Q 43: QI Poster II (joint session QI/Q)

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

Q 43.1 Wed 16:30 Empore Lichthof

New techniques to improve zero-noise extrapolation on superconducting qubits — •Kathrin Koenig[1,2], Thomas Wellens[1], and Finn Reinecke[1,2] — [1]Fraunhofer IAF, Freiburg, Germany — [2]University of Freiburg, Germany

Currently available quantum computing hardware suffers from errors due to environmental influences, nearest-neighbour interactions and imperfect gate operations. To achieve robust quantum computing, there are techniques like error mitigation by zero-noise extrapolation [1]. We propose a method for estimating the strength of the error occurring in a given quantum circuit in order to improve the result of this extrapolation. Furthermore, the impact of gate errors on observable expectation values can be reduced by noise tailoring, which converts arbitrary errors into stochastic Pauli errors [2]. Using these techniques, we elaborate on the implementation of error mitigation on a superconducting quantum computer and its impact on the computation of expectation values.

[1] He, A. et al., Zero-noise extrapolation for quantum-gate error mitigation with identity insertions, Phys. Rev. A 102, 012426 (2020)

[2] Wallman, J. J.; Emerson, J., Noise tailoring for scalable quantum computation via randomized compiling, Phys.Rev. A 94, 052325 (2016)

Q 43.2 Wed 16:30 Empore Lichthof

Introducing Non-Linear Activations into Quantum Generative Models — •Mykolas Sveistrys[1,2], Kaitlin Gili[2], and Chris Ballance[2] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, U.K.

One prominent difference between most classical generative models and current quantum ones is linearity: classical neural-network-based models require non-linear activations for quality training, while embedding such activations in quantum models is challenging due to the linearity of quantum mechanics. We introduce a quantum generative model that adds non-linear activations via a neural network structure onto the standard Born Machine framework - the Quantum Neuron Born Machine (QNBM). We utilize a previously introduced Quantum Neuron subroutine, which is a repeat-until-success circuit with mid-circuit measurements and classical control. We then compare the QNBM to the linear Quantum Circuit Born Machine (QCBM). With gradient-based training, we show that while both models can easily learn a trivial uniform probability distribution, on a more challenging class of distributions, the QNBM achieves an almost 3x smaller error rate than a QCBM with a similar number of tunable parameters. We therefore provide evidence that suggests that non-linearity is a useful resource in quantum generative models, and we put forth the QNBM as a new model with good generative performance and potential for quantum advantage.

Q 43.3 Wed 16:30 Empore Lichthof

Quantum low-precision neural networks and their classical counterparts — •Felix Soest, Konstantin Beyer, and Walter Strunz — Institut für Theoretische Physik, Technische Universität Dresden, Dresden, Germany

With increasing accessibility of quantum computing devices and the successes of classical machine learning, efforts have been made to combine the two. Whether using quantum resources can provide an advantage to trainability or generalisability remains an open question, as the size of classical neural networks is much larger than what current quantum technologies can offer. Moreover, a clear indication of a quantum advantage is usually hard to identify. An often considered ansatz is that of parametrised unitaries, where the quantum machine learning model comprises multiple layers the parameters of which are trained classically. It has recently been shown that these models have classical surrogates [1], allowing for a classical benchmark to compare these models to. However, classical feed-forward neural networks can in general not be mapped to unitaries, in part due to the lack of irreversibility. Therefore we aim to construct a framework using intermediate measurements which has a classical counterpart. The resulting network is a parametrised quantum channel that allows us to reproduce classical low-precision networks as a special case. Allowing for quantum operations in this framework extends the classical regime, providing a good benchmark.

[1] Schreiber et al. arXiv:2206.11740

Q 43.4 Wed 16:30 Empore Lichthof

Learning Quantum Processes — Kerstin Beer[1], Dmytro Bondarenko[1,2], Terry Farelly[1], Younes Javanmard[1], Tobias J. Osborne[1], Debora Ramaciotti[1], Nils Renziehausen[1], Robert Salzmann[1,3], •Viktoria-Sophie Schmiesing[1], Robin Syring[1], Nils Zolitschka[1], and Ramona Wolf[1] — [1]Institut für theoretische Physik, Leibniz Universität Hannover — [2]Stewart Blusson Quantum Matter Institute, University of British Columbia — [3]Department of Applied Mathematics and Theoretical Physics, University of Cambridge

Machine learning and quantum computing are both emerging topics of research. In this poster, we tackle the issue of learning quantum processes. To do so, we use dissipative quantum neural networks.

Q 43.5 Wed 16:30 Empore Lichthof

Exact Qubit Resonance Calibration and Power Narrowing — •Ivo Mihov and Nikolay Vitanov — Department of Physics, St Kliment Ohridski University of Sofia, 5 James Bourchier blvd, 1164 Sofia, Bulgaria

At resonance, pulse shapes do not affect the population transfer; nevertheless, pulse shapes play a vital role in shaping the resonance response curves of a qubit. The response curves react differently to Rabi frequency increases, where some exhibit power broadening (e.g. rectangular pulses) but other ones do not change their width. In this work, the experimental frequency response curves of various pulse shapes were validated against theoretical predictions. Also, the effects of symmetrical truncation of Lorentzian-shaped pulses to different degrees were examined. More significantly, a solid power narrowing pattern was observed in Lorentzian pulses.

Q 43.6 Wed 16:30 Empore Lichthof

The QuMIC project - Towards a scalable ion trap with integrated high-frequency control — •Sebastian Halama[1] and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Ion traps are a promising candidate for a scalable quantum computer [1]. A major challenge is the integration of qubit control into the device. With the microwave near-field approach [2], qubit control realized by microwave conductors that are integrated into the ion trap naturally scale with the trap itself. However, the microwave signal generation currently takes place outside of the vacuum chamber in which the ion trap is located. The QuMIC project researches and develops novel highly integrated BiCMOS chips at high frequencies and their hybrid integration with quantum electronics like ion traps. This approach enables the scalability of a quantum computer to a large number of qubits and a drastic reduction in the number of required high-frequency lines, which also benefits the cooling capabilities of the cryostat used to cool down the ion trap to around 4 K. We describe the setup of a cryogenic ion trap apparatus for rapid testing of traps, such as the ion traps with integrated microwave sources developed for QuMIC. We will report on the current status of the project.

[1] Chiaverini et al., Quantum Inf Comput **5**, 419-439 (2005)

[2] Ospelkaus et al., Phys. Rev. Lett. **101**, 090502 (2008)

Q 43.7 Wed 16:30 Empore Lichthof

Tailored based composite pulses for NV-color centers towards the realization of ensembles-based quantum tokens — •Jan Thieme, Josselin Bernardoff, Ricky-Joe Plate, and Kilian Singer — Experimentalphysik I, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel

We present numerical and experimental results of the application of tailored composite pulses [1] to shape the excitation profile addressing only selected resonances of quantum states in the system. By using analytical methods applied to the Rosen-Zener excitation model [2], we derive excitation profiles for a broadband excitation profile with respect to detuning and pulse duration. Towards this goal we are using an arbitrary waveform generator to supply these pulses to single nitrogen-vacancy color centers [3]. In the outlook we will describe how this scheme is relevant for the realization of ensemble-based quantum tokens [4].

[1] B. T. Torosov and N. V. Vitanov, Phys. Rev. A 83, 053420 (2011). [2] N. Rosen and C. Zener, Phys. Rev. 40, 502 (1932). [3] A. Schmidt, J. Bernardoff, K. Singer, J. P. Reithmaier and C. Popov, Physica Status Solidi A, 216, 1900233 (2019). [4] https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/diqtok

Q 43.8 Wed 16:30 Empore Lichthof

Quantum speed limit dependence on the number of controls in a qubit array. — •David Pohl, Fernando Gago-Encinas, and Christiane P. Koch — Arnimallee 14, 14195 Berlin

Qubit arrays form the basic unit of quantum computers. As such, it is desirable to be able to manipulate each qubit as needed. However, including a local control on every qubit is not scalable to a large number of qubits. On the other hand, reducing the number of controls might be sufficient for manipulation but slow down the implementation of quantum gates, bringing the system closer to the decoherence limit. Here, we investigate how quickly quantum gates can be implemented depending on the number of local controls. In particular, we show how the quantum speed limit (the shortest time to generate a quantum gate) increases when reducing the number of controls. We determine this limit for a universal set of gates for different 3-qubit systems using Krotov's optimization method.

Q 43.9 Wed 16:30 Empore Lichthof

Towards realizing an ultra-high vacuum chamber and experimental control of trapped ion systems using surface traps. — •Maharshi Pran Bora, Ulrich Warring, Florian Hasse, Deviprasath Palani, Phillip Kiefer, Apurba Das, Lucas Eisenhart, Tobias Spanke, and Tobias Schaetz — Physikalisches Institut, Freiburg, Albert-Ludwigs-Universität, Deutschland

Trapped ion systems are promising platforms for realizing quantum systems for quantum simulations and quantum information processing.The scalability and performance of these trapped ion systems depends crucially on the vacuum apparatus in which the trap is operated in and also on the efficiency and robustness of the experimental control of these systems. The project firstly aims at designing and characterizing an ultra-high vacuum chamber for the Phoenix surface trap produced at the Sandia National Laboratories . The Phoenix trap is a state of the art linear surface trap with high optical access. The scope of the project will include reaching an vacuum pressure of less than 10^{-9} Pa and consideration of an optimum design for the proper functioning of the trap . Secondly, to attain better experimental control, addressing of individual ions with a local beam using piezo devices will be also explored in this project . The calibration and characterization of the piezo driven platform will be reported. Hence, this project will aim at providing an improved understanding of the impact of UHV design and experimental control on the quality of operation of trapped ion systems.

Q 43.10 Wed 16:30 Empore Lichthof

Towards Quantum Control of Calcium Ions for the use in Molecular Spectroscopy — •Manika Bhardwaj, Josselin Bernardoff, Jan Thieme, Daqing Wang, and Kilian Singer — Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

We are building a measurement methodology for selective spectroscopy of long-lived states with a calcium ion. We want to use binary search on the $4^2S_{1/2}$-$3^2D_{5/2}$ transition of the calcium atom for the resonance search. Through the use of composite pulses techniques, we will change the narrow excitation profile with a passband pulse [1] for binary search. The final goal is to employ this method to identify the long-lived states of the lanthanoid molecular ions [2] targeting their use in molecular quantum information processing platforms.

References:

[1] B. T. Torosov, and N. V. Vitanov, Physical Review A 83, 053420 (2011).

[2] K. Groot-Berning, T. Kornher, G. Jacob, F. Stopp, S. T. Dawkins, R. Kolesov, J. Wrachtrup, K. Singer, and F. Schmidt-Kaler, Physical Review Letters 123, (2019).

Q 43.11 Wed 16:30 Empore Lichthof

Optimising gate performance of transmon qubits coupled by a central tunable bus — •Alexander Möller[1,2], Matthias G. Krauss[2], Daniel Basilewitsch[2,3], and Christiane P. Koch[2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Freie Universität Berlin, Berlin, Germany — [3]Universität Innsbruck, Innsbruck, Austria

For transmon qubits coupled via a transmission line cavity, optimal control theory (OCT) has identified the quasi-dispersive regime to be optimal for universal quantum computing. For a single control driving the harmonic coupler, both local and entangling gates can be implemented with high fidelity and short gate durations [Goerz et al., *npj Quantum Information* **3**, 37 (2017)]. In an analogous manner we aim at exploring the transmon parameter landscape for a system of two transmons addressed by a third transmon acting as a tunable bus. We investigate how the anharmonicity of this central coupler affects the implemented gates and the OCT optimisation. Here we especially focus on the controllability of the two-transmon-subsystem as well as the achievable gates for different pulse durations and from this determine their respective quantum speed limit. Furthermore, we present an effective analytical model for the coupling between the outer transmons.

Q 43.12 Wed 16:30 Empore Lichthof

Single qubit gate optimization based on ORBIT cost functions — •Catharina Broocks[1,2], Max Werninghaus[1], Niklas Glaser[1,2], Federico Roy[1,3], and Stefan Filipp[1,2,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik Department, Technische Universität München, Garching, Germany — [3]Theoretical Physics, Saarland University, Saarbrücken, Germany — [4]Munich Center for Quantum Science and Technologies (MCQST), Munich, Germany

Analytic control solutions for qubit gates are limited by the knowledge about modeled experimental hardware properties. To achieve high-fidelity gates for superconducting qubit devices, we optimize pulse parameters of analytic solutions with respect to experimental feedback loops. As cost function the ground state population after a net-identity series of Clifford gates is used. For small parameter sets, the parameter-landscape can serve as a reference to verify numerical system models and provide insight into the sensitivity and correlation of individual parameters. To find an optimal parameter configuration, we apply simultaneous multi-parameter optimization of single-qubit gates in form of CMA-ES closed-loop optimization. We analyze the behavior of the optimization algorithm when using features such as sensitivity adjustment, influence of various noise contributions and the design of the cost function to achieve a reliable and complete convergence of the algorithm. The optimization routine can then be used to verify and address various optimal control problems, such as robustness and avoidance of leakage out of the qubit subspace.

Q 43.13 Wed 16:30 Empore Lichthof

Predicting the minimum control time of quantum protocols with artificial neural networks — •Sofia Sevitz[1], Nicolás Mirkin[1], and Diego A. Wisniacki[1,2] — [1]Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Física, Buenos Aires, Argentina — [2]CONICET - Universidad de Buenos Aires, Instituto de Física de Buenos Aires (IFIBA), Buenos Aires, Argentina

Quantum control relies on the driving of quantum states without the loss of coherence, thus the leakage of quantum properties onto the environment over time is a fundamental challenge. One work-around is to implement fast protocols, hence the Minimal Control Time (MCT) is of upmost importance. Here, we employ a machine learning network in order to estimate the MCT in a state transfer protocol. An unsupervised learning approach is considered by using a combination of an autoencoder network with the k-means clustering tool. The Landau-Zener (LZ) Hamiltonian is analyzed given that it has an analytical MCT and a distinctive topology change in the control landscape when the total evolution time is either under or over the MCT. We obtain that the network is able to not only produce an estimation of the MCT but also gains an understanding of the landscape's topologies. Similar results are found for the generalized LZ Hamiltonian while limitations to our very simple architecture were encountered.

Q 43.14 Wed 16:30 Empore Lichthof

Error Budget for the Sørensen-Mølmer Gate — •Susanna Kirchhoff[1,2], Frank Wilhelm-Mauch[1,2], and Felix Motzoi[3] — [1]Institute of Quantum Computing Analytics (PGI 12), Forschungszentrum Jülich, Germany — [2]Theoretical Physics, Saarland University, Saarbrücken, Germany — [3]Institute of Quantum Control (PGI-8), Forschungszentrum Jülich, Germany

The Sørensen-Mølmer gate is an entangling gate for ion qubits, where the entanglement is achieved by a bichromatic laser beam. The gate speed and fidelity are limited by leakage to other levels. We present a detailed expression for the fidelity including higher Lamb-Dicke orders and propose methods to improve gate speed and fidelity.

Q 43.15 Wed 16:30 Empore Lichthof

Optimizing for an arbitrary Schrödinger cat state — •Matthias G. Krauss[1], Anja Metelmann[2], Daniel M. Reich[1], and Christiane P. Koch[1] — [1]Freie Universität, Berlin, Germany — [2]Karlsruhe Institute of Technology, Karlsruhe, Germany

Schrödinger cat states are non-classical superposition states that are useful in quantum information science, for example for computing or sensing. Optimal control theory provides a set of powerful tools for preparing such superposition states, for example in experiments with superconducting qubits [Ofek, et al. *Nature* **536**, 2016]. We present a set of cat state functionals which provide more freedom to the optimization algorithms, compared to state-to-state functionals. By using Krotov's method [Reich et al. *J. Chem. Phys.* **136**, 2012], we demonstrate their application by optimizing the dynamics of a Kerr-nonlinear system with two-photon driving and analyze the robustness of the cat state preparation under single and two-photon decay. In addition, we explore the generation of cat states in higher order Kerr systems. Furthermore, we show the versatility of the framework by applying it to a Jaynes-Cummings model and optimize towards arbitrary entangled cat states. We identify the strategy of the obtained control fields and determine the quantum speed limit as a function of the cat state's excitation. Finally, we extend the investigation to open quantum systems to analyze the benefit of reoptimization together with the changes in the control strategy induced by decay.

Q 43.16 Wed 16:30 Empore Lichthof

Operation of a microfabricated 2D trap array — •Marco Valentini[1], Matthias Dietl[1,2], Silke Auchter[1,2], Michael Dieter[1,2], Philip Holz[3], Clemens Rössler[2], Thomas Monz[1,3], Philipp Schindler[1], and Rainer Blatt[1,3,4] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstrasse 25, 6020 Innsbruck, Austria — [2]Infineon Technologies Austria AG, Villach, Austria — [3]Alpine Quantum Technologies GmbH, 6020 Innsbruck, Austria — [4]Institute for Quantum Optics and Quantum Information, 6020 Innsbruck, Austria

We investigate scalable surface ion traps for quantum simulation and quantum computing. We have developed a microfabricated surface trap consisting of two parallel contiguous linear trap arrays with 9 trapping sites each. An interconnected three-metal-layer structure provides addressing of the DC electrodes across the chip and shielding of the silicon substrate. The trap fabrication is carried out by Infineon Technologies in an industrial facility, which allows for complex electrode designs and ensures high process reproducibility. We demonstrate trapping and shuttling of multiple ions in the trap array, and form square and triangular ion-lattice configurations with up to six ions. We characterize stray electric fields and measure ion heating rates between 131(13) and 470(50) ph/s in several trapping sites. Furthermore, we engineered our setup to control independently the RF voltage in between the two linear trap arrays, and we will make use of it to demonstrate motional coupling of ions across the lattice.

Q 43.17 Wed 16:30 Empore Lichthof

Engeneering of tin vacancies in diamond by lattice charging — •Vladislav Bushmakin[1,2], Oliver von Berg[1], Santo Santonocito[1], Sreehari Jayaram[1], Petr Siyushev[1], Rainer Stöhr[1,2], Andrej Denisenko[1,2], and Jörg Wrachtrup[1,2] — [1]Universität Stuttgart, 3. Physikalisches Institut, Allmandring, 13, 70569, Stuttgart, Germany — [2]Max-Plank-Institut für Festkörperforschung Heisenbergstraße 1, 70569 Stuttgart, Germany

Recent advances in the integration of spin-bearing solid-state defects in optical cavities for efficient spin-photon entanglement are mostly associated with silicon vacancy in diamond. Meanwhile, the implantation of diamond with heavier group IV ions promises similar performance but at elevated temperatures above 1 K, which contrasts with the stringent requirement of approximately 100 mK for the coherent manipulation of the SiV electron spin. However, the generation of defects involving heavier atoms, such as tin is accompanied by a high density of defects induced by ion implantation. Here we present a method of reduction of the implantation-induced density of defects by implanting through the Boron-doped charged lattice with a subsequent etching of the damaged layer. The given method is an extension of the conventional implantation technique and hence significantly less experimentally demanding than techniques relying on CVD overgrowth or HPHT annealing. Additionally, it provides better accuracy of implantation and allows for the efficient generation of tin vacancies with a narrow inhomogeneous zero-phonon line distribution.

Q 43.18 Wed 16:30 Empore Lichthof

Robust and miniaturized Zerodur based optical and vacuum systems for quantum technology applications — •Sören Boles[1], Jean Pierre Marburger[1], Moritz Mihm[3], André Wenzlawski[1], Ortwin Hellmig[1], Klaus Sengstock[2], and Patrick Windpassinger[1] — [1]Institut für Physik, JGU, Mainz — [2]Institut für Laserphysik, UHH, Hamburg — [3]Centre for Quantum Technologies, NUS, Singapore

In the ongoing quantum revolution of science, many current studies aim to bring quantum systems to market maturity, such as quantum computers and quantum sensors. Ongoing efforts attempt to increase the accessibility of such systems, while minimizing size, mass and power requirements.

We previously demonstrated the succesful use of stable optical and laser systems based on the glass ceramic Zerodur in space borne atom interferometry experiments, e.g. FOKUS, KALEXUS and MAIUS.

On this poster, we present current developments of Zerodur to metal vacuum flanges, enabling accessible, yet mechanically and thermally stable vacuum systems. Furthermore, we report on the ongoing effort of the construction of a passively pumped Zerodur vacuum chamber for quantum sensoric applications, using optical activation of passive pumps and atom dispensers to demonstrate a MOT.

Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant numbers 50WM2266B, 50WP1433 & 50WP2103.

Q 43.19 Wed 16:30 Empore Lichthof

Spin coherence control in an optically pumped magnetometer for space-borne magnetomyography — •Simon Nordenström[1], Victor Lebedev[1], Stefan Hartwig[1], Kirti Vardhan[2], Sascha Neinert[2,3], Jenichi Felizco[3], Martin Jutisz[2,3], Markus Krutzik[2,3], and Thomas Middelmann[1] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Humboldt-Universität zu Berlin, Berlin, Germany — [3]Ferdinand-Braun-Institut, Berlin, Germany

Detecting astronauts' neuromuscular degeneration with conventional methods such as surface or needle electromyography is inadequate or too detrimental. Optically pumped magnetometers (OPMs), on the other hand, allow for flexible handling and non-invasive measurements, utilizing the unique properties of alkali atom vapors interacting with external magnetic fields and laser light.

In this poster, we report on our progress in implementation of minimally necessary field control facilities to support the highest performance of the OPM, compatible with measurements on a space station. We investigate the balance between atomic spin coherence relaxation processes, anticipated dynamic range and response bandwidth in a magnetically perturbing environment. We present the anticipated system design and test results under lab conditions.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under grant numbers 50WM2168 and 50WM2069.

Q 43.20 Wed 16:30 Empore Lichthof

Miniaturized fiber-based endoscope with direct laser written antenna structures — •Stefan Dix[1], Jonas Gutsche[1], Erik Waller[1,2], Georg von Freymann[1,2], and Artur Widera[1] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

Fiber-based endoscopic sensors are established and widely applied as local fluorescence detectors for various samples, replacing bulky microscopes. Such sensors require the integration of sensing objects, such as nitrogen-vacancy (NV) centers in diamond and microwave antennas on small scales. Here, the microwave (MW) field addresses a transition in the NV center for magnetic field sensing. The MW fields needed are usually created using thin conducting wires or chip-based antennas close to the diamond sample. These approaches either lead to fragile, bulky, or inefficient sensor tips.

Here, we present a robust fiber-based endoscope with a direct laser written silver antenna structure close to a 50 μm multimode fiber core for optimal efficiency. Using such an endoscope, we measure an ODMR sensitivity of $17.8\,\mathrm{nT}/\sqrt{\mathrm{Hz}}$ by probing 15 μm large diamonds entirely through the endoscope. Furthermore, we demonstrate a new method for measuring distances based on measurements of the Rabi frequency.

Q 43.21 Wed 16:30 Empore Lichthof

Status and perspective of a next generation, GHz bandwidth, on-demand single-photon source — •Felix Moumtsilis[1], Max Mäusezahl[1], Moritz Seltenreich[1], Jan Reuter[2,3], Hadiseh Alaeian[4], Harald Kübler[1], Matthias Müller[2], Charles Stuart Adams[5], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Forschungszentrum Jülich GmbH, PGI-8, Germany — [3]Universität zu Köln, Germany — [4]Departments of Electrical & Computer Engineering and Physics & Astronomy, Purdue University, USA — [5]Department of Physics, Joint Quantum Centre (JQC), Durham University, UK

The ultimate challenge of coherent experiments in thermal vapors lies in the inevitable movement of atoms that must be overcome to profit from this highly scalable and miniturizable platform e.g. for high fidelity Rydberg logic gates. GHz interaction energies and nanosecond dephasing times in a thermal rubidium vapor demand equally fast coherent control of the atomic excitations, movement, and density.

Here we report on the current state, technical challenges, and the perspective of our next generation single photon source based on the Rydberg blockade. This involves an electronic pulse shaping system with sub-nanosecond jitter, two state-of-the-art 1010 nm pulsed fiber amplifiers, an ultra narrow yet high-contrast wavelength filtering of single photons, high NA focussing, and detection. Beyond our established micrometer thick wedged cells, we investigate novel glass cell geometries requiring a whole new set of manufacturing technologies.

Q 43.22 Wed 16:30 Empore Lichthof

Magnetometry with NV centers and Waveguide-Assisted Detection Channels — •Sajedeh Shahbazi[1], Michael Hoese[1], Michael K. Koch[1,2], Vibhav Bharadwaj[1,3], Johannes Lang[1], Argyro N. Giakoumaki[3], Roberta Ramponi[3], Fedor Jelezko[1,2], Shane M. Eaton[3], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Ulm, Germany — [3]Institute for Photonics and Nanotechnologies (IFN) - CNR, Milano, 20133, Italy

The negatively charged Nitrogen-Vacancy(NV) center in diamonds has shown great success in nanoscale, high-sensitivity magnetometry. Efficient fluorescence detection is crucial for improving sensitivity and for practical sensor-integrated devices. One way to approach such a goal is using ultrafast laser writing waveguides on the diamond to create such an on-chip integrated quantum sensor. Here, we present femtosecond laser-written type II waveguides on a diamond surface, integrated with NV centers a few nanometers below the diamond surface while covering the entire mode field of waveguides [1]. We experimentally verify the coupling efficiency and the detection of magnetic resonance signals through the waveguides to perform magnetic field sensing. In the future, our approach will enable the development of two-dimensional sensing arrays facilitating spatially and temporally correlated magnetometry.

[1] M. Hoese et al., Phys. Rev. Applied 15, 054059 (2021)

Q 43.23 Wed 16:30 Empore Lichthof

Experimentation platform towards a standardized characterization of ion traps for industrial and academic users — •Hemanth Kalathur[1], André P. Kulosa[1], Erik Jansson[1], Elena Jordan[1], Jan Kiethe[1], Nicolas Spethmann[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Leibniz Universität Hannover, Hannover

Enabling technologies for quantum technologies (QT), such as ion traps, have become indispensable in the fields of quantum computing, quantum simulation, and quantum sensing. A successful commercialization of QT requires extensive knowledge exchange between research and industry.

The Quantum Technology Competence Center (QTZ) at PTB has the central goal of becoming the bridge between research and industry in Germany. The user facility "Ion Traps" of QTZ will provide a user-friendly experimentation platform for the standardized characterization of ion traps. In the long term, the performance of ion traps, e.g. ion micromotion and heating rates will be characterized. We will use incorporated automated routines to enable intuitive access to our measurement platform for collaborators even with a non-physics background. Here, we report about our experimentation platform in operation and the first comprehensive characterization of an ion trap as a cornerstone for the future standardization activities of QTZ.

Q 43.24 Wed 16:30 Empore Lichthof

Absorption sensing mode in radio frequency electrometry using Rydberg atoms in hot vapors — •Matthias Schmidt[1,2], Stephanie Bohaichuk[1], Chang Liu[1], Harald Kübler[2], and James P. Shaffer[1] — [1]Quantum Valley Idea Laboratories , 485 Wes Graham Way, Waterloo, ON N2L 6R1, Canada — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffendwaldring 57, 70569 Stuttgart

We present progress in atom-based RF E-field sensing using Rydberg atoms in hot vapors. There are two distinct strategies to detect the electric field strength of the RF wave, namely the Autler-Townes limit, where the splitting of the dressed states is proportional to the incident RF electric field strength and the amplitude regime, where we determine the electric field by measuring the difference of transmission in the presence of the RF electromagnetic field. We present theoretical calculations for the amplitude regime, using a two photon excitation scheme, that show how the scattering of the probed transition changes in the presence of the RF electromagnetic field. We find an analytical expression in the thermal limit with finite wave vector mismatch that yields an accurate approximation compared to full density matrix calculation in the strong coupling limit. Our work extends the understanding of the detection of weak RF E-fields with Rydberg-atom based RF sensors. Furthermore, we present a three photon excitation scheme, with which residual Doppler broadening is suppressed. This enables a spectral resolution comparable to the Rydberg state decay rate, the spectral bandwith limitation.

Q 43.25 Wed 16:30 Empore Lichthof

Measurement of the phase-matching function in PPKTP waveguides — •Jan-Lucas Eickmann, Florian Lütkewitte, Kai-Hong Luo, Michael Stefszky, Laura Padberg, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

Single-photon sources with high purity are a prerequisite for the development of practical photonic quantum computation. Spontaneous parametric down-conversion in periodically poled potassium titanyl phosphate (PPKTP) is a promising approach to generate spectrally pure quantum light by achieving a phase-matching function perpendicular to the pump function. However, the phase-matching function varies with the condition of waveguide fabrication and the quality of periodic poling. Therefore, a precise measurement of the phase matching dependence is crucial for integrated photonic quantum source engineering. In this work, we present a method for measuring the phase-matching function in PPKTP waveguides by exploiting sum-frequency generation. Using the measured phase-matching function, we reconstruct the joint spectral intensity (JSI) for different pump fields to assure the spectral purity of the heralded photon. We observe that the phase matching results in JSI functions with a tilt of around 60°, deviating 15° from a symmetric function required for optimum pure state preparation.

Q 43.26 Wed 16:30 Empore Lichthof

Control of NV centers in nanodiamonds for sensing applications — •Dennis Lönard and Artur Widera — Physics Department and State Research Center OPTIMAS, RPTU Kaiserslautern, Erwin-Schroedinger-Str. 46, 67663 Kaiserslautern, Germany

The nitrogen-vacancy (NV) color center in diamond is an essential platform for magnetic field sensing for technical and biological applications. One major advantage is that the spin state of the NV-center can be read out optically via the fluorescence. Different spin manipulation schemes, like Ramsay or Hahn echo sequences, have been proposed to influence the interaction between the final spin state and the magnetic field that is to be measured. However, the experimentally achieved sensitivities to outer magnetic fields is still far from their theoretical limits, each measurement scheme having its own set of limitations, often due to the dephasing of the spin states of neighboring NV-centers. I will present our work to further improve the limits of sensing, spanning from technical control to the prospect of combining different methods of manipulating and sensing the NV center and exploiting their multi-level structure.

Q 43.27 Wed 16:30 Empore Lichthof

Predicting coupling efficiency of KTP waveguides and fibers by mode measurement — •Florian Lütkewitte, Jan-Lucas Eickmann, Kai Hong Luo, Michael Stefszky, Laura Padberg, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098, Paderborn, Germany

Reliable generation of photonic quantum states is of high importance for fundamental physics and quantum networks. Due to its unique dispersion properties, spontaneous parametric downconversion (SPDC) in potassium titanyl phosphate (KTP) has gathered extensive research attention as a source of heralded single photons in the telecom range. Fiber-based devices allow for plug-and-play usage omitting time-intensive free-space coupling. Integration of SPDC sources in fiber networks can be achieved with fiber-pigtailed KTP waveguides. However, single-mode waveguides in KTP show imperfect overlap with single-mode fibers due to their asymmetry and a size-mismatch between modes. Thus, optimized mode-adapted fibers are required to obtain a plug-and-play heralded photon source in KTP. In this work, we measured the mode profile of waveguides and several tapered fibers. Comparing the mode overlap, the optimal waveguide-fiber combination has been determined with upper-bound coupling efficiency of $(90\pm1)\%$, based on the mode overlap integral over their measured mode profile.

Q 43.28 Wed 16:30 Empore Lichthof

Integrated optics for scaling up the performace of ion based quantum computers — •Steffen Sauer[1,2], Carl-Frederik Grimpe[3], Anastasiia Sorokina[1,2], Guochun Du[3], Pascal Gehrmann[1,2], Tunahan Gök[6,7], Radhakant Singh[6,7], Pragya Sah[6,7], Babita Negi[7], Maxim Lipkin[6,7], Stephan Suckow[6], Elena Jordan[3], Tanja Mehlstäubler[3,4,5], and Stefanie Kroker[1,2,3] — [1]Institut für Halbleitertechnik, Technische Universität Braunschweig, Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, Braunschweig, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [5]Laboratorium für Nano- und Quantenengineering, Hannover, Germany — [6]AMO GmbH, Advanced Microelectronic Center Aachen, Aachen, Germany — [7]Chair of Electronic Devices, RWTH Aachen University, Aachen, Germany

Ions trapped on chips are one of the most promising approaches for quantum computers. The approach offers the advantage of high fidelity, long coherence time and scalability. In addition, the ion physics and trap chip technology are well understood. The key component for the scalability of this quantum computers are integrated optical devices, such as waveguides to transport light or grating outcouplers to emit *m beams to the ions. In the joint project ATIQ, this approach is being pursued with the aim of realising a quantum computer with 40 qubits (ions). We present simulations of integrated optical components, their applications on chips and our characterization setups.

Q 43.29 Wed 16:30 Empore Lichthof

Towards a Micro-Integrated Optically Pumped Magnetometer for Biomagnetism in Space — •Kirti Vardhan[1], Sascha Neinert[1,2], Jenichi Felizco[2], Marc Christ[1,2], Kai Gehrke[2], Andreas Thies[2], Olaf Krüger[2], Martin Jutisz[1,2], Mustafa Gündoğan[1,2], Victor Lebedev[3], Stefan Hartwig[3], Simon Nordenström[3], Thomas Middelmann[3], and Markus Krutzik[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany — [3]Physikalisch-Technische Bundesanstalt, Berlin, Germany

Detecting astronauts' neuromuscular degeneration with conventional methods such as surface or needle electromyography is inadequate or too detrimental. Optically pumped magnetometers (OPMs), on the other hand, allow for flexible handling and non-invasive measurements, utilizing the unique properties of alkali atom vapors interacting with external magnetic fields and laser light.

In this poster, we report on our progress towards a miniaturised, ruggedized OPM sensor head based on in-house fabricated MEMS cells for measuring biomagnetic signals in a moderately shielded environment. To this end we compare the performance of first prototypes of a micro-integrated sensor to a functional lab-scale magnetometer setup.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under grant numbers 50WM2168 and 50WM2169.

Q 43.30 Wed 16:30 Empore Lichthof

Additive manufacturing, micro-integration and semiconductor fabrication for compact cold atom systems — Marc Christ, •Alisa Ukhanova, Simon Kanthak, Thomas Flisgen, Conrad Zimmermann, Jörg Fricke, Olaf Brox, Andrea Knigge, Wolfgang Heinrich, and Markus Krutzik — Ferdinand-Braun-Institut (FBH), Leibniz-Institut für Höchstfrequenztechnik, Berlin

Atom-based quantum sensors allow time- and field-sensing applications with an unrivalled precision compared to their classical counterparts. While lab-based operation of cold atom-based devices is well established, a transition to mobile applications requires miniaturized subsystems with reduced complexity, high stability and low size, weight and power requirements. At FBH, we start to address the miniaturization of the sensor*s physics package towards cm-scale systems, including micro-integrated, vacuum-compatible optical systems for atom trapping and manipulation, compact, 3D-printed vacuum chambers and diffraction grating based atom sources. This poster presents an overview of our efforts towards this goal.

This work is supported by FBH and partially supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under grant number 50WM1949 and 50WM2070.

Q 43.31 Wed 16:30 Empore Lichthof

Fiber-coupled NV Ensembles in Microdiamond as miniaturized Magnetic Field Probes — •Jonas Homrighausen[1], Jens Pogorzelski[2], Peter Glösekötter[2], and Markus Gregor[1] — [1]Department of Engineering Physics, University of Applied Sciences, Münster, Germany — [2]Department of Electrical Engineering and Computer Science, University of Applied Sciences, Münster, Germany

NV centers in diamond are a very promising candidate for precise measurement of magnetic fields. Especially NV ensembles offer the inherent ability for threedimensional reconstruction of the magnetic field vector while being optically adressable in an optically detected magnetic resonance (ODMR) setup. We utilize these properties by coupling NV ensembles in microdiamond to optical fibers in order to create magnetic probes with high spatial resolution. This however poses challenges, amongst which the efficient delivery of microwave exciation to the fiber tip. In this poster, different methods are discussed for this particular application. We use finite element simulations to compare microwave structures and investigate the according ODMR results. Furthermore, we analyse the effect of crystal orientation with respect to locally homogeneous microwave and magnetic fields.

Q 43.32 Wed 16:30 Empore Lichthof

Towards Optically Integrated Trapped Ion Quantum Computing — •Marco Schmauser[1], Philipp Schindler[1], Thomas Monz[1], Marco Valentini[1], Clemens Rössler[2], Klemens Schüppert[2], Bernhard Lamprecht[3], and Rainer Blatt[1,4] — [1]Universität Innsbruck, Innsbruck, Austria — [2]Infineon Technologies Austria AG, Villach, Austria — [3]Joanneum Research, Weiz, Austria — [4]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften

Trapped ion quantum computers are known to be large and complex experiments. One of the reasons for this is that light guidance between lasers and ions is done mainly by free-beam optics, which means that the overall system requires a lot of space and is susceptible to drifts and vibrations. The only way to make such a system compact and scalable is to increasingly integrate functionality, in this specific case optical elements, from external components directly into the ion trap. To solve this problem, a method has been developed to write single-mode and polarization-maintaining waveguides directly into quartz glass using ultrashort laser pulses. These light guides can be tuned to a specific wavelength, ranging from UV to near infrared. The next step is to realize an ion trap with such integrated waveguides. In this context, the approach of a microstructured trap is pursued, which allows for a scalable trap architecture and is compatible with industrial production. In parallel, an integrated cryogenic quantum computing system is being built to enable fast trap changes and additionally investigate the light delivery to the trap chip.

Q 43.33 Wed 16:30 Empore Lichthof

Quantum memory in noble-gas nuclear spins with alkali metal vapour as optical interface — •Norman Vincenz Ewald[1], Tianhao Liu[2], Luisa Esguerra[1,3], Ilja Gerhardt[4], and Janik Wolters[1,3] — [1]German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin — [2]Physikalisch-Technische Bundesanstalt, FB 8.2 Biosignale, Berlin — [3]Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin — [4]Leibniz University Hannover, Institute of Solid State Physics, Light and Matter Group, Hannover

Quantum memories with storage times well beyond 1 s will spawn manifold applications in quantum communication and information processing, e.g. as quantum token for secure authentication. We present our first steps towards a quantum memory with long storage time in a mixture of the noble gas ^{129}Xe and an alkali metal vapour of ^{133}Cs. A custom glass cell at about room temperature contains both species and is placed inside a table-top magnetic shield. Information will be stored in the collective excitation of nuclear spins of ^{129}Xe, which exhibit hours-long coherence times [1]. ^{133}Cs serves as optical interface for signal photons, which we store in a collective spin excitation using EIT [2]. Coherent information transfer to the noble gas spins is based on spin-exchange collisions and will be controlled by synchronisation of Larmor precession [3].

[1] C. Gemmel et al., *Eur. Phys. J. D* **57**, 303–320 (2010).
[2] L. Esguerra et al., arXiv:2203.06151 (2022).
[3] O. Katz et al., *Phys. Rev. A* **105**, 042606 (2022).

Q 43.34 Wed 16:30 Empore Lichthof

Rack-mounted Laser Systems for Quantum Computing with Be$^+$ and Ca$^+$ Ions — •Gunnar Langfahl-Klabes[1], Niels Kurz[2], Malte Stoepper[1,2], Stephan Hannig[1], and Piet Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Institute of Quantum Optics, Leibniz University Hannover

Co-locating quantum processing units based on ion traps with classical computers in data centers requires highly integrated, transportable, modularized, turn-key laser systems in an overall form factor that complies with 19-inch rack-mount standards.

The ion trap-based quantum computer of Quantum Valley Lower Saxony (QVLS-Q1) uses Be$^+$ ions as qubits and Ca$^+$ ions for sympathetic cooling. Within three half-height server racks we provide all of the necessary lasers for cooling, repumping, and detection. Our systems feature four monolithic rack drawers that contain customized setups for sum-frequency generation, second-harmonic generation, and frequency shifting. All rack-mounted laser outputs are fiber-coupled. Free-space components for ablation and photoionization are placed close to the vacuum chamber.

The wavelengths used in our setup range from deep-UV to near-IR (235, 313, 375, 397, 422, 470, 515, 626, 854, 866, 1051, 1552 nm). With red light at 626 nm we realize a laser stabilization setup via Doppler-free iodine spectroscopy for the Be$^+$ cooling and detection laser system at 313 nm.

We report on the current status of our laser systems.

Q 43.35 Wed 16:30 Empore Lichthof

Towards coherent single praseodymium ion quantum memories in optical fiber microcavities — •Sören Bieling[1], Nicholas Jobbitt[1], Roman Kolesov[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Universität Stuttgart, 70569 Stuttgart, Germany

Rare earth ions doped into solids show exceptional quantum coherence in their ground-state hyperfine levels. These spin states can be efficiently addressed and controlled via optical transitions and are thus ideally suited to serve as quantum memories and nodes of quantum networks. However, while long storage times, high storage efficiencies and storage on the single photon level have all been demonstrated separately, they could not yet be achieved simultaneously. We aim to demonstrate both long and efficient single quantum storage in the ground-state hyperfine levels of single Pr^{3+} ions doped into yttrium orthosilicate (YSO) by integrating them as a membrane into optical high-finesse fiber-based Fabry-Pérot microcavities. This allows for efficient addressing and detection of individual ions. We report on the design, commissioning and initial characterization of a next-gen cryogenic scanning microcavity as well as on its experimental integration into and design of a self-built vector magnet. It allows for future coherence prolongation by operating under a zero first-order Zeeman (ZEFOZ) shift magnetic field alongside dynamical decoupling sequences. Together with the Purcell enhanced emission and ultrapure Pr^{3+}:YSO membranes this strives to realize efficient and coherent spin-photon interfaces suitable for deployment in scalable quantum networks.

Q 43.36 Wed 16:30 Empore Lichthof

Towards the implementation of microwave near-field entangling gates in a cryogenic surface-electrode ion trap apparatus — •Niklas Orlowski[1], Chloë Allen Ede[1], Niels Kurz[1], Sebastian Halama[1], Timko Dubielzieg[1], Celeste Torkzaban[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Physikalisch Technische Bundesanstalt, 38116 Braunschweig, Germany

We discuss ion loading using different lasers for the ablation, ionization, cooling and detection of Beryllium ions and describe measures taken to isolate ions from environmental influences, for example by using vibrational decoupling, electromagnetic shielding, and an XUHV-environment [1]. We demonstrate hyperfine state preparation and manipulation with microwave pulses and discuss requirements on radial mode stability for the implementation of entangling microwave quantum gates [2].

[1] Dubielzig et al. RSI 92.4 (2021): 043201
[2] Zarantonello et al. PRL 123, 260503

Q 43.37 Wed 16:30 Empore Lichthof

Synthesis of depth confined nitrogen vacancy centers in diamond — •Karolina Schüle[1], Christoph Findler[1,2], Johannes Lang[1,2], and Fedor Jelezko[1,3] — [1]Institute for Quantum Optics, Ulm University, Ulm, Germany — [2]Diatope GmbH, Ummendorf, Germany — [3]Center for Integrated Quantum Science and Technology (IQST), Ulm, Germany

The negatively charged nitrogen-vacancy center (NV) is a paramagnetic defect (S=1) in diamond which shows coherence times T2 up to milliseconds even at room temperature. The NV is a promising candidate for quantum applications as its spin state can be initialized, read out optically, and manipulated by a microwave field. One way to fabricate NV centers is ion implantation where nitrogen is added into a single crystal diamond layer followed by an annealing process. The depth of the implanted nitrogen can be adjusted by the implantation energy. Larger kinetic energies are leading to deeper NV centers. At the same time, however, the depth distribution gets also broader limiting the degree of depth confinement. This contradicts the goal of homogeneous properties of the NVs beneficial for e.g. NMR applications. Using the method of indirect overgrowth, where implanted nitrogen is buried below a nanometer-thin capping layer of diamond. The resulting depth of the NV centers is decoupled from the implantation ion energy. Here, we show outstanding depth confinement resulting in single NVs which are located at a depth of around 20 nm confined in a range of approx. 1.4 nm. These NV centers are exhibiting a T2 up to ~100 μs.

Q 43.38 Wed 16:30 Empore Lichthof

Industrially microfabricated ion traps for quantum information processing — •Schey Simon[1,2], Pfeifer Michael Dieter Josef[1,3], Glantschnig Max[1,4], Anmasser Fabian[1,3], Abu Zahra Mohammad[1], Auchter Silke[1,3], Brandl Matthias[1], Schüppert Klemens[1], Colombe Yves[1], and Rössler Clemens[1] — [1]Infineon Technologies Austria AG, Villach, Austria — [2]Stockholm University, Stockholm, Sweden — [3]University of Innsbruck, Austria — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Infineon Technologies is fabricating 2D and 3D ion trap chips in its industrial facilities [1,2]. This poster gives an overview of our work towards large-scale, reliable ion traps.

We are developing multiple fabrication processes on silicon and dielectric substrates for, e.g., multi-metal stacks with low resistance at cryogenic temperatures, and surfaces resilient to UV laser beam exposure, which we characterize using analytical tools (cryogenic probe station, KPFM microscopy). Together with partners, we design and produce ion traps with integrated optical waveguides, and traps for ion shuttling with ~200 electrodes, that will be operated with a custom cryo-compatible electronic chip. We present a second-generation ion trap socket that allows fast exchange of traps, which we use in our ion trapping lab and make available to our partners.

[1] Ph. Holz, S. Auchter et al., Adv. Quantum Technol. 3, 2000031 (2020)
[2] S. Auchter, C. Axline at al., Quantum Sci. Technol. 7, 035015 (2022)

Q 43.39 Wed 16:30 Empore Lichthof

Characterization of single-photon emitters in hexagonal boron nitride at room temperature — •Leonora Meier[1], Pablo Tieben[2], Stefan Kück[1], Andreas Schell[2], and Marco López[1] — [1]PTB, Braunschweig, Deutschland — [2]Leibniz Universität, Hannover, Deutschland

In this work we present a study on point defects of hexagonal boron nitride (hBN) which exhibit high brightness and narrow band single photon properties. So far, several samples containing hBN defects with different concentrations have been fabricated and characterized. The characterization is performed in terms of their spectrum, single-photon purity (g(2)(0)) and stability.

It has been observed that different emitters with hBN defects exhibit different spectra, even though the single-photon purity of g(2)(0) is less than 0.3. The single-photon emission stability remains a challenge. Blinking and bleaching were observed even though the time period of stability differs greatly between different emitters.

To improve the stability of the single-photon emission, different annealing procedures will be applied; for example, heating the sample to 500°C. In addition, the variation of photoluminescence as a function of an in-plane magnetic field will be studied to determine whether hBN point defects can be used as a magnetic sensor.

Q 43.40 Wed 16:30 Empore Lichthof

Near Field Modeling for Quantum Gate Operation — •Axel Hoffmann[1], Florian Ungerechts[2], Rodrigo Munoz[2], Brigitte Kaune[2], Teresa Meiners[2], Christian Ospelkaus[2,3], and Dirk Manteuffel[1] — [1]Institut für Hochfrequenztechnik, Hannover, Leibniz Universität Hannover — [2]Institut für Quantenoptik, Hannover, Leibniz Universität Hannober — [3]PTB Braunschweig, Braunschweig

Surface-electrode ion traps with integrated microwave conductors for near-field quantum control are a promising approach for scaleable quantum computers. The goal of the QVLS-Q1 Project is to realize a scaleable quantum computer based on surface-electrode ion traps. Realizing quantum gate operations with magnetic near-field control comes with high demands on the electromagnetic field design, regarding spatial field distribution and radiation efficiency. Typically the wave length of the gate frequency is much larger than the entire application. Therefore common criteria to design efficient radiating structures can not be applied in a straight forward way. Additionally the spatial distribution, especially the position of the field minimum, is constrained to match specific requirements. These challenges will be discussed in this poster, emphasizing on the possibilities to face the complex goal of minimizing gate errors. A systematic approach will be shown including advanced simulation approaches.

Q 43.41 Wed 16:30 Empore Lichthof

Single Photon Sources at Telecom Wavelengths — •Jonas Grammel[1], Julian Maisch[2], Nam Tran[2], Thomas Herzog[2], Simone Luca Portalupi[2], Peter Michler[2], and David Hunger[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart

Semiconductor single photon sources are fundamental building blocks for quantum information applications. The current limitations of such quantum dot sources are the emitting wavelength and insufficient collection efficiency in fiber-based implementations. In the project *Telecom Single Photon Sources* we aim to realize high brightness, fiber coupled sources of single and indistinguishable photons at the telecom wavelength for the upcoming realization of fiber-based quantum networks. We employ open cavities realized with fiber-based mirrors, in combination with InGaAs quantum dots emitting in the telecom O-band and C-band. To achieve Fourier-limited photons we utilize the lifetime reduction of the emitters via the Purcell effect. We optimize the mode matching between the cavity mode and the guided fiber mode by introducing a fiber-integrated mode-matching optics that can basically reach near-unity collection efficiency.

Q 43.42 Wed 16:30 Empore Lichthof

Packaging and Microfabrication Technology for Scalable Trapped Ion Quantum Computer — •Nila Krishnakumar[1,2,3], Friederike Giebel[1,2,3], Eike Iseke[1,2,3], Konstantin Thronberens[1,2,3], Jacob Stupp[1,2,3], Amado Bautista-Salvador[1,2,3], and Christian Ospelkaus[1,2,3] — [1]PTB, Bundesallee 100, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]LNQE, Schneiderberg 39, 30167 Hannover

Ion traps are a leading platform for scalable quantum computing. A physical implementation is based on microfabricated surface-electrode ion traps. A multilayer fabrication method [1] allows geometries which are impossible in single-layer traps. Thick and planarized dielectric-metal layers provide flexibility and better signal routing. The multilayer method requires microfabrication techniques such as UV Photolithography, Reactive Ion Etching(RIE), electroplating and more. Improving the efficiency and yield of the fabrication flow involves testing and updating each technology.

For scalability and hybrid integration of different control techniques, we discuss the implementation of TSVs (Through substrate vias) and better packaging technologies such as flip-chip bonding. As an alternative to the conventional wire bonding which limits the packaging density, a solder free thermocompression method proposed in [2] using gold stud bumps for flip-chip bonding is studied.

[1] A. Bautista-Salvador et al., New J. Phys. 21, 043011, Patent DE 10 2018 111 220 (2019)

[2] M. Usui et al.,(ICEP-IAAC) pp. 660-665 (2015)

Q 43.43 Wed 16:30 Empore Lichthof

Multi-Output Quantum Pulse Gate: a High-Dimensional Temporal-Mode Decoder — •Laura Serino, Jano Gil-Lopez, Michael Stefszky, Raimund Ricken, Christof Eigner, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

Future quantum technologies will require the implementation of complex quantum communication (QC) networks. Temporal modes (TMs) provide an appealing high-dimensional encoding alphabet based on the time-frequency degree of freedom of photons, leading to important advantages for QC applications. A TM-based QC scheme requires the simultaneous detection of multiple TMs of single photons, which has not yet been achieved.

In this work, we demonstrate high-dimensional single-photon TM decoding with a multi-output quantum pulse gate (mQPG). The mQPG is a device that provides simultaneous projection of multiple TMs onto all the elements of a chosen alphabet (or their superpositions) and maps each result onto a different output frequency. We demonstrate that the mQPG is compatible with single-photon-level input states from a full set of five-dimensional mutually unbiased bases, and we characterize its performance through a detector tomography. We then proceed to demonstrate a proof-of-principle decoder for high-dimensional quantum key distribution based on the mQPG.

Q 43.44 Wed 16:30 Empore Lichthof

Two Stage Quantum Frequency Conversion of SnV-Resonant Photons to the Telecom C-Band — •David Lindler, Tobias Bauer, Marlon Schäfer, and Christoph Becher — Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

Tin-Vacancy-Centers (SnV) in diamond are a promising candidate for Quantum Nodes in quantum communication networks that store and distribute quantum information [1,2]. Transferring the spin state of the SnV-Center onto single photons enables the exchange of information between these nodes over long distances through optical fiber links. The photons are converted into the low-loss telecom bands via quantum frequency down-conversion, to avoid the problem of high loss in fibers for SnV-resonant photons at 619 nm.

We here present a two-stage scheme for quantum frequency conversion of SnV-resonant photons to the telecom C-band based on difference frequency generation in PPLN waveguides. The two step process $619\,\mathrm{nm} - 2061\,\mathrm{nm} = 885\,\mathrm{nm}$, $885\,\mathrm{nm} - 2061\,\mathrm{nm} = 1550\,\mathrm{nm}$ drastically reduces noise at the target wavelength compared to the single stage process $619\,\mathrm{nm} - 1030.5\,\mathrm{nm} = 1550\,\mathrm{nm}$, due to pumping in the long wavelength regime. We will present the characterization of key components as well as first results on conversion efficiency and conversion induced noise count rates.

[1] J. Görlitz et al., npj Quant.Inf. 8, 45 (2022).

[2] R. Debroux et al., Phys. Rev. X 11, 041041 (2021).

Q 43.45 Wed 16:30 Empore Lichthof

Entangled Photon Pair Source based on Photonic Chips with Spontaneous Four-Wave-Mixing and Pulsed PDH-Locking — •Maximilian Mengler, Erik Fitzke, Jakob Kaltwasser, and Thomas Walther — TU Darmstadt, Institute for Applied Physics, 64289 Darmstadt

For many applications, such as quantum key distribution (QKD), entangled photon pairs are desirable. We use the process of spontaneous four-wave-mixing to create such pairs in microring resonators on silicon nitride photonic chips. Results in terms of, for example, pair generation rate and coincidental-over-accidental ratio obtained from two distinct chips with different setups, specifications and waveguide geometries will be presented and compared. As the chips are intended as sources for our QKD-System, which is based on time-bins, the PDHtechnique used for the locking of the microring resonators to the pump light was adapted to work with pulsed light.

Q 43.46 Wed 16:30 Empore Lichthof

Cavity-enhanced fluorescence of ensemble NV centers — •Kerim Köster[1], Maximilian Pallmann[1], Rainer Stöhr[2], Julia Heupel[3], Cyril Popov[3], and David Hunger[1] — [1]Physikalisches Institut, Karlsruher Institute für Technologie (KIT) — [2]3. Physikalisches Institut, University of Stuttgart — [3]Institute of Nanostructure Technologies and Analytics (INA), Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel

Building a long-distance quantum network is one of the big challenges in the field of quantum communication, which requires the development of a quantum repeater. A crucial component of this device is an efficient, coherent spin-photon interface. Coupling color centers in diamond to a microcavity is a promising approach therefore.

In our experiment, we integrate a diamond membrane into an open access fiber-based Fabry-Perot microcavity to attain emission enhancement in a single well-collectable mode. We observe cavity-enhanced fluorescence spectra of an ensemble of shallow-implanted nitrogen vacancy centers in diamond and report a significant Purcell-enhancement of the zero-phonon line (ZPL). Furthermore, the emission yields temporal bunching of ZPL photons, which indicates a collective behavior in the emission process that can be attributed to superfluorescence.

Q 43.47 Wed 16:30 Empore Lichthof

The Twente-Münster high-speed quantum key distribution link — •Niklas Humberg[1], Alejandro Sánchez-Postigo[1], Daan Stellinga[2], Pepijn Pinkse[2], and Carsten Schuck[1] — [1]Departement for Quantum Technology, Münster, Germany — [2]University of Twente, Enschede, Netherlands

To build a pan-European network for quantum communication, many local nodes are needed to provide every city with access to quantum-secure encryption. One such link between local nodes is being developed between the University of Twente (UT) and the Westfälische Wilhelms-Universität Münster (WWU), to open a secure communication channel between the Netherlands and Germany. High-speed generation of quantum keys over the roughly 85km long dark fiber will be achieved by using wavelength division multiplexing into several frequency channels that operate in parallel. The qubit preparation and detection will be done using silicon nitride-on-insulator photonic integrated circuits. The receiver chip will integrate an interferometer with a 150 ps low-loss delay line in one arm for time bin encoding and an arrayed waveguide grating (AWG) for demultiplexing the wavelength channels. Each AWG output channel will be equipped with an efficient and low-noise superconducting nanowire single-photon detector, which have timing accuracies that are significantly better than the optical delay in the interferometer. We show progress on the chip design and the fabrication of detector devices.

Q 43.48 Wed 16:30 Empore Lichthof

Photon emission from a segmented ion-trap – cavity system: simulation and implementation — •Stephan Kucera, Max Bergerhoff, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

Atom-photon interfaces [1,2] are basic requirements for quantum networks with single trapped ions. The efficiency of such interfaces has been shown to increase significantly by the use of resonators [3]. Following this direction, we are developing a new segmented ion trap for $^{40}Ca^{+}$ ions with an integrated fiber cavity [4,5] envisaging the implementation of a high-rate and high-purity quantum repeater cell (QR-cell) according to [6,7] on the basis of single-photon emission.

[1] C. Kurz et al., Nat. Commun. 5, 5527 (2014)
[2] M. Bock et al., Nat. Commun. 9, 1998 (2018)
[3] M. Meraner et al., Phys. Rev. A 102, 052614 (2020)
[4] H. Takahashi et al., New J. Phys. 15, 053011 (2013)
[5] B. Brandstätter et al., AIP 84, 123104 (2013)
[6] D. Luong et al., Appl. Phys. B 122, 96 (2016)
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Q 43.49 Wed 16:30 Empore Lichthof

Polarisation-independent Conversion of single photons from infrared to ultraviolet — •Alireza Aghababaei — Nußallee 12, 53115 Bonn

Wavelength conversion at the single-photon level is required to forge a quantum network from distinct quantum devices. Such devices could include solid-state emitters of single or entangled photons, as well as network nodes based on atoms or ions. We convert single photons emitted from an III-V semiconductor quantum dot at 853nm via sum frequency conversion to the wavelength of the strong transition of Yb ions at 370nm. In this poster, we will present a sagnac setup that allows polarization-independent frequency conversion.

Q 43.50 Wed 16:30 Empore Lichthof

Polarization stabilization of an urban telecom fiber link — •Jonas Meiers, Christian Haen, Stephan Kucera, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

Many quantum network designs rely on glass fibers to transmit quantum information encoded into the polarization of photons [1]. Long glass fiber links, especially those deployed outside a laboratory environment are exposed to environmental influences that change the birefringence of the fiber and, as a result, the polarization of transmitted light [2], degrading the polarization-encoded information.

Here, we present the polarization stabilization of a 14 km long urban fiber link running through Saarbrücken, by utilizing lasers as polarization reference and a Gradient-Descent algorithm for error correction. This stabilization provides the necessary transmission process fidelity for quantum communication experiments, which we demonstrate by high-fidelity entanglement distribution with photon pair sources, or by quantum repeater operations.

[1] S. Neumann et al., Nat. Commun. 13, 6134 (2022)
[2] O. Karlsson et al., Journal of Lightwave Technology, 18 (2000)

Q 43.51 Wed 16:30 Empore Lichthof

Observation of quantum Zeno effects for localized spins — •Vitalie Nedelea — Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany

One of the main dephasing mechanisms for the localized carrier spins in semiconductors is the coupling to the fluctuating nuclear spin environment. Here we present an experimental observation on the effects of the quantum back action under pulsed optical measurements of spin ensemble and demonstrate that the nuclei-induced spin relaxation can be influenced. We show that the fast measurements freeze the spin dynamics and increase the effective spin relaxation time, the so-called quantum Zeno effect. Furthermore, we demonstrate that if the measurement rate is comparable with the spin precession frequency in the effective magnetic field, the spin relaxation rate increases and becomes faster than in the absence of the measurements, an effect known as the quantum antiZeno effect. A theory describing both regimes allows us to extract the system parameters and the strength of the quantum back action.

Q 43.52 Wed 16:30 Empore Lichthof

Quantum Computation and Simulation with Neutral Alkaline-Earth-like Ytterbium Rydberg Atoms in Optical Tweezers — •Nejira Pintul[1], Tobias Petersen[1], Benjamin Abeln[1], Marcel Diem[1], Oscar Murzewitz[1], Koen Sponselee[1], Christoph Becker[1,2], and Klaus Sengstock[1,2] — [1]Zentrum für optische Quantentechnologien, Universität Hamburg, Deutschland — [2]Institut für Laserphysik, Universität Hamburg, Deutschland

Experiments with neutral cold atoms trapped in reconfigurable optical tweezer arrays have recently developed into one of today's leading platforms for quantum simulation and computation, due to the innate scalability, single atom control and Rydberg blockade mechanism for generating two-atom entangling gates. However, to achieve fault-tolerant quantum computing, current atomic life- and coherence times still need improvement to increase fidelities in preparation, gate operation and read-out. Here we present our pathway in constructing an optical tweezer experiment utilizing the alkaline-earth-like atom ^{171}Yb. This isotope offers a multitude of viable advantages for encoding novel high-fidelity qubit and error correction architectures, such as the presence of a highly coherent metastable state, a two valence-electron structure with an optically active ion core and single-photon Rydberg transitions. Main milestones include the characterization of two microscope objectives, the design of magnetic coils along with electric field compensation, the development of homogeneous 2D tweezer holograms and mobile dipole traps for efficient array initialization.

Q 43.53 Wed 16:30 Empore Lichthof

Polarization-preserving quantum frequency conversion for entanglement distribution in trapped-atom based urban area quantum networks — •Tobias Bauer and Christoph Becher

— Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

In quantum communication networks information is stored in internal states of quantum nodes, which can be realized e.g. in trapped ions like 40Ca+ [1]. By transferring the states onto flying quantum bits, i.e. photons, it is possible to exchange information between these nodes over long distances via optical fiber links. In order to minimize attenuation in fibers, which is particularly high for typical transition frequencies of trapped ions, quantum frequency down-conversion of the transmitted photons to low-loss telecom bands is utilized [2].

We present a high-efficiency, rack-integrated quantum frequency converter for polarization-preserving conversion of 40Ca+-resonant photons to the telecom C-band. This converter is highly suited for real-world application in entanglement distribution experiments in urban area fiber networks, e.g. photonic entanglement [3] or creation of remote entanglement of atomic systems.

[1] C. Kurz et al., Phys. Rev. A. 93, 062348 (2016)
[2] M. Bock, P. Eich et al., Nat. Commun. 9, 1998 (2018)
[3] E. Arenskötter, T. Bauer et al., arXiv:2211.08841

Q 43.54 Wed 16:30 Empore Lichthof

high sensitivity magnetometry with NV centers in diamond at zero field — •Muhib Omar, Arne Wickenbrock, Dmitry Budker, Georgios Chatzidrosos, Till Lenz, Omkar Dungel, and Joseph Rebeirro — Helmholtz Institut Mainz, Deutschland

We investigate a magnetometric protocol for sensing weak ac magnetic fields inside magnetic shieldings using ensembles of Nitrogen-Vacancy (NV) centres in diamond. The aim is to utilise this sensor for zero to ultra low field NMR detection, promising improved Signal-to-Noise ratio by the smaller standoff distance to a NMR sample this type of magnetometer would allow compared to standard optically pumped magnetometers. We present a scheme to enhance photon collection to improve so called shot noise limited sensitivity of magnetic field detection of this sensor type and a scheme that would allow measuring weak ac fields stroboscopically without being limited by effects dominating at very low fields like strain and NV-NV dipolar coupling.

Q 43.55 Wed 16:30 Empore Lichthof

Compact and portable atomic vapor memory for single photon storage — •Alexander Erl[1,2,3], Leon Messner[3,2], Martin Jutisz[3], Luisa Esguerra[2,1], Elizabeth Robertson[2,1], Norman Vinzenz Ewald[2], Elisa Da Ros[3], Mustafa Gündoğan[3], Markus Krutzik[3,4], and Janik Wolters[2,1] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Optische Sensorsysteme, Berlin, Germany — [3]Humboldt-Universität zu Berlin, Institut für Physik, Berlin, Germany — [4]Ferdinand-Braun-Institut, Institut für Höchstfrequenztechnik, Berlin, Germany

Quantum memories for single photons are a key component of quantum repeaters for sattelite-based quantum communication over long distances [1,2]. Memories on sattelites for feasible quantum repeater networks must be compact, maintainable and scalable. Reliable storage and retrieval of photons on demand would make a significant contribution to memory assisted quantum key distribution.

We present a compact, rack-mounted, stand-alone warm vapor quantum memory based on electromagnetically induced transparency (EIT) on the Cs D1 line at 895 nm [3]. This mobile setup realizes high fidelity light storage at single photon level with minimal readout noise level.

[1] M. Gündoğan et. al., npj Quantum Information 7, 128 (2021)
[2] N. Sangouard et. al., arXiv:0906.2699 (2009)
[3] L. Esguera, et al., arXiv:2203.06151 (2022)

Q 43.56 Wed 16:30 Empore Lichthof

Quantum network with interacting network qubits — •Emanuele Distante, Severin Daiss, Stefan Langenfeld, Stephan Welte, Philip Thomas, Lukas Hartung, Olivier Morin, and Gerhard Rempe — Max Planck Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Quantum networks can be realized out of single atoms trapped at the centre of optical resonators which stand at the network nodes and are then connected via optical fibres. In this platform, quantum information is stored into the long-lived ground states of an atom, and the resonator provide an efficient way to entangle the atomic states with flying optical photons. Traveling over the network via the fibres, photons can not only distribute the entanglement over large distance but also provide a means for making two largely separated atoms interact. In this poster we will show how this effective long-distance interaction can be exploited for the realization of different protocols. First, we present a quantum logic gate between distant atoms[1], which denote a rudimental example of distributed quantum computation, then we show the realization of a novel quantum teleportation scheme[2], as well as realization of joint nondestructive measurement on distant qubits leading to entanglement[3].

[1] S. Daiss *et al.*, Science **371**, 614-617 (2021)
[2] S. Langenfeld *et al.*, Phys. Rev. Lett. **126**, 130502 (2021)
[3] S. Welte *et al.*, Nat. Phot. **15**, 504-509 (2021)

Q 43.57 Wed 16:30 Empore Lichthof

Measuring the temporal mode function of photonic states — •Olivier Morin, Stefan Langenfeld, Matthias Körber, Philip Thomas, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Quantum physics, and quantum information in particular, relies on the accurate control of the quantum states. For optical states, while some well-establish techniques exist for the characterization of polarization and spatial degrees of freedom, it remains a non-trivial task to measure the temporal mode function of a photonic quantum state. Here we present an easy-to-implement and accurate solution [1]. Our method is based on homodyne measurements. We show that the proper processing of the auto-correlation function can give access to any complex-valued temporal mode function. Beyond the theoretical principle, we also consider the experimental constraints and provide the key aspects to obtain a trustworthy reconstruction. We have tested our method on an advanced temporal shape and reach a fidelity as high as 99.4%. This technique has also been used to characterize the complex-valued temporal shape of a single photon emitted from a CQED system. Hence, we believe that this method can be applied to many other systems and become a standard routine in quantum optics laboratories.

[1] O. Morin *et al.*, Phys. Rev. A **101**, 013801 (2020)

Q 43.58 Wed 16:30 Empore Lichthof

Characterization of Polarization Drifts on a Deployed Inter-City Fiber Link for Quantum Communication — •Pritom Paul[1,2], Gregor Sauer[2,1], Shreya Gouravaram Navalur[2,1], and Fabian Steinlechner[2,1] — [1]Institute of Applied Physics, Friedrich Schiller University Jena, Albert-Einstein-Straße 15, 07745 Jena, Germany. — [2]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Straße 7, 07745, Germany.

Quantum communication involves the transmission of quantum information between two or more distant nodes in a network by encoding it, for example into the polarization state of photons. Such photons can be transmitted to distant nodes via free space or fiber-based links. In our experiment, we use a fiber link to transmit such photons.

The state of polarization of light changes with propagation along an optical fiber. These changes are irregular over time and occur due to perturbations from the environment such as temperature fluctuations throughout the day as well as the actual movement of the fibers. In the end, one must compensate for these polarization changes in order to effectively readout the quantum correlations in the polarization degree of freedom[1]. In this work, we want to understand the different aspects of these polarization changes on a 150km deployed fiber link between Jena and Erfurt in order to develop and improve our existing polarization compensation techniques. We report on the current status of the project.

[1] C.Z. Peng, et.al, Phys. Rev. Lett. 98, 010505(2007).

Q 43.59 Wed 16:30 Empore Lichthof

Towards optical tweezer arrays for cavity based quantum information processing — •Matthias Seubert, Lukas Hartung, Stephan Welte, Emanuele Distante, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

In recent decades, single neutral atoms in a strongly coupled optical resonator have developed to a powerful tool for quantum information processing and network application [1]. Increasing the number of individually controllable atoms in this platform provides the possibility to increase the efficiency of existing protocols by multiplexing, and additionally opens the way towards novel information processing and network protocols. However, this requires precise control of the atom position within the cavity mode which is a challenging demand.

Here, we show the implementation of a tweezer setup, capable of positioning atoms within an optical cavity, using a 2D acousto-optic deflector. ^{87}Rb atoms are first loaded at the center of the cavity, then transferred into optical tweezers and finally repositioned at sub-wavelength precision. In this manner, tweezer arrays allow one to load a deterministic number of atoms and to move individual atoms from a strongly coupled to a non-coupled position. In the future, this setup offers the possibility to address individual atoms, detect or rotate their state and generate single atom-photon entanglement.

[1] A. Reiserer and G. Rempe, Rev. Mod. Phys. 87, 1379 (2015)

Q 43.60 Wed 16:30 Empore Lichthof

A quantum frequency converter for the connection of Rb atoms in a cavity over long distances — •Maya Büki, Emanuele Distante, and Gerhard Rempe — Max-Planck-Institute für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Rubidium atoms in a cavity are a promising platform for realizing long-distance quantum networks as the atomic ground states can be efficiently entangled with optical photons [1]. However, photons entangled with Rb atoms are typically at a wavelength ($\lambda_{\mathrm{Rb}} = 780\,\mathrm{nm}$) which is unfavourable for long-distance communication due to intrinsic fiber losses in this regime. To efficiently transport the quantum information encoded in optical polarisation qubits over long distances, a wavelength conversion to the telecom regime ($\lambda = 1460 - 1565\,\mathrm{nm}$) is necessary.

Here, we demonstrate such a polarisation conserving quantum frequency converter (QFC) in a Sagnac configuration [2] and investigate the possibilities of increasing the signal-to-noise ratio (SNR) by choosing a suitable final wavelength. Provided a good SNR and high fidelities, the QFC represents one of the many necessary building blocks to establish a long distance quantum network. Furthermore, it can be used to connect diverse platforms operating at different wavelengths, thus forming a hybrid quantum network which takes advantage of the specific capability of each system.

[1] A. Reiserer, G. Rempe, Rev. Mod. Phys. **87**, 1379 (2015).
[2] R. Ikuta *et al.*, Nat. Commun. **9**, 1997 (2018).

Q 43.61 Wed 16:30 Empore Lichthof

Transport waveforms for through-junction ion transport on surface-electrode ion traps for a QCCD architecture — •Rodrigo Munoz[1], Florian Ungerechts[1], Axel Hoffmann[1,2], Brigitte Kaune[1], Teresa Meiners[1], and Christian Ospelkaus[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Institut für Hochfrequenztechnik und Funksysteme, Leibniz Universität Hannover, Appelstraße 9a, 30167 Hannover, Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Register-based ion traps are among the leading approaches for scalable quantum processors. These are defined by the spatial division of different operations such as storage, state preparation and readout. A fundamental characteristic of the register-based approach is the translation of ions to reach the different registers of the QCCD architecture. Here, we discuss registers interconnected through a x-junction. We will focus on the necessary through-junction transport.

We will present the different constraints applied to our optimization algorithm in order to obtain trapping potentials for different ion species. Besides, we will also discuss additional conditions that allow a reliable trough-junction transport.

Q 43.62 Wed 16:30 Empore Lichthof

A Quantum Network Node with Crossed Fiber Cavities — •Tobias Frank[1], Gianvito Chiarella[1], Pau Farrera[1], Manuel Brekenfeld[1], Joseph Christesen[1,2], and Gerhard Rempe[1] — [1]MPQ, Hans-Kopfermann-Str. 1, 85748Garching, Germany — [2]NIST, Boulder, Colorado 80305, USA

Recent development in the field of optical cavity QED mainly concern a further reduction of the mode volumes of the resonators, driven by the development of fiber-based Fabry-Perot cavities (FFPCs) [1], and an increase in the number of well-controlled modes the emitters can couple to. We implemented an experiment which combines these two experimental advancements in a single platform consisting of single neutral atoms trapped at the center of two crossed FFPCs. Exploiting the possibilities provided by this platform, we have realized a quantum network node that couples to two spatially and spectrally distinct quantum channels. The node functions as a passive heralded quantum memory [2], achieving a heralded average state fidelity of $94.7 \pm 0.2\,\%$ and neither requires amplitude- or phase-critical control fields [3] nor error-prone feedback loops [4]. Our platform is therefore excellently suited for the realization of future large-scale quantum networks and quantum repeaters.

[1] Hunger et al., New J. Phys. 12, 065038 (2010)
[2] Brekenfeld et al., Nature 591, 570 (2020)
[3] Specht et al., Nature 473, 190 (2011)
[4] Kalb et al., Phys. Rev. Lett. 114, 220501 (2015)

Q 43.63 Wed 16:30 Empore Lichthof

Nondestructive detection of photonic qubits — •Pau Farrera, Dominik Niemietz, Stefan Langenfeld, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching, Germany

Qubits encoded in single photons are very useful to distribute quantum information over remote locations, but at the same time are also very fragile objects. The loss of photonic qubits (through absorption, diffraction or scattering) is actually the main limitation in the maximum reachable quantum communication distance. In this context, the nondestructive detection of photonic qubits is a great scientific challenge that can help tracking the qubit transmission and mitigate the loss problem. We recently implemented such a detector [1] with a single atom coupled to two crossed fiber-based optical resonators, one for qubit-insensitive atom-photon coupling and the other for atomic-state detection. We achieve a nondestructive detection efficiency of 79(3)% conditioned on the survival of the photonic qubit, a photon survival probability of 31(1)%, and we preserve the qubit information with a fidelity of 96.2(0.3)%. To illustrate the potential of our detector we show that it can provide an advantage for long-distance entanglement and quantum-state distribution, resource optimization via qubit amplification, and detection-loophole-free Bell tests.

[1] D. Niemietz et al., Nature 591, 570-574 (2021)

Q 43.64 Wed 16:30 Empore Lichthof

Towards a compact polarization entanglement source based on WGMR — •Sheng-Hsuan Huang[1,2], Thomas Dirmeier[1,2], Golnoush Shafiee[1,2], Alexander Otterpohl[1,2], Florian Sedlmeir[1,2], Dmitry Strekalov[3], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91108, USA

Crystalline Whispering Gallery Mode Resonators (WGMR) made from nonlinear materials have been proven to be compact and efficient sources of quantum states, e.g. squeezed states [1] or narrow-band heralded single photons[2,3]. Another feature of WGMR is, that it is possible to couple two pump beams propagating in opposite directions at the same time. As a result, we can treat the WGMR similar to a Sagnac interferometer which is simultaneously a pair of two independent and indistinguishable SPDC sources. Combined, these features make WGMR a potential platform for developing compact and narrow-band entanglement sources.

In our presentation, we discuss the concept and progress of developing a compact polarization entanglement source based on a WGMR that is pumped from two directions.

[1]A. Otterpohl, et.al., Optica 6, 1375-1380 (2019)
[2]J. U. Fürst, et al., Physical review letters 104.15 153901 (2010)
[2]M. Förtsch, et al., Physical Review A 91(2) 023812 (2015)

Q 43.65 Wed 16:30 Empore Lichthof

Apparatus design for scalable cryogenic trapped-ion quantum computing experiments — •Lukas Kilzer, Tobias Pootz, Celeste Torkzaban, Timko Dubielzig, and Christian Ospelkaus — Institute of Quantum Optics, Leibniz University Hannover

Further progress in trapped-ion quantum computing requires a dramatic increase in the number of ion qubits that can interact with each other. We describe the design of cryogenic demonstrator machines for this task, focusing on the implementation of surface-electrode ion traps. Trap design and implementation is facilitated through the use of a universal interchangeable socket. The apparatus design is based on a vibration isolated cold head to cool a cryogenic vacuum system to temperatures around 5K. The apparatus features a high density of DC control lines to support transport of qubits through complex processor structures including junctions, dedicated storage, detection and manipulation registers. Multi-qubit quantum gates can be implemented through the use of chip-integrated microwave methods. Two setups are currently under construction, the first being based on $^{9}\mathrm{Be}^{+}$ qubits and $^{40}\mathrm{Ca}^{+}$ ions for sympathetic cooling; the second setup will be based on $^{43}\mathrm{Ca}^{+}$ qubits and $^{88}\mathrm{Sr}^{+}$ cooling ions. The first setup will benefit from our experience with the $^{9}Be^{+}$ qubit, whereas the second setup with longer wavelengths for cooling and detection will be amenable for integrated chip-integrated photonics. The system has been designed to accommodate the integration of new components for scaling as the development of the underlying enabling technologies progresses.