Q 64: Solid State Quantum Optics II

Time: Friday 11:00–13:00 Location: HS 3219

Q 64.1 Fri 11:00 HS 3219

Chip-fibre interface for integrated quantum networks — •Tim Engling[1,3], Jonas Zatsch[1,3], Jeldrik Huster[1,3], Simon Abdani[1,3], Christian Schweikert[2], and Stefanie Barz[1,3] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute of Electrical and Optical Communications Engineering, University of Stuttgart, 70569 Stuttgart, Germany — [3]Center for Integrated Quantum Science and Technology (IQST)

Integrated photonics provides a compact and robust way to process quantum information, and thus, offers a platform for scaling up quantum technologies. We introduce a silicon-on-insulator chip, which offers control of quantum states on the chip, and also, allows converting different degrees of freedom. The manipulation of path is achieved through the use of integrated beam splitters and phase shifters. Furthermore, switching between encoding in path and polarisation, and vice versa, is facilitated by 2D grating couplers. We demonstrate the chip's functionality by utilizing it for the generation, analysis, and conversion of quantum states of light. Our approach enables the connection of multiple integrated photonic chips, laying the foundation for implementing networked protocols in quantum communication and quantum computing.

Q 64.2 Fri 11:15 HS 3219

Towards Cavity-Enhanced Spectroscopy of Single Europium Ions in Yttria Nanocrystals — •Timon Eichhorn[1], Jannis Hessenauer[1], Philippe Goldner[2], Diana Serrano[2], and David Hunger[1] — [1]Karlsruher Institut fuer Technologie, Karlsruhe, Germany — [2]Université PSL, Chimie ParisTech, Paris, France

A promising approach for realizing scalable quantum registers lies in the efficient optical addressing of rare-earth ion spin qubits in a solid state host. We study Eu^{3+} ions doped into Y_2O_3 nanoparticles (NPs)[1] as a coherent qubit material and work towards efficient single ion detection by coupling their emission to a high-finesse fiber-based Fabry-Pérot microcavity [2,3]. A beneficial ratio of the narrow homogeneous line to the inhomogeneous broadening of the ion ensemble makes it possible to spectrally address single ions. The coherent control of the $^5D_0 -^7 F_0$ transition then permits optically driven single qubit operations on the Europium nuclear spin states. A Rydberg-blockade mechanism between nearby ions permits the implementation of a two-qubit CNOT gate to entangle spin qubits and perform quantum logic operations. We observed fluorescence signals from small ensembles of Europium ions at cryogenic temperatures and measured cavity-enhanced optical lifetimes of half the free-space lifetime resulting in effective Purcell-factors of one. We will report on measurements of the optical coherence of small Eu^{3+} ion ensembles and our progress towards single ion readout and control. [1] Nano Lett. 17 (2017) 778-787, [2] New J. Phys. 12 (2010) 065038, [3] New J. Phys. 20 (2018) 095006

Q 64.3 Fri 11:30 HS 3219

Maximizing photon-number resolution from an SNSPD — •Niklas Lamberty, Timon Schapeler, Thomas Hummel, Fabian Schlue, Michael Stefszky, Benjamin Brecht, Christine Silberhorn, and Tim J. Bartley — Institute for Photonic Quantum Systems, Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

Recent work has shown intrinsic Photon-Number Resolution (PNR) of Superconducting Nanowire Single-Photon Detectors (SNSPDs) based on the evaluation of various properties of the electrical output signal. In order to gain a more comprehensive understanding of the features responsible for PNR in SNSPDs, we record a data set of electrical output signals under coherent state illumination and analyze the data using Principal Component Analysis (PCA).

PCA generates a set of basis functions, where the coefficients obtained from projection of the data set onto these basis functions have maximized variance. The basis functions thus indicate areas which are most relevant for PNR and the coefficients indicate which photon-number was measured on the detector.

Using this technique we demonstrate PNR up to four photons and show which features contribute most to the PNR. These results are then verified using a time to digital converter. This intrinsic PNR without the need for multiplexing schemes will simplify many quantum optical experiments like single photon heralding or gaussian boson sampling.

Q 64.4 Fri 11:45 HS 3219

Efficient heralding of pure single-photons at telecom wavelength from pulsed cavity-enhanced SPDC — •Xavier Barcons Planas[1,2], Helen M. Chrzanowski[2], Leon Messner[2], and Janik Wolters[2,3] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Institute of Optical Sensor Systems, German Aerospace Center, Berlin, Germany — [3]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany

Entangled quantum states of multiple photons are crucial for pushing the boundaries of photonic quantum technologies. The generation of large multi-photon entangled states demands light sources that provide highly pure photons with high efficiency (either deterministic or heralded), as these factors limit scalability. A popular approach is to herald single-photons from photon-pair sources based on spontaneous parametric down-conversion (SPDC). Despite the spatial and spectral multimode emission of the process, potentially constraining the heralding efficiency and purity, the emitted photons can be engineered with single-mode characteristics, through waveguide geometries [1], group velocity matching techniques [2] or cavity resonators [3]. Here, we present a narrowband (170 MHz) single-photon source at the C-band based on pulsed SPDC in a monolithic crystal cavity. Pure ($P > 95\%$) and fiber-compatible single-photons have been generated with 85% heralding efficiency.

[1] A. Christ *et al.*, Phys. Rev. A **80**, 033829 (2009).
[2] P. J. Mosley *et al.*, Phys. Rev. Lett. **100**, 133601 (2008).
[3] R. Mottola *et al.*, Opt. Express **28**, 3159 (2020).

Q 64.5 Fri 12:00 HS 3219

Quantum optical properties of higher harmonics generated in semiconductors — •Philip Heinzel[1] and René Sondenheimer[1,2] — [1]Friedrich-Schiller-University — [2]Fraunhofer Institute for Applied Optics and Precision Engineering

The exploration of resource state generation for quantum applications has gained increased attention in recent years. Higher harmonics, generated through non-classical effects, stand out as promising candidates for their potential quantum attributes. To delve deeper into this phenomenon, our study focuses on the generation of non-classical light via laser-driven semiconductor intraband excitations, as investigated in [1]. Building upon the parametrical approximation method [2], we adopt the approach outlined in [1] to characterize the generated states. Our objective is to extend the linearized Hamiltonian approximation up to the quadratic order, introducing potential squeezing effects and rotations. Furthermore, we aim to investigate the resulting states, exploring their photon number statistics and quantum effects such as entanglement between different harmonic modes. This examination will provide a more nuanced understanding of the quantum properties inherent in states generated through laser-driven semiconductor intraband excitations.

References
[1]https://arxiv.org/abs/2211.06177v2
[2]https://arxiv.org/abs/2106.15720

Q 64.6 Fri 12:15 HS 3219

Room-temperature ladder-type memory compatible with single photons from InGaAs quantum dots — •Benjamin Maass[1,2,3], Norman Vincenz Ewald[1,2,3], Avijit Barua[3], Stephan Reitzenstein[3], and Janik Wolters[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für optische Sensorsysteme, Berlin — [2]Technische Universität Berlin, Institut für Optik und atomare Physik, Berlin — [3]Technische Universität Berlin, Institut für Festkörperphysik, Berlin

The on-demand storage and retrieval of quantum information in coherent light-matter interfaces is a key requirement for future quantum network and quantum communication applications. Non-cryogenic alkali vapor memories offer scalable and robust high-bandwidth storage at high repetition rates which makes them a natural fit for interfaces with single-photon sources. We present a detailed experimental characterization of a room-temperature ladder-type atomic vapor-based

memory that operates on the Cs D1 line. We demonstrate on-demand storage and retrieval of weak coherent laser pulses (0.06 photons per pulse) at a high signal-to-noise ratio (SNR=625). The memory reaches a maximum internal storage efficiency of $\eta_{\text{int}} = 16$ % and a 1/e storage time of $\tau_s = 24$ ns. Benchmark properties for the storage of single photons from inhomogeneously broadened state-of-the-art solid state emitters are estimated from the memory's performance. Together with the immediate availability of InGaAs quantum dots emitting at 894 nm this provides a clear prospect for experiments on a heterogeneous on-demand quantum light interface.

Q 64.7 Fri 12:30 HS 3219

Solid state quantum emitter in wide band gap materials — •A. Kumar[1], C. Samaner[2], C. Cholsuk[1], T. Matthes[1], S. Suwanna[3], S. Ateş[2], and T. Vogl[4] — [1]FSU Jena, Germany — [2]İIT, Turkey — [3]Mahidol University, Thailand — [4]TU Munich, Germany

With the rapid development of quantum technology, there has been a growing demand for materials capable of hosting quantum emitters. One such material platform is fluorescent defects in wide band gap materials capable of hosting deep sub-levels within the band gap. Here, we investigate experimentally and theoretically using DFT simulations and compare the fabrication and photophysical properties of quantum emitters in multi-layer mica, hBN and other 3D crystals, such as silicon carbide and gallium nitride which are known to host quantum emitters. We used localized electron beam irradiation process to induce single emitters emitting at 575 nm in hBN with a high yield and emitter ensembles in Mica. The emitters in hBN present a strong correlation with hBN crystal axis, which provides an important step towards the identification of emitters and their formation process. Additionally, we explore temporal polarization dynamics, uncovering a mechanism that governs the time-dependent polarization visibility and dipole orientation of color centers in hBN and diamond. Our further investigation involves the integration of hBN emitters with a nanophotonics platform to develop on-chip quantum light sources for future quantum technology applications.

Q 64.8 Fri 12:45 HS 3219

Characterizing random laser and cavity exiton-polariton supported random laser action in disordered ensembles of the hybrid perovskite CH3 NH 3 PbBr 3 (MAPB) — •Regine Frank[1,2], Paul Bouteyre[3], Hai Son Nguyen[4,5], Christian Seassal[4,5], Emmanuelle Deleporte[3], and Bart A. van Tiggelen[6] — [1]College of Biomedical Sciences, Larkin University, Miami, Florida, USA — [2]Donostia International Physics Center, 20018 Donostia-San Sebastian, Spain — [3]Universite Paris-Saclay, ENS Paris-Saclay, CNRS, CentraleSupélec, LuMIn, Gif-sur-Yvette, France — [4]Universite de Lyon, Institut des Nanotechnologies de Lyon, INL/CNRS, Ecole Centrale de Lyon, Ecully, France — [5]Institut Universitaire de France (IUF), Paris, Franceb — [6]Universite Grenoble Alpes, Centre National de la Recherche Scientifique, LPMMC, Grenoble, France

We present semi analytical as well as numerical results (WENO) for photonic transport and Anderson localization of photons in laser active disordered ensembles of the hybrid perovskite CH3 NH3PbBr3 (MAPB) capped by PMMA. We compare experiments of two dimensional and three dimensional transport to time and space resolved numerics coherent to descriminate between directed random laser emission and exciton-polariton supported random laser emission. We present a systematic study of for disordered and quasi ordered ensembles.