that pairs of photons exhibit strongly non-classical properties that can be quantified. Our result is applicable to a wide range of quantum light sources and measurement methods.

Invited Talk HL 34.5 Wed 11:45 H17

Nonlinear Phenomena in Exciton-Polaritons from Bound States in the Continuum — •Dario Ballarini — CNR-NANOTEC, Lecce, Italy

Exciton-polaritons in semiconductor microcavities have demonstrated remarkable collective behaviors and nonlinear interactions. In this work, we introduce an alternative platform to study strong light-matter interactions within a waveguide configuration. Among other interesting phenomena and applications, such as dispersion engineering of waveguide exciton-polaritons or exciton tuning through the Stark effect [1,2], we highlight the demonstration of parametric nonlinearities, polariton lasing from bound-in-the-continuum (BIC) states, and the recent realization of polariton BICs operating at room temperature in 2D materials [3-5].

[1] Electrically controlled waveguide polariton laser, Optica 7, 1579 (2020). [2] Reconfigurable quantum fluid molecules of bound states in the continuum, Nature Physics 20, 61 (2024). [3] Polariton Bose-Einstein condensate from a bound state in the continuum, Nature 605, 447 (2022). [4] Emerging supersolidity from a polariton condensate in a photonic crystal waveguide, arXiv:2407.02373 (2024). [5] Strongly enhanced light-matter coupling of monolayer WS2 from a bound state in the continuum, Nature Materials 22, 964 (2023).