Q 27: Quantum Optics III

Time: Wednesday 11:00–13:00 Location: f342

Q 27.1 Wed 11:00 f342

Waveguide Integrated Superconducting Single-Photon Detector Array for Ultra-Fast Quantum Optics Experiments — •Martin A. Wolff[1,2], Fabian Beutel[1], Wladick Hartmann[1], Matthias Häussler[1], Helge Gehring[1], Robin Stegmüller[1], Nicolai Walter[1], Wolfram Pernice[1], and Carsten Schuck[1] — [1]Physics Institute, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]martin.wolff@wwu.de

Superconducting nanowire single-photon detectors (SNSPDs) have developed into a leading sensor technology for ultraviolet to mid-infrared light as they offer efficient photon-counting with high repetition rate, short timing jitter and low dark count rates [1]. The integration of these detectors with wideband transparent Si3N4 nanophotonic waveguides on silicon chips [2] enables novel functionality for quantum optics experiments through circuit configurability and superior sensing performance. Here we present progress towards realizing a massively parallelized system for ultra-fast single-photon detection. Our current chip comprises 16 SNSPDs fabricated from NbTiN thin-films on Si3N4 waveguides showing a fabrication yield of $> 90\%$. We realize efficient interfaces between the detectors on the chip and multiple optical fiber channels as low-loss and broadband out-of-plane couplers produced in 3D direct laser writing [3], therewith significantly widening the application space for waveguide-integrated SNSPDs, e.g. for high-bandwidth quantum key distribution with high system detection efficiency. [1] Nanophotonics, 7, 1725 (2018) [2] Appl. Phys. Lett., 102, 051101 (2013) [3] Opt. Lett. 44, 5089 (2019)

Q 27.2 Wed 11:15 f342

Characterization and Detector Tomography of Multi-Element Superconducting Single Photon Detectors — •Timon Schapeler[1], Johannes Tiedau[2], Christine Silberhorn[2], and Tim Bartley[1] — [1]Mesoskopische Quantenoptik, Department Physik, Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [2]Integrierte Quantenoptik, Department Physik, Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

Single photon detection is the basis of many applications in quantum optical technology. Increasingly, arrays of superconducting nanowire single-photon detectors (SNSPDs) are used, exploiting their high efficiency, low noise and fast recovery time. We demonstrate one way to characterize the photon statistics arising from four-element SNSPDs in terms of their detection efficiency. By a comparison of experimental data of a commercial four-pixel device and a theoretical model, we were able to account for the individual detection efficiencies of each pixel. Furthermore, we can use the statistics obtained for a multi-element device in response to known input states to perform detector tomography, thereby providing a fully quantum mechanical description of our measurement device.

Q 27.3 Wed 11:30 f342

Amorphous superconducting nanowire single-photon detectors integrated with nanophotonic waveguides — •Matthias Häussler[1], Mikhail Mikhailov[2], Martin A. Wolff[1], and Carsten Schuck[1] — [1]Institute of Physics and Center for Nanotechnology, University of Münster, D-48149 Münster, Germany — [2]B. Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, 61103 Kharkiv, Ukraine

Waveguide-integrated superconducting-nanowire single photon detectors (SNSPDs) are a highly promising detector technology to enable complex integrated quantum photonic experiments. While SNSPDs offer very attractive performance characteristics, current material systems only achieve limited fabrication yield, thus preventing large-scale implementations.

Here we show that waveguide-integrated SNSPDs can be realized from amorphous superconducting thin films, which promise highly reproducible nanowire fabrication because of their inherent insensitivity to the substrate material. We develop a multi-layer lithography process for patterning molybdenum silicide nanowires in travelling-wave geometry on silicon-nitride waveguides. The resulting detectors show a saturated on-chip detection efficiency of 73 % for 1550 nm wavelength photons at a temperature of 2.1 K. We further find a reset time below 5 ns allowing for high detection rates in the range of several hundred MHz. Our results pave the way for in-depth studies of fabrication yield and performance of amorphous SNSPDs integrated in large numbers on a wide range of photonic platforms.

Q 27.4 Wed 11:45 f342

Microwave cavity-free hole burning spectroscopy of Er^{3+}:Y_2SiO_5 at sub-Kelvin temperatures — •Nadezhda Kukharchyk[1], Anton Mladenov[1], Natalya Pankratova[2], Dmitriy Sholokhov[1], Alexey A. Kalachev[3], Sebastian Probst[4], Vladimir Manucharyan[2], and Pavel A. Bushev[1,5] — [1]Experimentalphysik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Department of Physics, Joint Quantum Institute and Center for Nanophysics and Advanced Materials, University of Maryland, College Park, MD 20742, USA — [3]RFC Kazan Scientific Center of RAS, 420029 Kazan, Russian Federation — [4]Quantronics group, SPEC, CEA, CNRS, Universite Paris-Saclay, CEA Saclay 91191 Gif-sur-Yvette Cedex, France — [5]JARA-Institute for Quantum Information (PGI-11), Forschungszentrum Jülich, 52428 Jülich, Germany

Spectral hole burning technique is well-deployed in optical inhomogeneously broaden medium for realization of slow light and optical memory based on atomic frequency combs. First implementation of this technique into the microwave regime has been recently demonstrated with NV-centers coupled to a cavity [1]. Here, we develop this idea by applying spectral hole burning technique to Erbium spin ensemble in a cavity-free regime. We investigate Erbium-doped Y_2SiO_5 crystal coupled to a superconducting transmission line. Here, we show the influence of the magnetic field and temperature on the dynamics of the attained spectral hole and discuss processes governing it. [1] Putz, S., Angerer, A., Krimer, D. et al. Nature Photon **11**, 36-39 (2017)

Q 27.5 Wed 12:00 f342

Enhancing magnetic resonance via quantum optimal control — •Marco Rossignolo[1,2], Peter Höfer[3], Patrick Carl[3], Ressa S. Said[1], Tommaso Calarco[4], Fedor Jelezko[1], and Simone Montangero[2] — [1]Institute for Quantum Optics and Center for Integrated Quantum Science and Technology, Universität Ulm, D-89081 Ulm — [2]Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, I-35131 Padova — [3]Bruker BioSpin, Silberstreifen 4, D-76287 Rheinstetten — [4]Institute for Quantum Control, Peter Grünberg Institut 8, Forschungszentrum Jülich GmbH, D-52525 Jülich

Electron Paramagnetic Resonance (EPR) is the technology that provides you the possibility to study the materials by exploring the internal structure and interactions between atoms and molecules via microwave fields. Exploiting particular pulse sequence schemes one can in principle decouple the system under investigation from the surrounding environment. Due to the inhomogeneities in the material, standard rectangular pulses could not work as expected and a clear view of the physics could be compromised. Here we show that by shaping the control time-dependent pulses via Optimal Control the intensity of the dominating signal has been increased in basic pulse sequences. Moreover, we enhanced furthermore the intallows of the signal, in a remote closed-loop optimization, that is, exploding the experiment feedback. This allows us to take into account unexpected sources of ntestedd perform calibration according to unknown properties of the physical system. The aforementioned results are tested for relevant industrial applications in collaboration with Bruker BioSpin.

Q 27.6 Wed 12:15 f342

Demonstration of Coherent Multitone Microwave Sequences for Simultaneous Control of all Electronic Ground States of the Nitrogen-Vacancy Center in Diamond — •Florian Böhm, Niko Nikolay, Sascha Neinert, Bernd Sontheimer, and Oliver Benson — Institut für Physik & IRIS Adlershof, Humboldt-Universität zu Berlin, Germany

The nitrogen-vacancy (NV) center in diamond is the most prominent defect in diamond due to its outstanding properties as a quantum light source and its manipulable electron spin which can easily be read-out optically. NV applications range from quantum information processing to high sensitivity nano-magnetometry [1].

In our work we explore the possibility of applying multitone microwave pulses, allowing a full simultaneous control of all three electronic ground states of the NV center. This here presented spin manipulation scheme opens up new measurement possibilities. For example spin echo techniques operating on a superposition state including all three ground states could be used to increase the NV center's magnetic field sensitivity.

After investigating the spin-forbidden coherent population swapping between the ms = -1 and ms = +1 states, without undergoing the spin allowed transition into the ms = 0 state via microwave Raman transitions we also assess if more complex multitone pulse sequences could be suitable for an enhanced magnetic field sensing.

[1] Awschalom, D. D., et al., Nat. Photonics 12.9 (2018): 516-527.

Q 27.7 Wed 12:30 f342

Purcell-Enhanced Emission from Individual Color Center in Diamond to Photonic Crystal Cavities — •Konstantin Fehler[1,2], Anna P. Ovvyan[3], Lukas Antoniuk[2], Niklas Lettner[2], Nico Gruhler[3], Valery A. Davydov[4], Viatcheslav N. Agafonov[5], Wolfram H.P. Pernice[3], and Alexander Kubanek[1,2] — [1]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Germany — [2]Institute for Quantum Optics, Ulm University, Germany — [3]Institute of Physics and Center for Nanotechnology, University of Münster, Germany — [4]L.F. Vereshchagin Institute for High Pressure Physics, Moscow 142190, Russia — [5]Universite F. Rabelais, 37200 Tours, France

Classical photonic platforms combined with quantum emitters, like the NV^- and the SiV^- center in diamond, enable for efficient quantum photonic devices. In a hybrid approach, we combine the SiV^- center in nanodiamonds with an efficient on-chip Photonic Crystal Cavity based on a Si_3N_4 photonic platform [1]. Utilizing an atomic force microscope, we developed a routine for placing and optimization of the emitter inside the mode of the cavity. For individual optical transitions of a single SiV^- center we achieved a Purcell enhancement of more than 4 [2].

[1] Fehler, Konstantin G., et al. ACS Nano 2019, 13, 6, 6891-6898.
[2] Fehler, Konstantin G., et al. arXiv:1910.06114 (2019).

Q 27.8 Wed 12:45 f342

Stochastic coherence analysis of superluminescent diodes — •Kai Hansmann and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

Superluminescent diodes are semiconductor-based opto-electronic emitters with a wide range of experimental applications. For example so-called broad-area quantum-dot superluminescent diodes (QDSLDs) can be used as light sources for ghost imaging without the necessity of external diffusers [1]. The unique coherence properties of such diodes have already been the subject of theoretical investigations from a quantum mechanical point of view [2].

We present a stochastic approach to the investigation of the temporal coherence properties of QDSLDs. For this we model the spectral emission characteristics of such diodes as a superposition of stochastically fluctuating electric fields and use numerical simulations to perform coherence investigations. The results show that the properties of this spectrally broadband emitter with large intensity output can be investigated from a quantum mechanical and stochastic point of view equivalently.

[1] S. Hartmann et al.. A novel semiconductor-based, fully incoherent amplified spontaneous emission light source for ghost imaging. *Scientific Reports*, 7:41866, 2017.
[2] S. Hartmann et al.. Tailored quantum statistics from broadband states of light. *New Journal of Physics*, 17:043039, 2015.