Q 5: Quantum Technologies I

Time: Monday 14:00–16:00 Location: Q-H13

Q 5.1 Mon 14:00 Q-H13

Monolithic double resonant Bragg-Cavities for efficient Second Harmonic Generation in MoS2 and WS2 — •Heiko Knopf[1,2,3], Sai Shradha[1], Fatemeh Alsadat Abtahi[1], Gia Quyet Ngo[1], Emad Najafidehaghani[4], Antony George[4], Ulrike Schulz[2], Sven Schröder[2], and Falk Eilenberger[1,2,3] — [1]Institute of Applied Physics, Abbe-Center of Photonics, Friedrich-Schiller-University, Albert-Einstein-Straße 15, 07745 Jena — [2]Fraunhofer-Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Straße 7, 07745 Jena — [3]Max Planck School of Photonics, Albert-Einstein-Straße 7, 07745 Jena — [4]Institute of Physical Chemistry, Friedrich Schiller University Jena, Lessingstraße 10, 07743 Jena

Transition metal dichalcogenides (TMDCs) are semiconducting 2D-materials with a strong second-order nonlinearity per unit thickness, making them interesting for nonlinear light-conversion devices. Due to their small thickness, an interaction enhancement is, however, required for efficient operation. Considering the dispersion of real optical layers, double-resonant monolithic Fabry-Perot systems with integrated MoS2 monolayers are designed that provide the required efficiency enhancement through resonances for both fundamental and SHG modes at λ_"FW" =800 "nm" and λ_"SHG" =400 "nm" respectively. We then report on the fabrication of such cavities, with an ion-assisted deposition process. We demonstrate enhanced second-harmonic generation and discuss possible generalization schemes.

Q 5.2 Mon 14:15 Q-H13

Maximising qubit per node in a quantum memory node using silicon vacancy color center and isotope nuclear spin in 4H-SiC — •Shravan Kumar Parthasarathy[1], Roland Nagy[2], Berwian Patrick[1], and Birgit Kallinger[1] — [1]Fraunhofer IISB — [2]FAU Erlangen

The silicon vacancy color center (V_{Si}^{-}) in 4H-SiC is examined to be a potential candidate for quantum technology applications. The experimental feasibility of realizing a quantum memory node is probed into currently by coupling the spin of VSi- in a 4H-SiC sample which is composed of electrons with that of the isotope nuclear spin (^{13}C or ^{29}Si) in the lattice. The coupling of the isotope with the color center can be utilized using a controlled rotation (CROT) pulse sequence to achieve maximal entanglement between the corresponding spins. Maximizing the isotope nuclear spin qubits entangled within one node would prove to be beneficial to the construction of a distributed quantum computing network. It is hence important to analyze how many such nuclear spins could be identified to achieve maximal entanglement. A numerical model that makes use of a protocol to identify the nuclear spin is hence constructed. The sample parameters like the concentration of the isotope and that of the experimental parameters of the microwave pulse sequence which plays a vital role are fed into the simulation and a statistical analysis is performed to understand their corresponding influence. The simulation is aimed at providing a direction on how to adjust the sample and experimental parameters to optimise the control over maximal number of qubits within one quantum memory node.

Q 5.3 Mon 14:30 Q-H13

Successful nanophotonic integration of silicon vacancy colour centres in silicon carbide — •Florian Kaiser[1], Charles Babin[1], Rainer Stöhr[1], Naoya Morioka[1,2], Tobias Linkewitz[1], Timo Steidl[1], Raphael Wörnle[1], Di Liu[1], Erik Hesselmeier[1], Vadim Vorobyov[1], Andrej Denisenko[1], Mario Hentschel[1], Christian Gobert[3], Patrick Berwian[3], Georgy V Astakhov[4], Wolfgang Knolle[5], Sridhar Majety[6], Saha Pranta[6], Marina Radulaski[6], Nguyen T Son[7], Jawad Ul-Hassan[7], and Jörg Wrachtrup[1] — [1]Universität Stuttgart — [2]Kyoto University — [3]IISB Erlangen — [4]HDZI Dresden — [5]IOM Leipzig — [6]Davis University — [7]Linköping University

We nanofabricate silicon vacancy (VSi) centres in silicon carbide (SiC) without degrading their good spin-optical properties. We show nearly lifetime limited optical lines and record spin coherence times for single defects generated via ion implantation and in SiC waveguides.

We show further controlled coupling to nearby nuclear spin qubits with fidelities of 95%. In this regard, VSi centres are unique central spins due to their high operation temperature (T=20 K). The high cooling powers of cryogenic equipment at these temperatures make it possible to directly control nuclear spins via radiofrequency drive.

This shows that VSi centres are prime candidates for developing next-generation quantum networks based on integrated quantum computational clusters with efficient spin-photon interfaces. We will also highlight how the electrical control capabilities offered by the semiconductor SiC platform will play a major role towards scalability.

Q 5.4 Mon 14:45 Q-H13

Fiber-coupled plug-and-play heralded single-photon source based on Ti:LiNbO3 and polymer technology — •Christian Kiessler[1], Harald Herrmann[1], Hauke Conradi[2], Moritz Kleinert[2], and Christine Silberhorn[1] — [1]Paderborn University, Integrated QuantumOptics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn — [2]Fraunhofer HHI, Einsteinufer 37, 10587 Berlin

The large amount of research in quantum technology has led to much progress in this field. Nevertheless, many of the experimental setups in the laboratories are very large, expensive and not robust. In order for quantum technology to take the next step and follow a success story like microelectronics, it is necessary to convert these complex meter-sized systems into millimeter-sized chips. This transition reduces size and cost, improves robustness and reproducibility and opens up the possibilty for future commercialization.
Here, we present the first chip-size plug-and-play heralded single photon source (HSPS) module based on Ti:LiNbO3 and Polymer technology. A SPDC process in a periodicly-poled Ti:LiNbO3 waveguide with a pump wavelength of 532 nm leads to signal and idler of 810 nm and 1550 nm. The chip has a size of $2 \times 1\,\mathrm{cm}^2$ and is fully fibercoupled with one pump input fiber and two output fibers for seperated signal and idler. Additional components like optical filters and heaters are integrated within the module. For $1\,\mu$W pump power we can achieve a heralded second-order correlation function of $g_h^{(2)}(0) < 0.07$ with a heralding efficiency of $\eta_h = 4\,\%$.

Q 5.5 Mon 15:00 Q-H13

Engineering of Quantum Light with Space-Time Correlations — •Fabian Schlue, Marcello Massaro, Jano Gil López, Benjamin Brecht, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Deterministic single photon sources are necessary for numerous quantum applications, e.g., quantum communication, quantum metrology, and quantum computing. To approximate a deterministic single photon source with probabilistic sources, source-multiplexing can be used. Examples are spatial multiplexing and frequency multiplexing, which both have challenges: the former requires a large resource overhead, the latter relies on fast and efficient frequency shifting of single photons, which is still an outstanding goal.

Here, we demonstrate a time-frequency multiplexing scheme. Different sources are encoded in the frequency of one photon and, simultaneously, the timing of the partner photon. Frequency-resolved detection reads out the source and low-loss electro-optic time shifting realises the routing. This requires a specially designed source. We utilize our in-house design and production capabilities to fabricate a dispersion-engineered photon-pair source. We combine this with techniques from ultrafast pulse shaping and demonstrate the operation of a tuneable, user-chosen number of multiplexed sources. This demonstration brings us one step closer to a deterministic single photon source based on multiplexing.

Q 5.6 Mon 15:15 Q-H13

Coupling function from bath density of states — •Somayyeh Nemati[1], Carsten Henkel[1], and Janet Anders[1,2] — [1]University of Potsdam, Institut für Physik und Astronomie, 14476 Potsdam, Germany. — [2]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK.

Quantum technologies face many challenges, often arising due to the unavoidable coupling of any system to its environment. Modelling of such open quantum systems requires parameters and the functional form of this coupling, which critically affects the system dynamics [1,2].

However, beyond relaxation rates, realistic parameters for specific environments or materials are rarely known.

Here [3] we present a method of inferring the coupling function between a generic system and its bosonic (e.g., phononic) environment from the experimentally measurable density of states (DOS). The DOS of the well-known Debye model for three-dimensional solids is shown to be equivalent to an Ohmic bath. We further match a real phonon DOS to a series of Lorentzian coupling functions, and determine parameters for gold, yttrium iron garnet (YIG) and iron. The results also illustrate the functional shape of memory kernels. The proposed method may predict more accurately the relaxation of spin systems that are damped by coupling to the crystal lattice.

[1] Zou H. M., Liu R., Long D., Yang J., Lin D., Phys. Scr. **95**, 085105 (2020).
[2] Anders J., Sait C. R. J., Horsley S. A. R., arXiv:2009.00600.
[3] Nemati S., Henkel C., Anders J., arXiv:2112.04001.

Q 5.7 Mon 15:30 Q-H13

Quantum science and technology with small satellites — •Tobias Vogl[1,2], Sebastian Ritter[1], Josefine Krause[1], Mostafa Abasifard[1], Heiko Knopf[1,3], and Falk Eilenberger[1,3] — [1]Institute of Applied Physics, Friedrich-Schiller-University Jena, Germany — [2]Cavendish Laboratory, University of Cambridge, United Kingdom — [3]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Germany

The maximal transmission distance of quantum states in telecom fibers is limited due to absorption. Global quantum communication therefore requires to link metropolitan fiber networks with satellites. In space-to-ground scenarios, these satellites need to be equipped with efficient and space-compatible single photon sources. Quantum emitters hosted by hexagonal boron nitride (hBN) have been proven to be a suitable candidate for single photon quantum communication, due to their high intrinsic quantum efficiency and photon purity.

Here, we present the QUICK3 space mission, where we combine a quantum emitter in hBN with integrated optics. The optical circuit is based on a laser-written waveguide, that provides the necessary compact footprint for implementation on our 3U CubeSat. The satellite verifies the full functionality of the quantum light source in orbit. Moreover, the satellite has also a quantum interferometer on board, which allows us to test certain quantum gravity models - thereby searching for physics beyond the standard model. To route the photons to the different experiments, we use active Mach-Zehnder switches in the waveguide.

Q 5.8 Mon 15:45 Q-H13

Near-infrared single photon detector with μHz dark count rate — Katharina-Sophie Isleif and •ALPS Collaboration — Deutsches-Elektronen Synchrotron DESY, Hamburg, Germany

On behalf of the ALPS Collaboration we present the use of near-infrared photon-counting technology with μHz dark count rate in the Any Light Particle Search (ALPS II) at DESY. ALPS II is a laboratory-based light shining through a wall experiment that searches for axion-like particles (ALPs). It will utilize a superconducting transition edge sensor (TES) to detect single photons at a wavelength of 1064 nm, which are converted from axion-like particles about once per day assuming an axion-photon coupling strength of $g_{a\gamma\gamma} \approx 2 \times 10^{-11}\,\mathrm{GeV}^{-1}$. To detect this weak signal, a low dark count rate, a high detection efficiency and a good energy resolution are required. We present the experimental setup of the TES and how we reach an intrinsic dark count rate of μHz by using analysis routines in the time and frequency domain. Connecting an optical fiber increases the rate by three orders of magnitude, which can be explained by blackbody radiation and can be decreased by improving the detector's energy resolution and other measures. Additionally, we present the setup for characterizing system detection efficiency using a calibrated single photon source.