FM 32: Enabling Technologies: Sources of Quantum States of Light II

Time: Tuesday 14:00–16:00 Location: 1010

Invited Talk FM 32.1 Tue 14:00 1010

Next-generation single-photon sources for satellite-based quantum communication — •Tobias Vogl[1,2], Ruvi Lecamwasam[1], Ben C. Buchler[1], Yuerui Lu[1], Ping K. Lam[1], and Falk Eilenberger[2] — [1]The Australian National University, Canberra, Australia — [2]Friedrich-Schiller-Universität, Jena, Germany

Color centers in solid state crystals have become a frequently used system for single-photon generation, advancing the development of integrated photonic devices for quantum optics and quantum communication applications. Recently, defects hosted by two-dimensional (2D) hexagonal boron nitride (hBN) attracted the attention of many researchers, due to its chemical and thermal robustness as well as high single-photon luminosity at room temperature.

Here, we present recent advances in engineering this new type of emitter. The quantum emitter is coupled with a nanophotonic cavity, improving its performance so that the single-photon source is feasible for practical quantum information processing protocols. The cavity-coupled device is characterized by an increased collection efficiency and quantum yield, combined with off-resonant noise suppression and improvement of photophysics. Moreover, the complete source, including all control units and driving electronics is implemented on a 1U CubeSat platform. An application of particular interest is satellite-based single-photon quantum key distribution. Simulations predict the performance of the source is sufficient to outperform conventional decoy state protocols, the most efficient state-of-the-art protocols for quantum cryptography.

FM 32.2 Tue 14:30 1010

Quantum efficiency measurement of single photon emitters in hexagonal Boron Nitride — •Niko Nikolay[1], Noah Mendelson[2], Ersan Özelci[1], Bernd Sontheimer[1], Florian Böhm[1], Günter Kewes[1], Milos Toth[2], Igor Aharonovich[2], and Oliver Benson[1] — [1]AG Nanooptik & IRIS Adlershof, Humboldt-Universität zu Berlin, Germany — [2]School of Mathematical and Physical Sciences, University of Technology Sydney, Australia

Single photon emitters (SPEs) in two-dimensional hexagonal Boron Nitride (hBN) are promising candidates for future sources of quantum states of light [1]. In this paper the direct and absolute measurement of the quantum efficiency (QE) of these emitters in few layers hBN is discussed [2]. In contrast to earlier approaches to determine the QE of SPEs in hBN, we use a method [2] that is independent of incomplete excitation saturation, indirect excitation paths through the yet unknown energy level system, or the detection efficiency of the setup. We used a Drexhage-type configuration and performed lifetime measurements of the SPEs as a function of their distance to a metal hemisphere attached to the tip of a Atomic Force Microscope. Two emitter families with different QEs can be identified. The highest QEs found approach 87(7) % at a zero phonon line wavelength of 580 nm.

[1] Tran, Toan Trong, et al., Nature nanotechnology 11.1 (2016): 37.
[2] Nikolay, Niko, et al., arXiv preprint arXiv:1904.08531 (2019).

FM 32.3 Tue 14:45 1010

Towards directional, ultrafast and bright single-photon sources based on color centers in diamond — •Lukas Hunold, Assegid M. Flatae, Hossam Galal, Stefano Lagomarsino, Haritha Kambalathmana, Florian Sledz, and Mario Agio — Laboratory of Nano-Optics, University of Siegen

Diamond color centers exhibit promising properties for future applications in quantum information science. For example, they have high photo-stability and narrow bandwidth at room temperature. However, their effective count-rate is still limited by non-radiative decay channels, radiation at wide angles and total internal reflection at the diamond interface.

We develop techniques to tackle these main drawbacks, mainly focused on the silicon-vacancy (SiV) color center. We create single SiV centers in a controlled manner in different diamond samples (nano-membranes, micro-membranes and bulk) in a large range of implantation fluxes and energies [1]. Position accuracy is achieved by a mask with pinholes, which enables a matrix type of implantation. We also introduce resonant plasmonic nanostructures to achieve ultrafast single-photon emission at room temperature [2] and we develop schemes for efficient electrical pumping. Finally, we show how to increase the outcoupling efficiencies of the color centers by using planar Yagi-Uda antennas [3].

References [1] S. Lagomarsino, et al., Diam. Relat. Mater. 84, 196 (2018). [2] A. M. Flatae, et al., J. Phys. Chem. Lett. 10, 11, 2874-2878 (2019). [3] H. Galal, et al., arXiv:1905.03363 (2019).

FM 32.4 Tue 15:00 1010

A cavity-based optical antenna for color centers in diamond — •Philipp Fuchs, Thomas Jung, and Christoph Becher — Universität des Saarlandes, Fakultät NT - FR Physik, Campus E2.6, 66123 Saarbrücken

Color centers in diamond, e.g. the nitrogen (NV), silicon (SiV) or recently the tin (SnV) vacancy center, have become very promising candidates for the implementation of stationary qubits in quantum communication settings. One of the most challenging problems when working with these defects is the low rate of collectible photoluminescence (PL) out of unstructured diamond material. Because of total internal reflection at the diamond-air-interface, this problem cannot be solved simply by using high NA objectives and the collectible PL rate is limited to a few percent of the total PL rate.

Here, we present a simple but efficient design of a monolithic Fabry-Pérot-cavity based on thin (< 1 μm) single crystal diamond membranes, fabricated in commercially available, high purity diamond material via reactive ion etching. By applying appropriate metallo-dielectric coatings, we enable the cavity to work as an optical antenna, enhancing both the coupling of the excitation light to the color center as well as the outcoupling of the PL, while introducing also a moderate Purcell enhancement. Saturation measurements show that the the collectible PL rate of single SnV centers can easily be increased by more than an order of magnitude for a large fraction of emitters inside the membrane compared to unstructured diamond films.

FM 32.5 Tue 15:15 1010

Towards high-dimensional quantum communication in Space — Fabian Steinlechner[1,2], Oliver de Vries[1], •Daniel Rieländer[1,3], Markus Gräfe[1], and Erik Beckert[1] — [1]Fraunhofer IOF, Jena, Germany — [2]Friedrich Schiller University Jena, Abbe Center of Photonics, Jena, Germany — [3]Current address: University of Freiburg, Freiburg, Germany

Entangled photon pairs are a fundamental resource in quantum information processing and their distribution between distant parties is a key challenge in quantum communications. Optical satellite links allow transmitting entangled photons over longer distances than currently possible on ground and could provide a path towards global-scale quantum communication networks.

A key pre-requisite towards the next generation of challenging experiments and the realization of future quantum communication networks, is the development of space-proof entangled photon sources (EPS) with high pair yield and entanglement quality.

Here, we report on the development of a power-efficient polarizationentangled photon source that can sustain the strong vibrations and thermal fluctuations of space flight and operation in space. We outline the factors that led to the baseline optical design and opto-mechanical implementation and discuss some of the critical EPS performance parameters. We outline avenues towards further improvement of EPS performance and conclude with an overview of our efforts towards exploiting high-dimensional entanglement for free-space quantum communications channels with increased capacity.

FM 32.6 Tue 15:30 1010

Efficient fiber-coupling of spectrally filtered and unfiltered photon pairs — •Tobias B. Gäbler[1,2], Marta G. Basset[1,2], Markus Gräfe[1], Juan P. Torres[3,4], and Fabian Steinlechner[1,5] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Straße 7, 07745 Jena, Germany — [2]Friedrich-Schiller-Universität Jena, Institute of Applied Physics, Max-Wien-Platz 1, 07743 Jena, Germany — [3]ICFO-Institut de Ciencies Fotoniques, 08860 Castelldefels, Spain — [4]Universitat Politecnica de Catalunya, Jordi Girona 1-3, 08034 Barcelona, Spain — [5]Friedrich Schiller University Jena, Abbe Center of Photonics, Albert-Einstein-Str. 6, 07745 Jena, Germany

Efficient coupling of photon pairs, generated by SPDC, into single spatial modes is of great relevance to studies of quantum physics and technologies. While several studies have addressed the issue of Gaussian mode coupling in SPDC, these often involved different approximations and experimental configurations, thus arriving at different conclusions.

We analyze the spatial properties of SPDC emission from periodically poled nonlinear crystals in the framework of transverse momentum. We study the impact of Gaussian beam parameters on fiber-coupling efficiency and present the results of a comprehensive series of experiments. We elaborate on trade-offs between heralding and pair-collection efficiency, in different spectral case and the dependency of pair emission rates on crystal length. These results will serve as a design guideline for ultra-efficient sources as required for quantum technologies.

FM 32.7 Tue 15:45 1010

Spectral Compression of Narrowband Single Photons — Mathias A. Seidler[1], •Xi Jie Yeo[1], Alessandro Cerè[1], and Christian Kurtsiefer[1,2] — [1]Centre for Quantum Technologies, Singapore — [2]National University of Singapore, Singapore

We present a successful experimental demonstration of a spectral compression of heralded single photons with narrow spectral bandwidth around 795 nm. The original photons are generated through four-wave mixing in a cloud of cold Rubidium-87 atoms and have a bandwidth about 3 times larger than the corresponding atomic transition. Our spectral compression method was inspired by techniques to compress ultra-fast pulses. We chose an asymmetric cavity as the dispersion medium. The design of the cavity also ensures that spectral compression can be performed, in principle, without any optical losses. Experimentally. we were able to compress the spectral bandwidth of the photons by a factor of 2.6, from 20.6 MHz to less than 8 MHz, almost matching the corresponding atomic transition linewidth of 6 MHz. The better matching of photon bandwidths allow for more efficient of photon-atom interaction, which is crucial in many applications involving quantum interfaces.