QI 8: Photons and Photonic Quantum Processors

Time: Monday 16:30–18:30 Location: HFT-FT 131

Invited Talk QI 8.1 Mon 16:30 HFT-FT 131

Quantum Simulations in Integrated Waveguide Arrays — •Jasmin D. A. Meinecke[1,2,3,4], Florian Huber[1,2,3], Benedikt Braumandl[1,2,3], Sholeh Razavian[1,2,3], Jan Dziewior[1,2,3], Robert Jonsson[5], Johannes Knörzer[6], Harald Weinfurter[1,2,3], and Alexander Szameit[7] — [1]Department für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [4]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [5]Nordita, KTH Royal Institute of Technology and Stockholm University, Hannes Alfvens vag 12, SE-106 91 Stockholm, Sweden — [6]Institute for Theoretical Studies, ETH Zurich, 8092 Zurich, Switzerla — [7]Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, 18059 Rostock, Germany

Photons exhibit low decoherence and fast transmission, making them promising for emerging quantum technologies. In particular, integrated circuits provide stable structures for quantum computation and simulation. One example are integrated waveguide arrays for simulations based on quantum walk models. Especially the precise control of path as well as polarization degree of freedom allows the simulation of Markovian as well as non-Markovian dynamics as found in open quantum systems. We analyse information as well as energy flow in quantum systems revealing insights into time evolution and dynamics also of many-body systems.

QI 8.2 Mon 17:00 HFT-FT 131

Rigorous treatment of photon propagation between quantized quasinormal mode cavities — •Robert Fuchs[1], Juanjuan Ren[2], Sebastian Franke[1], Stephen Hughes[2], and Marten Richter[1] — [1]Nichtlineare Optik und Quantenelektronik, Institut für Theoretische Physik, TU Berlin, Berlin, Germany — [2]Department of Physics, Engineering Physics, and Astronomy, Queen's University, Kingston, Ontario K7L 3N6, Canada

Spatially extended systems consisting of separated quantum emitters or resonators that couple via propagating photons are key to implementations of many quantum technologies, including quantum communication and quantum computing applications. Quasinormal modes (QNMs) are solutions to a Helmholtz equation with open boundary conditions. Hence, QNMs are a powerful tool for calculating the resonances of open optical cavities including dispersive plasmonic nanoparticles.

However, the focus of study so far has mostly been on single cavities or coupled resonators with small spatial separation. We extend the quantized QNM theory to the case of multiple, distant cavities and define parameters to determine when a separate treatment of the individual systems is possible. We also include quantum emitters in the theory. Using a bath of propagating photons, we derive system-bath correlation functions to rigorously describe the time delayed interactions between the QNM cavities and quantum emitters that give rise to feedback-induced phenomena.

QI 8.3 Mon 17:15 HFT-FT 131

Towards Photon-Number-Entanglement from a Sequentially Excited Quantum Three-Level System — •Daniel A. Vajner[1], Nils Kewitz[1], Carlos Anton-Solanas[2], Stephen C. Wein[3], Martin von Helversen[1], Yusuf Karli[4], Vikas Remesh[4], Saimon F. Covre da Silva[5], Armando Rastelli[5], Gregor Weihs[4], and Tobias Heindel[1] — [1]Technical University of Berlin, Berlin, Germany — [2]Universidad Autónoma de Madrid, Madrid, Spain — [3]Quandela, Massy, France — [4]Universität Innsbruck, Innsbruck, Austria — [5]Johannes Kepler University Linz, Linz, Austria

As recently demonstrated, the sequential resonant excitation of 2-level quantum systems leads to the generation of time bin modes that are entangled in the photon-number-basis [1]. Here, we extend this notion to 3-level quantum systems, realized by a biexciton in a semiconductor quantum dot that is subject to sequential pulses that are resonant with the two-photon transition. The different decay rates of the exciton and biexciton, in combination with the cascaded emission, lead to the creation of a complex multi-dimensional entangled state which could be used in quantum information applications [2]. By performing energy- and time-resolved correlation experiments, in combination with extensive theoretical modelling and simulations, we analyze the generated state and confirm its high-dimensional structure. This represents a scalable way towards complex and on-demand entangled photonic states.

[1] Wein, Stephen C., et al. Nature Photonics 16.5 (2022): 374-379.
[2] Santos, Alan C., et al. arXiv:2304.08896 (2023).

QI 8.4 Mon 17:30 HFT-FT 131

Investigation of the degree of sequential indistinguishability of ZnSe-based single-photon sources — •Christine Falter[1,3], Yurii Kutovyi[1,3], Nils von den Driesch[2,3], Detlev Grützmacher[1], and Alexander Pawlis[1,2,3] — [1]Peter Grünberg Institute PGI-9, Forschungszentrum Jülich GmbH — [2]Peter Grünberg Institute PGI-10, Forschungszentrum Jülich GmbH — [3]JARA-Fundamentals of Future Information Technology, Jülich Aachen Research Alliance

The realization of secure quantum communication networks requires the development of efficient and scalable sources of single, indistinguishable photons. We recently demonstrated highly efficient and spectrally tunable single photon emission from spatially isolated Cl donors in ZnSe/ZnMgSe quantum well nanopillar structures covered with a resist mask. Photoluminescence measurements reveal a high photon extraction efficiency (PEE) of 16%. Utilizing 2D ray-tracing simulations, we estimate the internal quantum efficiency to be close to unity, which is confirmed by the short radiative lifetime of our emitters. Finally, we investigate the degree of indistinguishability using Hong-Ou-Mandel-type experiments. We employ Monte Carlo simulations to replicate the experimental signatures and to investigate the influence of various experimental factors on the measurements. We estimate the degree of sequential indistinguishability to be as high as 90%. This result paves the way for Cl-doped ZnSe/ZnMgSe nanopillars to serve as highly efficient SPSs in future quantum communication networks.

QI 8.5 Mon 17:45 HFT-FT 131

Single erbium emitters in nanophotonic silicon resonators — •Jakob Pforr[1,2], Andreas Gritsch[1,2], Alexander Ulanowski[1,2], Stephan Rinner[1,2], Johannes Früh[1,2], Florian Burger[1,2], Jonas Schmitt[1,2], Kilian Sandholzer[1,2], Adrian Holzäpfel[1,2], and Andreas Reiserer[1,2] — [1]Max-Planck-Institut für Quantuenoptik, 85748 Garching, Germany — [2]TU München and Munich Center for Quantum Science and Technology, 85748 Garching, Germany

Erbium is a promising candidate for quantum networks, because it offers coherent optical transitions in the minimal-loss window of optical fibers. Integrating it in silicon allows for CMOS compatible fabrication and scalability. Previous work showed narrow inhomogeneous broadening ($\sim$1 GHz) and narrow homogeneous linewidth ($<$0.01 MHz) in erbium ensembles [1]. We demonstrate that this can also be achieved in samples that were fabricated in a commercial nanophotonic foundry [2]. In addition, by integrating the dopants into suited resonators with $Q \sim 10^5$ and $V \sim \lambda^3$, the optical lifetime is reduced 60-fold via Purcell-enhancement and single dopants can be observed [3]. We present our recent advances towards spin control, which demonstrate that Er:Si is a suitable spin-photon interface for quantum networks in the telecom C band.

References:
[1] Gritsch et. al. 2021. PRX 12(4): 041009.
[2] Rinner et. al. 2023. Nanophotonics 12(17): 3455-3462.
[3] Gritsch et. al. 2023. Optica 10: 783-789

QI 8.6 Mon 18:00 HFT-FT 131

Squeezed light source on lithium niobate on insulator for quantum computing without periodic poling — •Tummas Napoleon Arge[1], Seongmin Su[2], Francesco Lenzini[3], Jonas Schou Neergaard-Nielsen[1], Tobias Gehring[1], and Ulrik Lund Andersen[1] — [1]Technical University of Denmark, Fysikvej 311, 2800 Kgs. Lyngby, Denmark — [2]University of Heidelberg, Grabengasse 1 69117 Heidelberg — [3]University of Munster, Schlossplatz 2 48149 Münster

Squeezed quantum states combined with a linear beamsplitter network and photon number resolving detectors can produce the holy grail in continuous-variable quantum computing, GKP states. Lithium niobate on insulator (LNOI) is an emerging platform suitable for producing squeezed states of light due to its ultra-low propagation loss and high non-linear $\chi\hat{}(2)$ coefficient. A squeezing source for a circuit generating GKP states must obey two conditions: 1) a high amount of squeezing and 2) high purity.

This work presents a design for a squeezer on an LNOI platform without using periodic poling. Perfect phase matching in a type-I OPO is achieved using a higher-order transversal mode TM2 as the pump field, producing a signal/idler pair in the TE0 mode. Preliminary experiments show a parametric gain of 3, which will lead to -0.5 dB of squeezing off chip. The nature of the phasematching suppresses unwanted modes, fulfilling condition 2).

In conclusion, further work is needed to demonstrate efficient squeezing on this platform fulfilling the two conditions.

QI 8.7 Mon 18:15 HFT-FT 131

Deterministic creation of isolated and ultra-bright quantum emitters in hexagonal boron nitride — •Safa L. Ahmed[1,2], Ioannis Karapatzakis[2], Luis Kussi[2], Marcel Schrodin[2], Rainer Kraft[2], Christoph Sürgers[2], and Wolfgang Wernsdorfer[1,2] — [1]IQMT, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]PHI, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Single-photon emitters (SPEs) in hexagonal boron nitride (hBN) show fascinating applications in quantum information processing and quantum sensing. In order to utilize quantum emitters as sensors it is crucial to have stable SPEs. We create defects via AFM nanoindentation [1] on multilayer hBN flakes followed by high temperature annealing in Ar environment. This produces ultra-bright SPEs which do not photobleach due to charge build-up, and are both spatially and spectrally deterministic. A high yield of single isolated emitters is observed. Their second order correlation measurements and Debye-Waller factors show a high quantum yield. In addition, low temperature measurements were carried out that show spectral changes and emitter robustness to thermal cycles. Such deterministic surface quantum emitters could be incorporated into quantum sensing devices with enhanced spatial resolution and sensitivity.