QI 4: Poster: Quantum Information

Time: Monday 18:00–20:00 Location: P2

QI 4.1 Mon 18:00 P2

Toward Digital-Analog Simulations using Superconducting Qubits and Resonators — •Riccardo Roma[1], Frank Wilhelm-Mauch[1,2], and Dmitry Bagrets[2,3] — [1]Theoretical Physics, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Forschungszentrum Jülich GmbH, Germany — [3]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937 Köln, Germany

We propose a novel architecture for processors based on superconducting qubits coupled to resonators for digital-analog simulations of bosonic-fermionic systems. More in detail we present some preliminary results of the numerical analysis of a system composed of a pair of superconducting qubits, each coupled to an ancillary qubit via a resonator, interacting with a cross-resonance gate.

QI 4.2 Mon 18:00 P2

Electronic Structure Simulations for Batteries and Fuel Cells Using a Quantum Computer — •Konstantin Lamp[1,2], Alejandro D. Somoza[1], Felix Rupprecht[1], Marina Walt[3], Nicolas Vogt[3], Giorgio Silvi[3], and Birger Horstmann[1,2] — [1]German Aerospace Center, Wilhelm-Runge Straße 10, 89081 Ulm — [2]Helmholtz Institute Ulm, Helmholtzstraße 11, 89081 Ulm — [3]HQS Quantum Simulations GmbH, Haid-und-Neu-Strasse 7, 76131 Karlsruhe

In the context of modern energy devices like batteries and fuel cells a description of challenging molecular structures is vital for the advancement of these technologies. However, classical algorithms for the simulation of such systems suffer from an exponential growth in required resources, which may be avoided by exploiting the correspondence between chemical orbitals and qubits of a quantum computer.

In this work, we show a variety of hybrid quantum algorithms for electronic structure calculations performed on the IBM System One quantum computer with state-of-the-art techniques of error mitigation and noise characterization. In particular, we focus on a class of hybrid algorithms that leverage additional measurements on the quantum processor without an increase in the complexity of the quantum circuits, like VQSE [Phys.Rev.X 10, 011004] and an extension of the QEOM method [Phys.Rev.Res. 2, 043140]. Furthermore, we investigate techniques like Entanglement Forging [arXiv:2104.10220] that exploit partitions of the initial problem into strongly correlated sectors in order to achieve efficient quantum simulations of larger systems.

QI 4.3 Mon 18:00 P2

Quantum simulation of the transverse field Ising models — •Sumeet Sumeet and Kai Phillip Schmidt — Friedrich-Alexander-Universität Erlangen-Nürnberg, Department of Physics, Staudtstraße 7, 91058 Erlangen, Germany

With the advancements in quantum technologies, it has become inevitable to investigate the potential existence of quantum advantages for quantum many-body systems. One of the most paradigmatic model is the transverse field Ising model (TFIM) that can be simulated on a quantum computer to compute properties such as the ground-state energy. This problem, when tackled on a classical computer, leads to an exponential surge in the cost of computation with increasing system size. Classical-quantum hybrid algorithms such as the Variational Quantum Eigensolver (VQE) algorithm, is considered reasonably good for obtaining the ground-state energy of quantum many-body systems in the current NISQ era. Here we explore various ansaetze, focusing mainly on the Hamiltonian variational ansatz, for calculating the ground-state energy of one-dimensional TFIMs. We devise strategies to compute the ground-state energy for relatively large spin systems leveraging the power of quantum computers. In addition to that, we explore the quantum advantage and access the resource requirement for a quantum computer to evaluate the properties of systems in difficult regions around the quantum phase transition, which is a computationally difficult problem for a classical computer. Further, we extend our considerations to explore geometrically frustrated TFIMs using quantum simulation.

QI 4.4 Mon 18:00 P2

Estimating the entangling power of a two-qubit gate from measurement data: artificial neural networks and randomized measurements versus standard tomography methods — •Salwa Shaglel — Universität Siegen, Siegen, Germany

Quantum logic gates are the building blocks of quantum circuits and algorithms, where the generation of entanglement is essential to perform quantum computations. The amount of entanglement that a unitary quantum gate can produce from product states can be quantified by the so-called entangling power, which is a function of the gate's unitary or Choi matrix representation.

I introduce two efficient approaches to the practical problem of estimating the entangling power of an unknown two-qubit gate from measurement data. The first approach is using a deep neural network trained with noisy data simulating the outcomes of prepare-and-measure experiments on random gates. The training data is restricted to 48 measurement settings, which is significantly less than the 256 dimensions of the ambient space of 16x16 Choi matrices and very close to the minimum number of settings that guarantees the recovery of a two-qubit unitary gate using the compressed sensing technique at an acceptable error rate. The second approach to determine the entangling power is based on the second moments of correlation functions obtained from locally randomized measurements. The two approaches do not make any prior assumptions about the quantum gate, and they also avoid the need for standard reconstruction tools based on full quantum process tomography, which is prone to systematic errors.

QI 4.5 Mon 18:00 P2

Frequency-degenerate Josephson mixer for quantum illumination — •Fabian Kronowetter[1,2,3], Florian Fesquet[1,2], Maria-Teresa Handschuh[1,2], Kedar Honasoge[1,2], Yuki Nojiri[1,2], Michael Renger[1,2], Achim Marx[1], Frank Deppe[1,2,4], Rudolf Gross[1,2,4], and Kirill G. Fedorov[1,2] — [1]Walther-Meißner-Institut, BAdW, 85748 Garching, Germany — [2]Physik-Department, TUM, 85748 Garching, Germany — [3]Rohde & Schwarz GmbH, 81671 Munich, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

In quantum illumination, the joint measurement of the signal and idler beams enables a quantum advantage in target detection, as compared to the ideal classical radar. This advantage is predicted to exist for the case of weak quantum signals propagating in a bright thermal background, where the latter potentially contains a weakly reflecting target. The joint measurement exploits non-classical correlations between the signal and idler modes. A promising detector concept allowing for a theoretical 3 dB quantum advantage implements this joint measurement by exploiting a frequency-degenerate Josephson mixer (JM). The circuit of this JM consists of two 180° hybrid ring beam splitters and two flux-driven Josephson parametric amplifiers. We present the first successful operation of the frequency-degenerate JM with Gaussian states and, thus, demonstrate an important milestone for the realization of the microwave quantum radar.

QI 4.6 Mon 18:00 P2

Fabrication of low-loss Josephson parametric circuits — •Kedar E. Honasoge[1,2], Yuki Nojiri[1,2], Daniil E. Bazulin[1,2], Leon Koch[1,2], Thomas Luschmann[1,2], Niklas Bruckmoser[1,2], Maria-Teresa Handschuh[1], Florian Fesquet[1,2], Michael Renger[1,2], Fabian Kronowetter[1,2,4], Achim Marx[1], Stefan Filipp[1,2,3], Rudolf Gross[1,2,3], and Kirill G. Fedorov[1,2] — [1]Walther-Meißner-Institut, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [4]Rohde & Schwarz GmbH, Munich, Germany

Interest in quantum-limited amplification based on Josephson superconducting circuits has increased drastically in the past decade due to the rapidly advancing field of quantum information processing. In this context, a key challenge lies in realizing low-loss superconducting devices by minimizing energy dissipation. We achieve this goal by employing various cleaning steps during fabrication of superconducting circuits. Respectively, we fabricate Josephson parametric amplifiers with internal quality factors in excess of 10^4. We characterize bandwidth, gain, noise, dynamic range, and other properties of the realized devices. Based on these investigations, we derive useful criteria for development of more intricate Josephson parametric circuits, such as

Josephson parametric converters.

QI 4.7 Mon 18:00 P2

Perspectives of microwave quantum key distribution — •Florian Fesquet[1,2], Fabian Kronowetter[1,2,4], Michael Renger[1,2], Kedar Honasoge[1,2], Yuki Nojiri[1,2], Maria-Teresa Handschuh[1,2], Achim Marx[1,2], Rudolf Gross[1,2,3], and Kirill. G. Fedorov[1,2] — [1]Walther- Meißner-Institut, 85748 Garching, Germany — [2]Physik-Department, TUM, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [4]Rohde & Schwarz GmbH, 81671 Munich, Germany

One of the cornerstones of quantum communication is an unconditionally secure distribution of classical keys between remote parties. This can be achieved by exploiting quantum features of electromagnetic waves, such as entanglement or the no-cloning theorem. However, these quantum resources are known to be susceptible to noise and losses, which are omnipresent in open-air communication scenarios. Here, we theoretically investigate the perspectives of continuous-variable open-air quantum key distribution (QKD) at microwave frequencies. We demonstrate that continuous-variable QKD with propagating microwaves can be unconditionally secure at room temperatures at distances up to 200 meters. Furthermore, we show that microwave QKD provides the potential to outperform conventional QKD protocols at telecom wavelengths for certain weather conditions

QI 4.8 Mon 18:00 P2

Simulating quantum repeaters with experimentally relevant parameters — •Julius Wallnöfer[1], Fabian Wiesner[1], Frederik Hahn[1], Nathan Walk[1], and Jens Eisert[1,2] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany

The quantum repeater protocol is a well established standard for distributing entanglement over long distances. However, there are a number of open questions when considering setups that go beyond the standard scenarios and error models. We have developed a numerical simulation platform for quantum repeaters to explore in multiple directions:

(i) With experiments of small scale quantum repeaters becoming a reality, it is of high interest to explore detailed error models that are close the real situations found in the experiment. Our simulation allows us to not only compare setups with different parameters, but also to assess the effect of improving certain aspects has on e.g. the achievable key rate.

(ii) We explore conceptual questions in larger scale quantum repeaters outside of standard situations - especially in asymmetric setups where e.g. the length or quality of quantum channels is not identical. Furthermore, we investigate strategies for quantum repeaters when considering entanglement purification and multi-mode memories.

QI 4.9 Mon 18:00 P2

Rare earth ion materials in micro-cavities as optically addressable qubits for quantum information — •Jannis Hessenauer[1], Christina Ioannou[1], Kumar Senthil Kuppusamy[1], Mario Ruben[1], Diana Serrano[2], Philippe Goldner[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]Université PSL, Chimie ParisTech, CNRS, Paris, France

Rare earth ions retain long optical and spin coherence times in solid state hosts and are therefore a promising realization of optically addressable spin qubits. Due to the dipole forbidden nature of the optical transitions, an efficient spin-photon interface for quantum information technology requires the coupling of single ions to an optical cavity to enhance the transitions via the Purcell effect. Recently, rare earth ions in molecular crystals have demonstrated outstanding coherence properties, while also promising a large parameter space for optimization by chemically engineering of the host molecule. We characterize the optical properties of molecular materials at low temperature using techniques such as photoluminescence spectroscopy, absorption spectroscopy and spectral hole burning. Furthermore, we present our progress towards integrating Yb^{3+}-doped materials into stable high finesse fiber-based Fabry-Pérot cavities.

QI 4.10 Mon 18:00 P2

Circular Bragg gratings for Integrated Enhancement of Quantum Emitters — •Dario Mekle, Jonas Grammel, and David Hunger — Physikalisches Institut, Karlsruher Institut für Technologie

Surface-emitting center-disk cavities, composed of circular Bragg gratings have been successfully employed for distributed feedback lasers and quantum emitter applications based on nitrogen vacancy centers and semiconductor quantum dots.

We aim to transfer this approach to achieve greater collection efficiencies of rare earth ion based emitters in the form of nanocrystals and molecules. The collection efficiency is improved through the use of cavity induced Purcell enhancement and by utilizing directional field emission patterns. A finite element analysis is used to perform geometric parameter optimizations of circular Bragg cavities consisting of PMMA (or similar polymers) and air layers.

The simulation predicts a Purcell factor of more than 140, significantly higher than previously published results. We report on progress in fabricating the simulated structures using electron beam lithography on gold substrates.

QI 4.11 Mon 18:00 P2

Enhancing the optical emission of erbium dopants in silicon with photonic crystals — •Florian Burger[1,2], Lorenz Weiss[1,2], Andreas Gritsch[1,2], Stephan Rinner[1,2], Johannes Früh[1,2], and Andreas Reiserer[1,2] — [1]Max Planck Institute of Quantum Optics, Garching bei München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), LMU Munich, Germany

Silicon photonics has developed into a mature technology platform that allows for rapid development cycles using standardized tools. Integrating coherent optical emitters into silicon chips would pave the way towards large-scale quantum networks. In this context, we explore the use of erbium dopants which feature both long spin coherence times and coherent optical transitions in the telecom C band, where the loss in optical fibers is minimal. Using low-loss nanowire waveguides, we performed resonant spectroscopy and were able to confirm the integration of erbium dopants at well-defined lattice sites, with narrow inhomogeneous linewidths of approximately 1 GHz and homogeneous linewidths of less than 20 kHz at temperatures below 8 K. As the practical use of the investigated transitions is hampered by their long excited-state lifetime, we plan to enhance the emission with tailored photonic nanostructures. To this end, we have designed and fabricated nanophotonic cavities, offering strong narrow-band Purcell enhancement, as well as photonic-crystal waveguides with moderate broadband Purcell enhancement. We will present details about the design and fabrication of these structures, and give an outlook on the control of single erbium dopants in silicon.

QI 4.12 Mon 18:00 P2

Cavity-enhanced spectroscopy of molecular quantum emitters — •Evgenij Vasilenko, Weizhe Li, Nicholas Jobbitt, Senthil Kuppusamy, Mario Ruben, and David Hunger — Kalrsruhe Institute of Technology (KIT)

Rare earth ions in solid-state hosts are a promising candidate for optically addressable spin qubits, owing to their excellent optical and spin coherence times. Recently, also rare earth ion-based molecular complexes have shown excellent optical coherence properties [1]. Due to the long optical lifetime of the optical transition $^5D_0$-$^7F_0$, an efficient spin-photon interface for quantum information processing requires the coupling of single ions to a microcavity. Open-access Fabry-Pérot fiber cavities have been demonstrated to achieve high quality factors and low mode volumes, while simultaneously offering large tunability and efficient collection of the cavity mode [2]. Since the used molecular quantum emitters require a cryogenic environment, the demands on mechanical stability of the cavity setup have a high priority. To tackle these challenges, we report on the development of a monolithic type of cavity assembly, sacrificing some lateral scanning ability for the purpose of significantly increasing the passive stability. We integrate molecules into the cavity in the form of a crystalline thin film on a macroscopic mirror and identify a sub-nanometer local surface roughness, sufficient to avoid excessive scattering loss. We report on first studies of cavity-enhanced emission spectroscopy.

[1] Serrano et al., to appear in Nature, arXiv:2105.07081
[2] Hunger et al., New J. Phys 12, 065038 (2010)

QI 4.13 Mon 18:00 P2

Finite-range multiplexing in tripartite quantum networks — •Julia Alina Kunzelmann, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf

Due to the interaction between qubits and their environment, long-distance communication still poses a challenge. To overcome this problem, quantum repeaters are used, in which the repeater rate can be maximized by utilizing multiplexing. In previous work (Abruzzo et al. (2014)), a finite-range multiplexing protocol for two parties was investigated. We extend this protocol to three parties and it turns out that also in the tripartite network, full-range multiplexing does not provide substantial advantages over finite-range multiplexing. We also analyze decoherence of quantum memories and various strategies to lower the experimental requirements. To achieve this, different three-dimensional matching strategies are analyzed.

QI 4.14 Mon 18:00 P2

Integrated Photonic Information Processing for Quantum Networks — •Jeldrik Huster[1], Simon Abdani[1], Jonas Zatsch[1], Christian Schweikert[2], Rouven Klenk[2], and Stefanie Barz[1] — [1]Institute for Functional Matter and Quantum Technologies & IQST, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute of Electrical and Optical Communications Engineering, University of Stuttgart, 70569 Stuttgart, Germany

The steady progression of photonic quantum systems allows the realisation of quantum computation, communication and networked applications. Key in pursuit of scalable photonic quantum technology are integrated devices operating in the telecom regime, due to their small footprint, high phase stability and low loss connectivity. Particularly, the generation of multipartite entangled states is of special interest. These states are the basis for measurement-based quantum computing and multiparty key exchange. Here, we present our recent progress on silicon-photonic quantum circuits operating at the single-photon level. The circuits consist of tuneable beam splitters, phase shifters and highly efficient grating couplers. They are powered by spontaneous parametric down conversion sources and used in combination with superconducting single-photon detectors. We show the characterisation of integrated devices and a pathway to generate complex entangled sates in an integrated manner.

QI 4.15 Mon 18:00 P2

Entanglement distribution over a cryogenic microwave link — •Simon Gandorfer[1,2], Michael Renger[1,2], Wun Kwan Yam[1,2], Florian Fesquet[1,2], Kedar Honasoge[1,2], Fabian Kronowetter[1,2,3], Yuki Nojiri[1,2], Maria-Teresa Handschuh[1,2], Achim Marx[1], Rudolf Gross[1,2,4], and Kirill G. Fedorov[1,2] — [1]Walther-Meißner-Institut, 85748 Garching, Germany — [2]Physik-Department, TUM, 85748 Garching, Germany — [3]Rohde & Schwarz GmbH & Co. KG, 81671 Munich, Germany — [4]Munich Center for Quantum Science and Technology, 80799 Munich, Germany

In the context of rapid progress in quantum technologies, the realization of hardware platforms for quantum communication networks is of utmost importance. Quantum local area networks connecting remote superconducting quantum nodes are crucial for the implementation of distributed quantum computing architectures. In this regard, we demonstrate a 6.5 m cryogenic link connecting two dilution cryostats via a cold network node. The respective microwave quantum communication channel is realized with superconducting microwave coaxial cables cooled to temperatures below 100 mK. By using this system, we demonstrate a successful distribution of squeezed states and two-mode entanglement between the remote dilution fridges and validate robustness of the quantum state transfer up to channel temperatures of 1 K.

QI 4.16 Mon 18:00 P2

Efficient spin-photon interface for NV centers in diamond — •Jeremias Resch[1], Kerim Köster[1], Maximillian Pallmann[1], Julia Heupel[2], Cyril Popov[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie (KIT) — [2]Universität Kassel

In order to achieve spin-photon-based quantum computers, we require excellent control of the qubit spin states, in addition to long coherence times of the nuclear spin states. By combining several computing nodes, and linking them to a global register via optical networks, scalability is achieved. A crucial component of this optical network is an efficient, coherent single-photon source. Coupling colour centers in diamond, such as the nitrogen-vacancy or tin-vacancy centers, to a microcavity is a promising approach in order to achieve efficient single-photon sources. In our experiment, we integrate a diamond membrane into an open access fiber-based Fabry-Perot microcavity to attain emission enhancement into a single well-defined mode. We present our fully tunable, cryogenic cavity platform operating in a closed-cycle cryostat, and we achieve a sub-picometer mechanical stability during quiet periods. We observe cavity-enhanced fluorescence spectra of an ensemble of shallow-implanted nitrogen-vacancy centers in diamond, showing Purcell-enhancement of the zero-phonon line.

QI 4.17 Mon 18:00 P2

Designing a microwave antenna for spectroscopy of nitrogen vacancy centers in a fiber-based cavity — •Matthias Klausmann, Maximilian Pallmann, Jeremias Resch, and David Hunger — Karlsruher Institut für Technologie

Overcoming losses in long distance fiber-based quantum networks is one of the big challenges in the field of quantum communication, which requires the development of a quantum repeater. Color centers in diamond are a promising platform for realizing the needed spin-photon interfaces due to the possibility of optical readout and initialization. The optical readout of coherent photons can be enhanced by integrating the diamond in a cavity by exploiting the Purcell-effect. In addition, the coherent control of the electron spin of the color center and nearby nuclear spins is necessary for such a device.

In our experiment, we look for different designs of microwave antennas to manipulate the electron spin of nitrogen vacancy centers in a fiber-based Fabry-Pérot micro-cavity with regard that this can also be used under cryogenic conditions. Testing the antenna designs is performed in a room-temperature confocal microscope setup. We observe large ensembles of shallow implanted nitrogen-vacancy centers but also single centers at a depth of a few micrometers below the diamond surface. With our antennas we are able to perform pulsed optically detected magnetic resonance, Rabi and Echo measurements. Using this measurement protocols, the hyperfine interaction between the electron spin and the nuclear spin of the hosting nitrogen atom as well as the interaction with a nearby 13C nuclear spin can be resolved.

QI 4.18 Mon 18:00 P2

Microwave quantum teleportation over thermal channels — •Wun Kwan Yam[1,2], Michael Renger[1,2], Simon Gandorfer[1,2], Florian Fesquet[1,2], Kedar Honasoge[1,2], Fabian Kronowetter[1,2,3], Yuki Nojiri[1,2], Maria-Teresa Handschuh[1,2], Achim Marx[1], Rudolf Gross[1,2,4], and Kirill G. Fedorov[1,2] — [1]Walther-Meißner-Institut, BAdW, 85748 Garching, Germany — [2]Physik-Department, TUM, 85748 Garching, Germany — [3]Rohde & Schwarz GmbH & Co. KG, 81671 Munich, Germany — [4]Munich Center for Quantum Science and Technology, 80799 Munich, Germany

Microwave quantum communication enables quantum local area networks between superconducting quantum processors and, thereby, paves the way towards distributed quantum computing. Quantum teleportation belongs to the most relevant quantum communication protocols. It permits efficient and unconditionally secure transfer of quantum states. Recent experimental demonstration of quantum teleportation with propagating microwaves [1] motivates the investigation of its resilience against experimental imperfections. To this end, we analyze the effect of thermal noise in the analog feedforward channel. We show that quantum teleportation implements an error correction scheme for loss and noise in the feedforward signal. Furthermore, we consider realistic operating parameters and find that the teleportation fidelity can exceed the no-cloning threshold for finite energy codebooks.

[1] K. G. Fedorov et al., "Experimental quantum teleportation of propagating microwaves", Sci. Adv. 7, eabk0891 (2021)

QI 4.19 Mon 18:00 P2

Quantum Polyspectra - Grand Unified Theory of Continuous Quantum Measurements — •Markus Sifft and Daniel Hägele — Ruhr University Bochum, Faculty of Physics and Astronomy, Experimental Physics VI (AG), Germany

The evaluation of continuous quantum measurements is a challenge in research areas like circuit quantum electrodynamics, spin noise spectroscopy, and quantum sensing. Measurement records can exhibit as diverse results as quantum jumps, mainly Gaussian noise, or even stochastic peaks from detectors with single photon resolution. Until now, specialized theories were used to model and eventually evaluate such measurement records. The poster reports on our recent progress in unifying all continuous measurement schemes into one theory. The theory is based on the measurement record, its power spectrum, and its third and fourth order generalizations, so-called polyspectra. Expressions for quantum polyspectra can be derived without approximation from the stochastic master equation [1]. System parameters follow from fitting quantum polyspectra to measured spectra [2]. This approach allows for a systematic evaluation of quantum measurements including coherent quantum dynamics, environmental damping, and measurement backaction at arbitrary measurement strength (Zeno-physics). We present and interpret quantum polyspectra of conventional spin noise spectroscopy, quantum transport through quantum dots, and spin noise spectroscopy in the single-photon regime.

[1] Hägele et al., PRB 98, 205143 (2018), [2] Sifft et al., PRR 3, 033123 (2021)

QI 4.20 Mon 18:00 P2

Multipartite High-dimensional Quantum Steering — •Sophie Egelhaaf and Roope Uola — Department of Applied Physics, University of Geneva, 1211 Geneva, Switzerland

Bipartite low dimensional entanglement has been studied extensively. However, many findings cannot be extrapolated to multiple parties and moreover, increasing the dimensions of the systems adds complexity to the entanglement structure.

We are interested in characterising the degree of high-dimensional entanglement, specifically focusing on various multipartite quantum steering scenarios. One such example is a triangle network with only one trusted party, or more generally a line network with some trusted parties. We investigate what can be deduced about the strength of entanglement between the different nodes of the network in such scenarios. We are especially interested in entanglement dimensionality, i.e. the question of how many degrees of freedom can be certified to be entangled, for which we provide analytical bounds.

QI 4.21 Mon 18:00 P2

Gate-error characterization via long-sequence quantum process tomography — •Andreas Ketterer and Thomas Wellens — Fraunhofer Institut für Angewandte Festkörperphysik (IAF), Tullastr. 72, 79108 Freiburg, Germany

Currently available quantum computing hardware realizes networks of tens of super-conducting qubits with the possibility of controlled nearest-neighbor interactions. However, the inherent noise and decoherence effects of such quantum chips considerably alter basic gate operations and lead to imperfect outputs of the targeted quantum computation. We show how to characterize such quantum gate errors in detail using a combination of quantum process and gate set tomography in order to estimate a complete set of single- and two-qubit gate operations. Key ingredients of our approach are the efficient characterization of a universal single qubit gate set via gate-set tomography and the subsequent reconstruction of one additional two-qubit entangling gate using a long-sequence version of quantum process tomography. The latter involves repeated applications of the respective target gate in combination with appropriately chosen single-qubit operations in order to assure a precise estimation of all involved error parameters. Lastly, we demonstrate the devised protocol by implementing it on IBMQ hardware and briefly discuss the impact of crosstalk effects on near-term quantum algorithms.

QI 4.22 Mon 18:00 P2

Solvable projected entangled pair states for ternary unitary quantum gates — •Richard Maximilian Milbradt[1], Christopher Assmus[1], and Christian Bernhard Mendl[1,2] — [1]Technical University of Munich, Department of Informatics, Boltzmannstraße 3, 85748 Garching, Germany — [2]Technical University of Munich, Institute for Advanced Study, Lichtenbergstraße 2a, 85748 Garching, Germany

Recently we introduced the so-called ternary unitary quantum gates. These are four-particle gates acting in 2+1-dimensions and are unitary in time and both spatial dimensions. Now we generalise the concept of solvable MPS[Phys. Rev. B 101, 094304 (2020)] to two spatial dimensions with cylindrical boundary conditions. We show that such *solvable PEPS* can be identified with matrix product unitaries. In the resulting tensor network for evaluating equal-time correlation functions, the bulk ternary unitary gates cancel out, and we delineate and implement a numerical algorithm for computing such correlations.

QI 4.23 Mon 18:00 P2

Towards digital-analog quantum computing with superconducting qubits — Julia Lamprich[1], Nicola Wurz[1], •Stefan Pogorzalek[1], Manish Thapa[1], Vicente Pina-Canelles[1], Antti Vepsäläinen[2], Miha Papič[1], Jayshankar Nath[1], Florian Vigneau[1], Daria Gusenkova[1], Ping Yang[1], Hermanni Heimonen[2], Hsiang-Sheng Ku[1], Adrian Auer[1], Johannes Heinsoo[2], Frank Deppe[1], and Inés de Vega[1] — [1]IQM Quantum Computers, Nymphenburgerstr. 86, 80636 Munich, Germany — [2]IQM Quantum Computers, Keilaranta 19, FI-02150 Espoo, Finland

Digital-Analog Quantum Computing (DAQC) is a novel approach to quantum computing. Here, one variant is banged DAQC where single qubit gates are applied on top of an analog (entangling) evolution. We have investigated the experimental and fundamental challenges in realizing banged DAQC for the example of preparing a Bell state. The main challenge in banged DAQC is the correct execution of single qubit gates under simultaneous qubit-qubit interaction. The latter is induced by a flux-tunable coupler element, which allows for the accumulation of conditional phase during the analog block. In addition, banged DAQC is compared to an alternative approach called stepwise DAQC, where the single qubit gates are executed only when the qubits do not interact. For both approaches, the relevant error sources are identified and fidelities are compared to the purely digital case.

We acknowledge support from the German Federal Ministry of Education and Research via the projects DAQC (13N15686) and Q-Exa (13N16062).

QI 4.24 Mon 18:00 P2

Thermo-optical properties of superconducting thin films for waveguide-integrated single-photon detectors. — •Anthony Chukwunonso Ogbuehi[1,2], Pierre Piel[1,2], Martin Wolff[1,2], Matthias Häussler[1,2], Carsten Schuck[1,2], and Ursula Wurstbauer[1,2] — [1]Institute of Physics, Münster University, Germany — [2]Center for Soft Nanoscience SoN, Münster University, Germany

Integrated quantum photonics relies on the generation, manipulation, and measurement of single quantum states of light. The latter can be achieved with superconducting nanowire single-photon detectors (SNSPD) embedded into photonic integrated circuits [1]. While SNSPDs show attractive detection efficiency and high timing accuracy [2], it remains largely unknown how detector performance characteristics are connected to superconducting material properties. Here we study the temperature-dependent dielectric function of niobium-titanium nitride (NbTiN) thin films above and below the critical temperature by means of spectroscopic ellipsometry by varying a number of parameters. Material optimization guided by spectroscopic ellipsometry provides a novel approach for both getting new insight into key parameters of the detection process and improving single-photon detector benchmarks, benefitting a wide range of integrated quantum technology applications.

[1] S. Ferrari et al., Nanophotonics 7, 1725 (2018) [2] M. A. Wolff et al., Appl. Phys. Lett. 118, 154004 (2021).

QI 4.25 Mon 18:00 P2

Quantum Possibilistic Paradoxes and Logical Contextuality — •Leonardo Santos — Universität Siegen, Siegen, Germany

Contextuality and nonlocality are nonclassical properties exhibited by quantum statistics whose implications profoundly impact both the foundations and applications of quantum theory. In this contribution we provide some insights into logical contextuality and inequality-free proofs. The former concept can be understood as the possibility version of contextuality, while the latter refers to proofs of quantum contextuality or nonlocality that are not based on violations of some noncontextuality (or Bell) inequality. By *possibilistic* we mean a description in terms of possibilities for the outcomes, which are Boolean variables assuming value 1 when the corresponding probability is strictly larger than zero and 0 otherwise. In this work we built a bridge between these two concepts from what we call possibilistic paradoxes, which are sets of possibilistic conditions whose occurrence implies contextuality and nonlocality. As the main result, we demonstrate the existence of possibilistic paradoxes whose occurrence is a necessary and sufficient condition for logical contextuality in a very important class of scenarios. Finally, we discuss some interesting consequences arising from the completeness of these possibilistic paradoxes.

QI 4.26 Mon 18:00 P2

Generating Entangled States on IBM Quantum — Sebastian Brandhofer[1], Jelena Mackeprang[2], •Daniel Bhatti[2], Ilia Polian[1], and Stefanie Barz[2] — [1]Institute of Computer Architecture and Computer Engineering & IQST, University of Stuttgart, Germany — [2]Institute for Functional Matter and Quantum Technologies & IQST, University of Stuttgart, Germany

Commercially available quantum computers have reached the NISQ era and already can be employed to run basic quantum algorithms. One of the most important resources for quantum computations are entangled multi-qubit quantum states. Therefore, it is necessary to produce these states deterministically and with a high fidelity. Based on the specific physical architectures of different IBM quantum computers we produce graph states and GHZ states with the help of CPHASE and CNOT gates, respectively, and assess the quality of the state preparation. To optimize the resulting state fidelities, we develop and implement a classical optimization algorithm that considers various error characteristics of the qubits and the two-qubit gates.

QI 4.27 Mon 18:00 P2

Quantum circuits for the preparation of spin eigenfunctions on quantum computers — •Alessandro Carbone[1,2], Davide Emilio Galli[2], Mario Motta[3], and Barbara Jones[3] — [1]Theory and Simulations of Materials (THEOS), and National Centre for Computational Design and Discovery of Novel Materials (MARVEL), École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [2]Dipartimento di Fisica, Università degli Studi di Milano, via Celoria 16, 20133 Milano, Italy — [3]IBM Quantum, IBM Research Almaden, 650 Harry Road, San Jose, CA 95120, USA

The preparation of accurate and efficient approximations for Hamiltonian eigenstates on quantum computers is a crucial step for building the quantum advantage when studying many-body quantum systems. If we can describe molecules or materials with a coarse-grained spin Hamiltonian, spin eigenfunctions can be a useful starting point for simulations which aim to understand their electronic structure. In particular the purpose of this work is to delve into the description of the quantum circuits which prepare total spin eigenfunctions in the case of spin-1/2 systems. We investigate the balance between generality, accuracy, and computational cost in the encoding of spin eigenfunctions by quantum circuits without ancillary qubits, by pursuing two approaches: an exact recursive construction of spin eigenstates, and a heuristic variational construction of approximate spin eigenstates. We have tested the described quantum circuits on the available IBM (classical) simulators and quantum devices in the cases of 3-spin and 5-spin systems.

QI 4.28 Mon 18:00 P2

Performances and limitations of variational quantum algorithms under realistic noise models — •Marco Schumann, Frank Wilhelm-Mauch, and Alessandro Ciani — Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, 52425 Jülich, Germany

As the field of quantum computing progresses, an intriguing question is if the currently available NISQ devices can deliver a quantum advantage for practical applications, like Variational Quantum Algorithms (VQAs). Due to the lack of error correction, noise limits the performance of these algorithms. Recently it was shown that a quantum state undergoing a variational quantum circuit with general Pauli noise approaches the completely mixed state with increasing circuit depth. In this ongoing project, we study the question of how variational quantum circuits behave under more realistic noise models, like dephasing or amplitude damping noise. We use the Quantum Approximate Optimization Algorithm (QAOA), which is a specific VQA, to solve combinatorial optimization problems. Considering the problem of MaxCut on different d-regular graphs with different qubit numbers, we run the circuit for many instances of randomly chosen circuit parameters. We find that for weak amplitude damping or dephasing noise the average purity of the output state of the circuit approaches the purity of the completely mixed state while the variance of the purity approaches zero with increasing circuit depth. The decrease of the average purity is well described by an exponential decay, where the decay rate is approximately linear in the noise strength.

QI 4.29 Mon 18:00 P2

A multi-qubit Bloch vector representation of density matrices in Julia — •Qunsheng Huang and Christian Mendl — Technische Universität München. Fakultät für Informatik. Boltzmannstraße 3. 85748 Garching

In the Bloch sphere picture, one finds the coefficients for expanding a single-qubit density operator in terms of the identity and Pauli matrices. A generalization to n qubits via tensor products represents a density operator by a real vector of length 4^n, conceptually similar to a statevector.

The tensor structure leads to computationally efficient algorithms for applying circuit gates and performing few-qubit quantum operations. In view of variational circuit optimization, we study backpropagation through a quantum circuit and gradient computation based on this representation, and generalize our analysis to the Lindblad equation for modeling the (non-unitary) time evolution of a density operator.

QI 4.30 Mon 18:00 P2

Efficient energy estimation for variational quantum algorithms using ShadowGrouping — •Alexander Gresch and Martin Kliesch — Quantum Technology Research Group, Heinrich Heine University, Düsseldorf

Hybrid variational quantum algorithms (VQAs) are one of the main candidates for relevant applications of quantum computation in the near future. However, due to the hybrid quantum-classical nature of VQAs, a large number of repeated energy measurements for various trial states is needed. Each of these states requires an estimate $\hat{E}$ of the target energy E.

In our work, we aim to find the optimal strategy with single-qubit measurements that yields the highest provable accuracy given a total measurement budget. To this end, we derive a new upper bound to the failure probability $\mathbb{P}[|\hat{E}-E] > \epsilon]$ for a given tolerable accuracy ϵ, which improves upon previous bounds obtained in the context of derandomized classical shadows. Moreover, we combine strategies that measure groups of commuting Hamiltonian terms with that framework. This combination results in a measurement allocation scheme which we call *ShadowGrouping*. Numerically, we demonstrate that ShadowGrouping outperforms state-of-the-art methods in estimating the electronic ground-state energies of various small molecules. Hence, this work provides a promising way to approach the measurement bottleneck of VQAs.

QI 4.31 Mon 18:00 P2

Single Photon Sources at Telecom Wavelengths — •Jonas Grammel[1], Dario Mekle[1], András Laukó[1], 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. Fundamentally new is also the combination of Fabry-Perot micro-cavity modes with lateral micro and nano structures to reduce the cavity mode volume and thereby boost the emission enhancement and efficiency of the single photon emitters.

QI 4.32 Mon 18:00 P2

Towards downscaling of inter-electode spacing in PDMR for quantum sensing applications — •Jan Heiden, Marcel Schrodin, and Wolfgang Wernsdorfer — KIT, Karlsruhe, Germany

Photoelectric Detection of Magnetic Resonances (PDMR) states a novel technique for the detection of electronic spin-states in nitrogen vacancy centers (NV centers). Contrary to the currently established optical detection (ODMR), which measures the spin-dependent fluorescence of the negatively charged NV- center, the new method relies on the selectivity of the photocurrent induced by the ionizing conversion between NV0 and NV-. Therefore, gold electrodes are deposited directly onto the diamond surface with current inter-electrode distances of down to 2 um.

Besides improved selectivity, PDMR promises enhanced spatial resolution, purely dependent on the process of micro-fabrication. Further advantages arise from the separation of excitation and signal processing paths towards integration of optical systems into on-chip electronic environments.

The work presented focuses on proceeding the down-scaling of the inter-electrode spacing towards the nanometer regime for diamond-spin based quantum information applications at milikelvin temperatures.

QI 4.33 Mon 18:00 P2

Addressing of superconducting qubit in rectangular waveguide. — •Romain Albert[1], Maximilian Zanner[1], Eric Rosenthal[2], Silvia Casulleras[1], Mathieu L. Juan[3], Konrad Lehnert[2], Oriol Romero-Isart[1], and Gerhard Kirchmair[1] — [1]University of Innsbruck, Innsbruck, Austria — [2]JILA - University of Colorado, Boulder, United States — [3]Université de Sherbrooke, Sherbrooke, Canada

Superconducting qubits embedded into microwave waveguides have shown great potential for analog quantum simulation. Such systems present a unique combination of short-range direct qubit interactions and long-range waveguide mediated interactions which make it possible to model a wide variety of Hamiltonians. However, it is challenging to address individual qubits in such systems, as they are often separated by less than the wavelength of their control field. One possible solution is to use the non-linear dispersion of the waveguide to focus frequency chirped pulses to a specific location and it was shown theoretically that such a pulse can be used to selectively control a qubit[1]. We experimentally demonstrate this control using transmon qubits embedded in a rectangular waveguide.

[1] Casulleras, Silvia, et al. "Remote individual addressing of quantum emitters with chirped pulses." Phys Rev Let (2021)

QI 4.34 Mon 18:00 P2

Reduction of frequency spread in superconducting quantum coherent circuits — •Tammo Sievers[1,2,3], Leon Koch[1,2,3], Niklas Bruckmoser[1,2,3], Yuki Nojiri[1,2,3], Thomas Luschmann[1,2,3], Kirill Fedorov[1,2,3], and Stefan Filipp[1,2,3] — [1]Physik- Department, Technische Universität München, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST)

Superconducting quantum circuits form the basis of emerging applications in quantum computing and other quantum technologies. A prominent example is the transmon qubit, a superconducting Josephson junction shunted with a large capacitance. To become practically useful, reliable fabrication methods are required to produce highperformance transmon qubits with lifetimes exceeding several hundred μs and well-controlled parameters, such as the junction frequency. Here, we present our results of different fabrication methods to reduce frequency variations of Manhattan-style Al-AlOx-Al Josephson junctions. To compare the influence of the investigated fabrication techniques, we measure the room temperature resistivity of Josephson junctions and use the Ambegaokar-Baratoff relation in order to quantify the critical current spread of the junctions.

QI 4.35 Mon 18:00 P2

Minimization of Loss Channels in Superconducting Resonators — •Niklas Bruckmoser[1,2], Leon Koch[1,2], Leonhard Hölscher[1,2], David Bunch[1,2], Tammo Sievers[1,2], Kedar E. Honasoge[1,2], Yuki Nojiri[1,2], Thomas Luschmann[1,2], Kirill G. Fedorov[1,2], and Stefan Filipp[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Realizing a fault-tolerant quantum computer is the goal of an ever-growing number of publicly funded and commercial research and development activities. Amongst many potential platforms, quantum computers based on superconducting quantum circuits with Josephson junctions are a promising candidate. However, the fidelity of superconducting qubits is limited by decoherence due to noise arising from various sources, in particular the local environment of the qubit. Driven by the development of partially noise-protected qubit designs, related lifetimes increased significantly from several nanoseconds to a few hundred microseconds. Nonetheless, it is crucial to gain an even better understanding of the origin of loss channels to further improve the qubit coherence by tailored design and fabrication processes. Here, we demonstrate a process for fabricating coplanar waveguide resonators and qubits based on niobium thin films sputtered on silicon substrates. We achieve qubit lifetimes up to 150 μs by systematically analyzing fabrication steps, such as surface treatment and thin film deposition.

QI 4.36 Mon 18:00 P2

Reduction of frequency spread in superconducting quantum circuits — •Tammo Sievers[1,2,3], Leon Koch[1,2,3], Niklas Bruckmoser[1,2,3], Yuki Nojiri[1,2,3], Thomas Luschmann[1,2,3], Kedar E. Honasoge[1,2,3], Kirill G. Fedorov[1,2,3], and Stefan Filipp[1,2,3] — [1]Physik- Department, Technische Universität München, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST)

Superconducting quantum circuits form the basis of emerging applications in quantum computing and other quantum technologies. A prominent example is the transmon qubit, a superconducting Josephson junction shunted with a large capacitance. As quantum processors scale to larger sizes, avoiding frequency collisions becomes a formidable task. Here, we present our results on different fabrication methods to reduce frequency variations of Manhattan-style Al-AlOx-Al Josephson junctions. To compare the influence of the investigated fabrication techniques, we measure the room temperature resistivity of Josephson junctions and use the Ambegaokar-Baratoff relation in order to quantify the critical current spread of the fabricated junctions.

QI 4.37 Mon 18:00 P2

Optimizing Fabrication Parameters for Superconducting Coplanar Waveguide Resonators — •David Bunch[1,2,3], Leon Koch[1,2,3], Niklas Bruckmoser[1,2,3], Kedar E. Honasoge[1,2], Yuki Nojiri[1,2,3], Thomas Luschmann[1,2,3], Tammo Sievers[1,2,3], Kirill G. Fedorov[1,2], and Stefan Filipp[1,2,3] — [1]Physik-Department, Technische Universität München, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST)

Superconducting circuits are a promising platform for the implementation of a universal quantum computer. However, the coherence times of superconducting qubits that make up such systems are limited by material losses, leading to errors in quantum gates. In particular, the coherence time is predominantly limited by coupling to unwanted two level systems (TLS) located at material interfaces. Identifying fabrication techniques, materials, and thin-film dielectrics that reduce losses is essential to achieve scalable architectures for superconducting quantum computing. To evaluate the efficacy of different fabrication techniques we measure the quality factor of superconducting microwave resonators. We present results on optimal sputtering parameters for enhancing the internal quality factor of superconducting coplanar waveguide resonators and investigate the effects of different etching processes, cleaning methods, and surface treatments on these resonators. We validate our results by fabricating qubits with high coherence times.

QI 4.38 Mon 18:00 P2

Nb/AlOx/Nb-trilayer based Dimer Josephson Junction Array Amplifiers — Fabian Kaap[1], Sergey Lothkov[1], Christoph Kissling[1], Victor Gaydamachenko[1], Marat Khabipov[1], Mark Bieler[1], and •Lukas Grünhaupt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Department Quantum Electronics, 38116 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Quantum Technology Competence Center, 38116 Braunschweig, Germany

Josephson parametric amplifiers are crucial components for superconducting quantum circuits as they enable high fidelity readout of qubits by improving the signal-to-noise ratio. Among them, Dimer Josephson Junction Array Amplifiers (DJJAA) [1] have shown promise as user-friendly devices with gain on the order of 20 dB, low added noise, saturation powers larger than approximately -110 dBm, and non-degenerate amplification over a bandwidth of up to ~10 MHz. Due to the use of dc-SQUIDS and multiple dimer modes the operating frequency can be tuned in the range of 2-10 GHz. Using results obtained on DJJAAs with Al/AlOx/Al Josephson junctions as a baseline, we present our progress towards realizing DJJAAs with Nb/AlOx/Nb-trilayer Josephson junctions. We will discuss the circuit design, our fabrication processes, and show preliminary cryogenic measurements of the device.

[1] P. Winkel et al., Phys. Rev. Applied 13, 024015 (2020)

QI 4.39 Mon 18:00 P2

High-fidelity gates and readout for scalable multi-qubit superconducting quantum processors — •Florian Wallner[1,2], Malay Singh[1,2], Gleb Krylov[1,2], Ivan Tsitsilin[1,2], Gerhard Huber[1,2], Niklas Bruckmoser[1,2], Leon Koch[1,2], Niklas Glaser[1,2], Christian Schweizer[1,2], and Stefan Filipp[1,2,3] — [1]Physik- Department, Technische Universität München, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, German — [3]Munich Center for

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To reach the goal of implementing an error-corrected quantum computer, qubits with long coherence times need to be manipulated in real time with high fidelity, followed by a fast and accurate readout. Currently, the main challenge for all hardware platforms is to scale up the number of qubits while at the same time maintain high quality gate operations.
Here, we report on our recent advances to build superconducting multi-qubit devices. Through a dedicated fabrication process we reach coherence times of up to 150 μs. We show single-qubit characterization measurements of gates and high fidelity dispersive readout. By applying this method to multi-qubit systems, we achieve simultaneous multiplexed readout of several qubits coupled to the same feed line. Furthermore, we demonstrate first randomized benchmarking results for single- and two-qubit gates. In addition we give an outlook on our efforts to build multi-qubit devices and qubits on alternative architectures that promise substantial longer coherence times.

QI 4.40 Mon 18:00 P2

Improving the Sørensen-Mølmer gate using analytical optimal control — •Susanna Kirchhoff[1,2], Frank K. Wilhelm[1,2], and Felix Motzoi[3] — [1]Forschungszentrum Jülich, Quantum Computing Analytics (PGI 12), D-52425 Jülich, Germany — [2]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [3]Forschungszentrum Jülich, Institute of Quantum Control (PGI-8), D-52425 Jülich, Germany

The Sørensen-Mølmer gate is an entangling gate for ion qubits [1]. The entangled state is obtained by the application of a bichromatic light beam which collectively drives the ions. This leads to an entangling gate if certain conditions on gate time, drive frequency and amplitude are fulfilled. These conditions can be derived from the propagator. However, the gate is not perfect. In [1] the authors apply the Lamb-Dicke approximation and neglect some fast rotating terms as well as the single qubit rotation before calculating the propagator. This leads to gate errors. We investigate how the approximations affect the gate fidelity and explore methods to avoid those errors and make the gate more robust against heating.

[1] Sørensen and Mølmer: Entanglement and quantum computation with ions in thermal motion. In: Physical Review A 62.2 (2000)

QI 4.41 Mon 18:00 P2

Spin defects in hBN as promising temperature, pressure and magnetic field quantum sensor — •Paul Konrad[1], Andreas Gottscholl[1], Andreas Sperlich[1], Igor Aharonovich[2], and Vladimir Dyakonov[1] — [1]Experimental Physics 6, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]School of Mathematics and Physical Sciences, University of Technology Sydney, Ultimo, NSW 2007, Australia

Colour centres in solid-state materials show great potential in quantum information technology and sensing applications. The lately discovered negatively charged boron vacancy (V_B^-) in hexagonal boron nitride (hBN)[1] has shown the defect to be host to a spin-triplet ground state with spin-dependent photoluminescence. The system can be exploited in terms of its application as temperature, magnetic field, and pressure sensor [2,3] which extends the already known applications of e.g. NV-centers in diamond not only due to its 2D character but also by highly improved temperature sensing especially at low temperatures.

Yet, the irradiation protocol is still unoptimized and achieving high contrast optically detected magnetic resonance (ODMR) on increasingly thinner flakes remains a challenge. We are on our way to tackle aforementioned challenges by performing measurements on V_B^- created by various types of irradiation and achieve tremendous improvement of ODMR contrast on flakes of down to 80nm thickness.

[1] Gottscholl et al., *Nat. Mat.*, **19**, 5, 540 (2020).
[2] Gottscholl et al., *Sci. Adv.*, **7** (14), eabf3630 (2021).
[3] Gottscholl et al., *Nat. Commun.*, **12**, 4480 (2021).