Q 53: Nano-Optics II

Time: Thursday 14:00–16:15 Location: Q-H11

Q 53.1 Thu 14:00 Q-H11

Spectral stability of nitrogen-vacancy defect centers in diamond nanostructures — •Laura Orphal-Kobin[1], Kilian Unterguggenberger[1], Tommaso Pregnolato[1,2], Natalia Kemf[2], Mathias Mattala[2], Ralph-Stephan Unger[2], Ina Ostermay[2], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institute, Berlin, Germany

Coherent photons are an important resource for many quantum applications, for example, in long-distant quantum networks stationary qubits can be entangled by photon-mediated protocols. In solid-state systems, noise in the environment of a quantum emitter, such as fluctuations of the local charge density, lead to a change of the optical transition frequency over time and therefore to inhomogeneous broadening, which is referred to as spectral diffusion. Overcoming spectral diffusion is still a major challenge for solid-state quantum emitters and limits the generation of indistinguishable single photons.

In our work, we investigate the spectral properties of NV defect centers in diamond nanostructures by performing photoluminescence excitation measurements. We analyze the impact of different excitation parameters on the optical linewidth and spectral dynamics of the NV zero-phonon-line. Moreover, excitation power and energy-dependent measurements combined with nanoscopic Monte Carlo simulations provide fundamental insights, relating the spectral properties of the NV to its charge environment. Based on our results, we propose a protocol for entanglement generation using NVs in nanostructures.

Q 53.2 Thu 14:15 Q-H11

Improving the purity of single photon emission from SnV^- centers in diamond — •Philipp Fuchs[1], Johannes Görlitz[1], Michael Kieschnick[2], Jan Meijer[2], and Christoph Becher[1] — [1]Universität des Saarlandes, Fachrichtung Physik, Campus E2.6, 66123 Saarbrücken, Germany — [2]Universität Leipzig, Angewandte Quantensysteme, Linnéstraße 5, 04103 Leipzig, Germany

Color centers in diamond have been demonstrated to be versatile systems that can be used as quantum sensors, long-living qubits, and single photon sources. However, their performance is often limited by imperfections from fabrication. For the negatively-charged tin vacancy center (SnV^-) in diamond, we found the ion implantation in combination with the subsequent annealing to induce severe surface and subsurface damage, leading to strongly fluctuating background fluorescence. This uncorrelated fluorescence reproducibly limits the achievable single photon purity of SnV^- centers created via ion implantation.

We demonstrate that a simple thermal oxidation process enables us to significantly reduce this damage and by this the background fluorescence, yielding a strongly enhanced single photon purity. We propose that the fluctuating background fluorescence originates from unoccupied surface states that become depleted after the thermal oxidation induces a proper surface termination. Finally, we distill all information from these and earlier experiments to a simple rate equation model, that helps gaining new insights into the charge stability and quantum efficiency of SnV^- centers in diamond.

Q 53.3 Thu 14:30 Q-H11

Experimental and theoretical investigation on spin-optical dynamics of silicon vacancy centers in silicon carbide — •Di Liu[1,2], Naoya Morioka[3], Öney Soykal[4], Nguyen Tien Son[5], Jawad Ul-Hassan[5], Florian Kaiser[1,2], and Jörg Wrachtrup[1,2] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]Institute for Quantum Science and Technology (IQST), Germany — [3]Institute for Chemical Research, Kyoto University, Japan — [4]Booz Allen Hamilton, McLean, VA, USA — [5]Department of Physics, Chemistry, and Biology, Linköping University, Sweden

Silicon vacancy centers (V_{Si}) in silicon carbide are promising spin-based quantum emitters for quantum information applications owing to their excellent spin-optical properties. Yet, the internal spin-optical dynamics of V_{Si} centers remains poorly understood, mainly due to the intrinsic limitations of $g^{(2)}$ measurements. In this work, we present a high-accuracy study of the electronic fine structure of V_{Si} including all interaction mechanisms. Our results are based on a new set of resonant and above-resonant excitation schemes in the high-power regime offering excellent data quality. Our results are confirmed by theory based on quantum mater equations. We also estimate the system's quantum efficiency with measured rates. In summary, our work provides an in-depth understanding of silicon vacancy centers' spin-optical dynamics and assists optimum designing of nanophotonic enhancement structures which play an important role in scalable quantum applications.

Q 53.4 Thu 14:45 Q-H11

Colloidal quantum dots as integrated single photon sources — •Alexander Eich, Tobias Spiekermann, Helge Gehring, Lisa Sommer, Julian Bankwitz, Wolfram Pernice, and Carsten Schuck — Institute of physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

The integration of nano-scale quantum emitters with photonic integrated circuits holds great promise for realizing a scalable quantum technology platform. However, interfacing large numbers of independently controllable single emitter systems efficiently with nanophotonic structures for quantum technologies is a major challenge.

In our work, we employ colloidal quantum dots as single photon emitter system that can be processed in solution at wafer-scale. We embed such quantum dots into tantalum pentoxide (Ta2O5) nanophotonic waveguides by utilizing lithographically patterned apertures in polymer thin-films that achieve high overlay accuracy with nanophotonic devices. We further employ broad-band polymer coupling structures produced in 3D direct laser writing 1 as fiber-chip interconnects and demonstrate anti-bunching behavior for the photoluminescence collected from waveguide-integrated quantum dots 2. Our work paves the way towards large-scale integration of quantum light sources into photonic integrated circuits. [1] Gehring, Helge, et al., Optics letters 44.20 (2019): 5089-5092. [2] Eich, Alexander, et al, arXiv preprint arXiv:2104.11830 (2021).

Q 53.5 Thu 15:00 Q-H11

Coherent control of group-4 vacancies in diamond for the purpose of cluster state creation — •Gregor Pieplow, Joseph H. D. Munns, Mariano I. Monsalve, and Tim Schröder — Department of Physics, Humboldt-Universität zu Berlin, Germany

One of the biggest challenges in measurement-based photonic quantum computation is the creation of 2d-cluster states, a type of highly entangled resource state. Cluster states enable quantum computation through purely local operations and measurements on the individual qubits that make up the state. Crucially, measurement-based quantum computation does not require additional entangling operations, because entanglement is already present in the resource state. The difficulty in entangling individual photons is thus separated from the details of the computation and can be studied in isolation. In this contribution we address the generation of a linear cluster state with group-4 vacancies such as the Silicon Vacancy (SiV) and Tin Vacancy (SnV) in diamond. An emission-based scheme for the generation of a linear cluster state on a group-4 vacancy platform requires local control operations and Purcell enhancement. This work explores local gate operations with a Raman scheme and addresses additional challenges that arise when Purcell enhancement is introduced.

Q 53.6 Thu 15:15 Q-H11

Electrical excitation of color centers in phosphorus-doped diamond Schottky diodes — •Florian Sledz[1], Igor A. Khramtsov[2], Assegid M. Flatae[1], Stefano Lagomarsino[1], Navid Soltani[1], Shannon S. Nicley[3], Ken Haenen[3], Jin Qun[4], Xin Jiang[4], Paul Kienitz[5], Peter Haring Bolivar[5], Dmitry Yu. Fedyanin[2], and Mario Agio[1] — [1]Laboratory of Nano-Optics, University of Siegen, Siegen Germany — [2]Laboratory of Nanooptics and Plasmonics, Moscow Institute of Physics and Technology, Dolgoprudny Russian Federation — [3]Institute for Materials Research (IMO) & IMOMEC, Hasselt University & IMEC vzw, Diepenbeek, Belgium — [4]Institute of Materials Engineering, University of Siegen, Siegen Germany — [5]Institute of Graphene-based Nanotechnology, University of Siegen, Siegen Germany

A robust single-photon source operating upon electrical injection at ambient condition is desirable for quantum technologies. Silicon-vacancy color centers in diamond are promising candidates as their emission is concentrated in a narrow zero-phonon line with a short

excited-state lifetime of ≈ 1 ns. Under optical excitation we observed single silicon-vacancy color centers in n-type diamond [1]. In contrast to common approaches based on p-n or p-i-n structures, we developed an approach for the electrical excitation based on color centers in a Schottky barrier diode. This paves the way for the predicted bright luminescence of electrically driven color centers in diamond [2]. Ref.: [1]. Flatae et al Diam. Relat. Mater. 105, 107797 (2020). [2]. Fedyanin and Agio, New J. Phys. 18, 073012 (2016).

Q 53.7 Thu 15:30 Q-H11

Direct Measurement of Emission Probabilities in Single Photon Emitters — •Pablo Tieben[1,2] and Andreas W. Schell[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Gottfried Wilhelm Leibniz Universität, Hannover, Germany

Single photon sources are an essential part in the development of a number of quantum technologies. Understanding the intrinsic properties of new sources of single photons is paramount for their successful application. One of the key properties, among others, is their saturation behavior in terms of the ratio of the number of excitation photons to the number of emitted photons. Especially for photoactive defect centers in semiconductors, the existence of intermediate dark states has been shown, which leads to a shelving effect at high excitation powers. To circumvent this limitation of the photon yield, a repumping from these long lived states can be implemented via two-color excitation, where the second wavelength is matched to the transition energy between the intermediate and the excited state. We report on a measurement technique to directly determine the excitation probability as a function of the pulse intensity by using a tunable, strongly fluctuating, pulsed source of laser light and performing time correlated measurements between the pulse intensity and the photon count events in a synchronized time basis. Furthermore, we apply this scheme to two-color excitation measurements of single photon emitters in hexagonal boron nitride (hBN) to simultaneously retrieve saturation functions over the two dimensional parameter space of wavelength dependent excitation power.

Q 53.8 Thu 15:45 Q-H11

Purcell effect and strong extinction observed on a single molecule coupled to a chip-based micro-resonator — •Dominik Rattenbacher[1,2], Alexey Shkarin[1], Jan Renger[1], Tobias Utikal[2], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich Alexander University, Erlangen, Germany

Coupling organic molecules to integrated optical circuits is a promising route to creating compact and controlled ensembles of interacting quantum emitters. We present our recent advances in realizing such an experimental platform based on sub-wavelength waveguides (nanoguides) and micro-resonators on a chip. We demonstrate the coupling of single molecules to linear nanoguides [1,2] and the control of the resonance frequencies via integrated microelectrodes [2,3]. Since the coupling efficiency between the molecule and the nanoguide is inherently limited by geometric and material constraints, we employed different host matrices and discuss various resonator designs to enhance the coupling. We demonstrate a resonator finesse up to 250 ($Q = 16000$), leading to significant Purcell enhancement and extinction dips of 60 % [3]. Furthermore, we show the controlled manipulation and tuning of molecular resonances, leading to the simultaneous coupling of two individual molecules to well-defined resonator modes [3].

[1] D. Rattenbacher et al., New J. Phys. 21, 062002 (2019)
[2] A. Shkarin et al., Phys. Rev. Lett. 126, 133602 (2021)
[3] D. Rattenbacher, A. Shkarin et al., in progress

Q 53.9 Thu 16:00 Q-H11

Photoelectrical imaging of the dark state of SiV in diamond — •Ilia Chuprina[1], Milos Nesladek[2], Adam Gali[3], Petr Siyushev[1], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, Ulm University, D-89081 Germany — [2]Institute for Materials Research (IMO), Hasselt University, Wetenschapspark 1, 3590 Diepenbeek, Belgium — [3]Wigner Research Centre for Physics, P.O. Box 49, H-1525, Budapest, Hungary

Group-IV defects in diamond are promising candidates for quantum information processing. Among them, silicon-vacancy (SiV) is the most studied one, and yet, many questions remain, particularly about optimization of the creation yield, stabilization in different charge states, etc. Recently, a developed photoelectrical imaging technique might be a powerful tool to unravel some of that questions. In this work, we present our recent results on the charge dynamics of SiV centers in diamond using optical and photoelectrical detection technics. Exploiting photoelectrical measurements, we visualize optically inactive defects, which can be turned on and off upon applying a different bias voltage to the electrodes. Using a combination of photoluminescence spectroscopy and photoelectrical imaging, we attribute these dark defects to another SiV charge state and discuss possible models of charge state dynamics. This behavior can be fairly extended to the whole family of the group-IV defects in diamond. Our findings might be useful for the development of the active charge state control of the group-IV defects.