Q 6: Solid State Quantum Optics I

Time: Monday 11:00–13:00 Location: HS 3118

Q 6.1 Mon 11:00 HS 3118

Spin properties of erbium dopants in nanophotonic silicon waveguides — •Kilian Sandholzer, Stephan Rinner, Kilian Baumann, Adrian Holzäpfel, Andreas Gritsch, and Andreas Reiserer — Technical University of Munich, Munich Center for Quantum Science and Technology, and Max Planck Institute for Quantum Optics, Garching, Germany

The optical transitions of 4f-electrons in implanted erbium ions are in the telecommunication range making this solid-state system well suited for quantum networks. The incorporation in silicon allows us to use industrial nanofabrication to shape the optical properties of the erbium ions via photonic mode engineering. Our implantation and annealing recipe provide reproducible site integration with promising spin properties of the erbium 4f-electrons. The crystal field splits the lowest spin-degenerate electronic state by 2.6 THz and 2.4 THz in the ground and excited state manifold, respectively, creating two optically coupled isolated effective spin-1/2 systems. We measure the strength and orientation of the effective g-tensors by spectroscopy of a rotating sample in an external magnetic field. Furthermore, the lifetime of the ground-state electron spin is measured using spectral hole burning in dependence of temperature and magnetic field. We find a lower bound of 1 s for the spin lifetime at temperatures below 4.5 K and observe an Orbach-type suppression at higher temperatures. These spin properties are measured on commercially fabricated samples[1] promising easy scalability of this quantum spin-photon interface.

[1] S. Rinner et al., *Nanophotonics* **12**, 3455, (2023)

Q 6.2 Mon 11:15 HS 3118

Design of a high-speed graphene optical modulator on Si3N4 platform for on-chip communication — •Ashraful Islam Raju[1], Pawan Kumar Dubey[1], Rasuole Lukose[1], Christian Wenger[1,2], Andreas Mai[1,3], and Mindaugas Lukosius[1] — [1]IHP-Leibniz Institut für innovative Mikroelektronik, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]BTU Cottbus Senftenberg, Platz der Deutschen Einheit 1, 03046 Cottbus, Germany — [3]Technical University of Applied Science, Hochschulring 1, 15745 Wildau, Germany

Electro-absorption (EA) optical modulator is essential for the advancement of on-chip optical signal processing. While silicon-photonics is a prime candidate, graphene photonics has garnered significant attention due to its remarkable electrical and optical properties. Graphene modulators typically use silicon-on-insulator (SOI) platforms, but Silicon-nitride on-silicon-dioxide (Si3N4-on-SiO2) is emerging as a promising alternative with low optical losses and wide compatibility. Despite potential advantages, achieving both high-speed and large modulation efficiencies simultaneously in a single graphene-based device has been challenging. To address this, we designed and simulated a waveguide-coupled double-layer graphene EA modulator on the Si3N4-on-SiO2 platform. We conducted detailed simulations to optimize waveguide dimensions, optical modes, and graphene layer spacing for optimum device performance. Simulation shows a 140 GHz bandwidth, 35 dB extinction ratio (equivalent to a 0.16 dB/um modulation depth), and a low 1.1 dB insertion loss at a wavelength of λ=1550 nm.

Q 6.3 Mon 11:30 HS 3118

An ultra-broadband, integrated mid-infrared photon pair source — •Abira Gnanavel, Franz Roeder, René Pollmann, Olga Brecht, Christof Eigner, Laura Padberg, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Broadband photon-pairs from parametric down-conversion (PDC) are of interest for spectroscopy at low light levels and applications such as quantum optical coherence tomography or entangled two-photon absorption.

Here, we present a type II PDC source realised in a 40 mm long in-house fabricated, dispersion engineered periodically poled Ti:$LiNbO_3$ waveguide yielding ultra-broadband, non-degenerate photon pairs with photons in the near-infrared and mid-infrared regime. A broad spectrum is achieved by matching both group velocities and group velocity dispersion of the signal and idler photons centered at 850 nm and 2800 nm, respectively. The spectral bandwidth of the photons exceeds 23 THz when pumping with a low-cost cw laser diode. A higher bandwidth in the frequency domain results in tighter correlations in the time domain and thus an increased photon simultaneity. This is especially desirable for ultrafast spectroscopy applications because it enables better measurement precision. We present first measurement results of the generated PDC light which are in high correspondence with the simulations.

Q 6.4 Mon 11:45 HS 3118

Trapping of Nanodiamonds using Optical Tweezers — •Alena Erlenbach, Isabel Cardoso Barbosa, Jonas Gutsche, Stefan Dix, Dennis Lönard, and Artur Widera — Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern-Landau, Erwin-Schroedinger-Str. 46, 67663 Kaiserslautern, Germany

The nitrogen-vacancy-center (NV) in diamond is a promising nanoprobe for measuring temperature and magnetic fields, for which they are incorporated into photonic structures such as waveguides. To optimize the excitation of the NV centers and the detection of their fluorescence through the photonic structure, it is necessary to control the nanodiamonds positions during the fabrication process precisely. Therefore, an optical-tweezer-setup can be incorporated into structuring systems to control the position of the nanodiamonds. In this work, we examine the trapping of nanodiamonds in optical tweezers to quantify the influence of different parameters for trapping, particularly the size of the nanodiamonds. Statistical measurements of nanodiamonds in different solvents reflect that trapping is more efficient for smaller particles. This observation agrees with a simple model considering the contributions of gradient and scattering forces. Furthermore, first nanoparticles were trapped in different solvents, suitable for mixing with photoresists needed to fabricate photonic structures. The results show initial requirements for positioning nanodiamonds in solutions prior to fabricate photonic structures with integrated NV centers.

Q 6.5 Mon 12:00 HS 3118

Pulse shaping approaches for quantum dot coherent control — •Vikas Remesh[1], Florian Kappe[1], Yusuf Karli[1], Ria Kraemer[2], Thomas Bracht[3], Armando Rastelli[4], Doris Reiter[3], Stefan Nolte[2], and Gregor Weihs[1] — [1]Institute für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria — [2]Abbe Center of Photonics, Friedrich Schiller University Jena, Germany — [3]Condensed Matter Theory, Department of Physics, TU Dortmund, Germany — [4]Johannes Kepler University Linz, Linz, Austria

Shaped laser pulses have been remarkably effective in investigating and controlling various light-matter interactions spanning a broad area of research. In quantum technologies, the techniques to shape complex spatiotemporal waveforms have found renewed interest, for instance in coherent control of quantum dots [1] and spectrotemporal mode shaping in parametric amplification and so on. In this talk, I will navigate through the impact of pulse shaping techniques in nanospectroscopy and how it enabled efficient preparation schemes in quantum dots, based on our recent works [2]. Afterwards, I will conclude with my vision on the future scope of nanophotonics-assisted-quantum technology roadmap. [1] Photonic Quantum Technologies: Science and Applications 1, 53 (2023) [2] Nano Letters 22, 6567 (2022), Materials for Quantum Technology 3, 025006 (2023), APL Photonics 8, 101301 (2023)

Q 6.6 Mon 12:15 HS 3118

Niobium-based plasmonic superconducting photodetectors for near- and mid-IR up to 12 μm — •Sandra Mennle, Philipp Karl, Monika Ubl, Ksenia Weber, Pavel Ruchka, Philipp Flad, Mario Hentschel, and Harald Giessen — 4th Physics Institute, Research Center SCoPE, and IQST, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Photon-based applications such as quantum technologies have become an important field of research, which requires fast and reliable detectors. Moreover, applications in the mid-IR like spectroscopy are in need for highly efficient photodetection. Superconducting nanowire photon detectors feature a great potential due to their high efficiency and sensitivity.

To enhance the absorption at larger wavelengths in the IR spectral range, a plasmonic perfect absorber geometry is used, which utilizes an

impedance-matched plasmonic resonance in combination with a spacer layer and a reflector.

In this work we present detectors which reach an absorption of over 95% for wavelengths up to 4 μm and demonstrate nanostructures with 90% absorption in the 8-12 μm spectral range. By design, these plasmonic resonances feature a large bandwidth and with simple changes of the geometry the resonance can be easily tuned over a wide spectral range. Another advantage of the plasmonic approach is large angle independence, thus high-NA optics can be used to decrease the spot size, resulting in even smaller detector areas and therefore faster response.

Q 6.7 Mon 12:30 HS 3118

Towards ultra-small superconducting Nb-based plasmonic fiber coupled photodetectors arrays — •Philipp Karl, Sandra Mennle, Monika Ubl, Ksenia Weber, Pavel Ruchka, Mario Hentschel, Philipp Flad, and Harald Giessen — 4th Physics Institute, Research Center SCoPE, and IQST, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Quantum technologies require high-quality and efficient photodetectors and the ability to detect single photons, which can be provided by superconducting nanowire single photon detectors.

We present a superconducting niobium-based plasmonic perfect absorber detector and with near-100% absorption efficiency in the near-infrared spectral range.

To reach the near-100% absorption over a wide spectral range, we take advantage of resonant plasmonic perfect absorber effects and their high resonant absorption cross-section, to enable ultra-small active areas and short recovery times.

To ensure the perfect coupling, we utilize directly coupled single mode fibers in combination with high NA micro optics, which are printed onto the fibers.

With this knowledge, we demonstrate a scalable pixel detector design, which inherits all the previous excellent detector properties.

Q 6.8 Mon 12:45 HS 3118

Direct measurement of coherent light proportion from a laser source without spectral filtering — •Xi Jie Yeo[1], Eva Ernst[1], Alvin Leow[1], Lijiong Shen[1], Jaesuk Hwang[1], Christian Kurtsiefer[1,2], and Peng Kian Tan[1] — [1]Centre for Quantum Technologies, Singapore, Singapore — [2]National University of Singapore, Singapore, Singapore

We present a method to measure the fraction of coherent light emitted by a practical laser source, using interferometric photon correlations; correlations between photoevents detected at the output ports of an asymmetric Mach-Zehnder interferometer. Using this technique, we characterize the fraction of coherent light emitted by a laser diode transiting across its lasing threshold.