QI 31: Single Quantum Emitters (joint session Q/QI)

Time: Thursday 14:30–16:30 Location: E214

Invited Talk QI 31.1 Thu 14:30 E214

Quantum information with atomic quantum metasurfaces and integrated nanophotonics — •Rivka Bekenstein for the SHIPTRAP-Collaboration — Hebrew University, Jerusalem, Israel

Quantum information processing with photonic qubits requires on-demand single photon sources, linear components, along with more advanced components such as quantum memories and deterministic nonlinearity to implement logic gates between photonic qubits. I will discuss two promising systems for generating and controlling photonic qubits. I will first present our fiber-coupled single-photon-source based on silicon-vacancy centers in nanophotonic cavity diamond. This source features high efficiency, purity, temporal control, and integrability. We have been able to demonstrate arbitrarily temporally shaped single photon pulses with high purity ($g2(0) = 0.0168$) and detection efficiency of 14.9. This achievement combined with previously demonstrated spin-photon gates and long-lived memory, enables on-demand generation of streams of correlated photons useful for one-way quantum computation. I will then present our quantum-metasurfaces-based quantum protocols for large-scale entanglement generation and quantum holography. These work build upon our recent analysis of quantum metasurfaces: two-dimensional atomic arrays which control light coherently by scattering.

QI 31.2 Thu 15:00 E214

Efficient High-Fidelity Flying Qubit Shaping — •Benedikt Tissot and Guido Burkard — Universität Konstanz

Single photon emission is the cornerstone of numerous quantum technologies, such as distributed quantum computing as well as several quantum internet and networking protocols. We find the upper limit for the photonic pulse emission efficiency for imperfect emitters and show a path forward to optimize the fidelity. The outlined theory for stimulated Raman emission is applicable to a wide range of physical systems including quantum dots, solid state defects, and trapped ions, as well as various parameter regimes in particular for any pulse duration. Furthermore, the mathematical idea to use input-output theory for pulses to absorb the dominant emission process into the coherent dynamics, followed by a quantum trajectory approach has great potential to study other physical systems.

QI 31.3 Thu 15:15 E214

Localized creation of yellow single photon emitting carbon complexes in hexagonal boron nitride — •Anand Kumar[1], Chanaprom Cholsuk[1], Askhan Zand[1], Mohammad Nasimuzzaman Mishuk[1], Tjorben Matthes[1], Falk Eilenberger[1], Sujin Suwanna[2], and Tobias Vogl[1] — [1]Abbe Center of Photonics, Institute of Applied Physics, Friedrich Schiller University Jena, 07745 Jena, Germany — [2]Mahidol University, Bangkok 10400, Thailand

Single-photon emitters in solid-state systems have received a lot of attention as building blocks for numerous quantum technology applications. Defect-based single-photon emitters in hexagonal boron nitride (hBN) stand out due to their optical and physical properties, such as room temperature operation and high single photon luminosity. However, the localized fabrication of these emitters in the crystal lattice is still not very well understood and thus the integration with optical and electronic platforms remains challenging. In the present work, we demonstrate the localized fabrication of emitters by electron beam irradiation using a scanning electron microscope with sub-micron lateral precision. Density functional theory calculations, coupled with experimentally observed emission lines at 575 nm show that the emitters are related to the presence of carbon-based defects, which are activated by the electron beam interaction. We also present results on correlating crystal structure properties and polarization dynamics. Our results indicate that these emitters have a high fabrication yield of identical emitters, which is a crucial advantage for the realization of quantum integrated devices.

QI 31.4 Thu 15:30 E214

Fingerprinting color centers in hexagonal boron nitride — •Chanaprom Cholsuk[1], Sujin Suwanna[2], and Tobias Vogl[1] — [1]Abbe Center of Photonics, Institute of Applied Physics, Friedrich-Schiller-University, Albert-Einstein-Straße 15, 07745 Jena — [2]Optical and Quantum Physics Laboratory, Department of Physics, Faculty of Science, Mahidol University, Bangkok, 10400, Thailand

Optical quantum technologies promise to revolutionize today's information processing and sensing. Crucial to many quantum applications are efficient sources of pure single photons. For a quantum emitter to be used in such application, or for coupling between different quantum systems, the optical emission wavelength of the quantum emitter needs to be tailored. Here, we use density functional theory (DFT) to calculate and manipulate the transition energy of fluorescent defects in the two-dimensional hexagonal boron nitride.

Our calculations feature the HSE06 functional which accurately predicts the electronic band structures of 267 different defects. Moreover, using strain-tuning we can tailor the optical transition energies of suitable quantum emitters to precisely match those of quantum technology applications. The complete photophysical properties of the emitters including spectrum profile, Huang-Rhys factor, radiative and non-radiative lifetime, quantum efficiency, and excitation and emission dipoles are also revealed. We thereby not only have a promising pathway for tailoring quantum emitters that can couple to other solid-state qubit systems but also get access to the complete fingerprint of the emitters for identifying the defect structure of the emitters.

QI 31.5 Thu 15:45 E214

Will a single two-level atom simultaneously scatter two photons? — •Luke Masters, Xinxin Hu, Martin Cordier, Gabriele Maron, Lucas Pache, Arno Rauschenbeutel, Max Schemmer, and Jürgen Volz — Department of Physics, Humboldt Universität zu Berlin, 10099 Berlin, Germany

The interaction of light with a single two-level emitter is the most fundamental process in quantum optics, and is key to many quantum applications. As a distinctive feature, two photons are never detected simultaneously in the light scattered by the emitter. This is commonly interpreted by saying that a single two-level quantum emitter can only absorb and emit single photons. However, it has been theoretically proposed that the photon anti-correlations can be thought to arise from quantum interference between two possible two-photon scattering amplitudes, which one refers to as coherent and incoherent. This picture is in stark contrast to the aforementioned one, in that it assumes that the atom even has two different mechanisms at its disposal to scatter two photons at the same time. Here, we validate the interference picture by experimentally verifying the 40-year-old conjecture that, by spectrally rejecting only the coherent component of the fluorescence light of a single two-level atom, the remaining light consists of photon pairs that have been simultaneously scattered by the atom. Our results offer fundamental insights into the quantum-mechanical interaction between light and matter and open up novel approaches for the generation of highly non-classical light fields.

QI 31.6 Thu 16:00 E214

Multi-channel waveguide-integrated single photon sources — •Chaiyasit Nenbangkaeo, Alexander Eich, Tobias Spiekermann, and Carsten Schuck — Institute of Physics, University of Münster, Germany

Integrated quantum photonic technology requires large numbers of single quantum emitters. While single-emitter systems have successfully been embedded into nanophotonic waveguides [1], the integration of larger numbers of single-photon sources into complex photonic circuits has remained a challenge. Here we show a novel approach that allows for simultaneously coupling single-photons from several independent colloidal quantum dots into tantalum pentoxide waveguides (Ta2O5). We employ a lithographic technique that probabilistically inserts quantum dots into a waveguide array and then deterministically remove multi-emitter systems until only a single-emitter per waveguide channel remains, thus achieving high-yield integration of single-photon sources across multiple nanophotonic channels. We demonstrate the feasibility of our method with autocorrelation measurements, showing anti-bunching of quantum dot photoluminescence for each individual channel. Our work paves the way for deterministically equipping photonic integrated circuits with large numbers of single-photon sources benefitting a wide range of applications in quantum technology.

[1] Eich, Alexander, et al., ACS Photonics 2022 9 (2), 551-558

QI 31.7 Thu 16:15 E214

Photoluminescence Excitation Characteristics of Color Centers in hBN at Room Temperature — •Pablo Tieben[1,2], Hiren Dobariya[2], Nora Bahrami[1,2], and Andreas W. Schell[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Gottfried Wilhelm Leibniz Universität, Hannover, Germany

In the rapidly developing field of quantum technologies single photons play an important role for a number of applications. Optically active color centers in hexagonal boron nitride (hBN) are of particular interest as they exhibit bright single photon emission over a broad range as well as narrow linewidths at and even well above room temperature. Furthermore, as a solid-state single photon source, these emitters can be reliably integrated into photonic circuits and thus offer a large advantage in terms of scalability. A dependency of the fluorescence emission of single emitters on the excitation wavelength has been observed recently, implying a more complex level structure. Systematic measurements of this dependency could reveal more information about the underlying energy levels and thus atomic structure of these defects. Particularly interesting are patterns in the separation between excited states for a classification of different types of emitters. We perform spectroscopic measurements while varying the excitation wavelength over a large range to gain further insight into their characteristic properties and energy level schemes. By analysis of the excitation spectrum of individual defects, we are extracting information on the distribution of energetic transitions across a large number of emitters.