Q 55: Quantum Computing II

Time: Friday 14:30–16:15 Location: P 2

Q 55.1 Fri 14:30 P 2

Estimating the error of a quantum simulator by additional measurments — Iris Schwenk, Sebastian Zanker, Jan Reiner, Juha Leppakangas, and •Michael Marthaler — Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We study an analog quantum simulator coupled to a reservoir with a known spectral density. The reservoir can cause decay and decoherence. The quantum simulator is used to measure an operator average, which can not be calculated using any classical means. Since we can not predict the result it is difficult to know the effect of the environment. Especially, we can not know whether the perturbation is small or if the actual result of the measurement is in fact very different from the ideal system we intend to study. We show that it is possible to use a perturbative approach which contains only measurable quantities to estimate the size of the error.

Q 55.2 Fri 14:45 P 2

Energy localization ensures robustness of digital quantum simulation — •Philipp Hauke[1,2], Markus Heyl[3], and Peter Zoller[1,2] — [1]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck — [3]Max-Planck-Institut fuer Physik komplexer Systeme, D-01187 Dresden

Following Lloyds seminal work from 1996, the Trotter error of digital quantum simulation (DQSs) is usually assumed to diverge with simulated time and particle number. This is true if one is interested in the correctness of the full time-evolution operator. In quantum simulation, however, the quantities of interest are typically few-body observables. Understanding the DQS as a periodically driven system, we demonstrate that, once the Trotter step is sufficiently small, the error of few-body observables remains bounded even for large systems and for arbitrarily long times. This is ensured for all systems that display energy localization. In that case, a sharp transition exists into a regime where Trotter errors in local observables become perturbative. Even in systems where energy localization does not exist, we argue that the DQS deteriorates only logarithmically with time. As these findings show, digital quantum simulation can be exponentially better than usually stated, as long as one is concerned with few-body observables.

Q 55.3 Fri 15:00 P 2

Scalable architecture for quantum simulation and quantum computation with more than 150 individually addressable qubits — •Dominik Schäffner, Daniel Ohl de Mello, Tilman Preuschoff, Lars Kohfahl, Jan-Niklas Schmidt, Malte Schlosser, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Efficient quantum simulation and quantum information processing requires scalable architectures that guarantee the allocation of large-scale qubit resources. In our work, we focus on the implementation of multi-site geometries based on microfabricated optical elements. This approach allows us to develop flexible, integrable and scalable configurations of multi-site focused beam traps for the storage and manipulation of single-atom qubits and their interactions [1].

We give an overview on the investigation of ^{85}Rb atoms in two-dimensional arrays of more than 400 individually addressable dipole traps featuring trap sizes and a tunable site-separation in the single micrometer regime. Furthermore, we experimentally demonstrate single-atom quantum registers with more than 150 occupied sites and single-site resolved addressing of single atom quantum states in a reconfigurable fashion. We will discuss progress in introducing Rydberg based interactions and present prospects of our platform for the investigation of many-body physics.

[1] For an overview see: M. Schlosser, S. Tichelmann, J. Kruse, and G. Birkl, Quant. Inf. Proc. **10**, 907 (2011).

Q 55.4 Fri 15:15 P 2

Continuous-Variable Instantaneous Quantum Computing is hard to sample — Tom Douce[1,2], Damian Markham[1], Elham Kashefi[1], Eleni Diamanti[1], Thomas Coudreau[2], Perola Milman[2], Peter van Loock[3], and •Giulia Ferrini[2,3] — [1]Lip6, UPMC-Sorbonne Universités, 4 Place Jussieu, 75005 Paris, France — [2]Laboratoire Matériaux et Phénomènes Quantiques, Sorbonne Paris Cité, Univ. Paris Diderot, CNRS UMR 7162, 75013, Paris, France — [3]Institute of Physics, Johannes-Gutenberg Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Instantaneous Quantum Computing (IQP) is a sub-universal class of quantum circuits composed of Pauli-X eigenstates, gates diagonal in the Pauli-Z basis, and Pauli-X measurements [1]. We translate this class of circuits to Continuous-Variables (CV). Using the correspondence between universal sets of gates [2], we define CV IQP circuits as composed of input momentum-squeezed states, gates diagonal in position and homodyne momentum measurements. We analyse their computational power by studying post-selected circuits [1], and we prove that CV IQP circuits are hard to sample [3]. In order to deal with post-selection we consider finite resolution homodyne detectors. Finite squeezing in the input squeezed states is treated by adding to the model ancillary GKP states and by relying on a GKP encoding of quantum information [4].

[1] M. J. Bremner, R. Josza, and D. Shepherd, Proc. R. Soc. A 459, 459 (2010). [2] M. Gu et al, PRA 79, 062318 (2009). [3] T. Douce et al, arXiv:1607.07605 (2016). [4] N. C. Menicucci, PRL 112, 120504 (2014).

Q 55.5 Fri 15:30 P 2

Towards all optical quantum computing with single molecules — •Mohammad Rezai, Jörg Wrachtrup, and Ilja Gerhardt — Universität Stuttgart 3. Physikalisches Institut

Single quanta of light known as photons are the key element for quantum communication of the future. One source, organic dye molecules, can be chemically designed to cover the full visible spectrum. They can simultaneously act as both a high flux and an extremely narrow-band single photon source [1]. Their spectral line-width in the range of 10-20MHz is lifetime limited, and their indistinguishability is high. For quantum hybridization experiments with atomic vapors, we use dibenzanthanthrene C30H16 which matches spectrally well with sodium D-line transitions around 589nm. This allows for spectral Faraday filtering against unwanted light, e.g. caused by the source of excitation [2]. This contributes to the single photon's indistinguishability, which is measured to be close to unity. Furthermore, we use this to realize a delayed-choice quantum eraser experiment based on photons resonant with sodium.

[1] - P. Siyushev et al., Nature, 2014, 509, 66-70 [2] - W. Kiefer et al., Scientific Reports, 2014, 4, 6552

Q 55.6 Fri 15:45 P 2

Implementing single qubit gates using RSFQ pulses — •Per J. Liebermann and Frank K. Wilhelm — Universität des Saarlandes, Saarbrücken

Rapid single flux quantum (RSFQ) pulses are a highly viable candidate for the on-chip generation of control pulses for quantum computers based on Josephson devices. With a switching time in the picoseconds range it is possible to implement fast quantum gates [1]. We show that RSFQ pulses can drive high-fidelity single-qubit rotations in leaky transmon qubits, if the sequence of these restricted digital pulses is suitably optimized compared to an evenly spaced pulse train [2]. Genetic algorithms are used to converge to gate control precision compatible with the requirements of fault tolerant quantum computing. RSFQ shift registers are essential to perform the optimized sequence, limiting the reachable set of gates in a single shot. Timing jitter of the pulses is considered as well, showing the robustness of the optimized sequence. This makes the underlying RSFQ pulse platform an attractive candidate for an integrated control layer in a quantum processor.

[1] R. McDermott and M.G. Vavilov, Phys. Rev. Appl. 2, 014007 (2014)

[2] P.J. Liebermann and F.K. Wilhelm, Phys. Rev. Appl. 6, 024022 (2016)

Q 55.7 Fri 16:00 P 2

Deterministische Einzel-Ionen Implantation zur Erzeugung

von NV-Zentren — •Karin Groot-Berning[1,2], Georg Jacob[2], Christian Osterkamp[3], Sebastian Wolf[2], Boris Naydenov[3], Fedor Jelezko[3], Kilian Singer[1] und Ferdinand Schmidt-Kaler[2] — [1]Experimental Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [3]Universität Ulm, Institut für Quantenoptik, Albert-Einstein-Allee 11, 89081 Ulm, Germany

Wir berichten über die erfolgreiche deterministische Implantation einzelner Stickstoff Ionen zur Erzeugung von NV-Zentren. Hierfür wurde auf der Grundlage einer linearen Paulfalle eine Einzelionenquelle realisiert. Um einzelne $^{15}N_2^+$ Ionen in die Falle zu laden, werden diese aus einem istopenreinen Reservoir ionisiert, gefangen und durch $^{40}Ca^+$ Ionen sympathetisch gekühlt. Mit einer Extraktionsspannung von 5.9 keV werden die Ionen aus der Falle beschleunigt. Dabei wird das zu implantierende N_2^+ Ion vom Calcium Ion getrennt und durch eine elektrostatische Einzellinse auf die Probe fokussiert [1].

Um die Herkunft der Zentren aus der deterministischen Implantation nachzuweisen, verwenden wir gepulste ODMR-Spektroskopie mit welcher die Hyperfeinaufspaltung des ^{15}NV Zentrums (Kernspin I=1/2) gemessen werden kann. Zudem berichten wir über die Kohärenzzeiten dieser NV-Zentren und über Perspektiven zur Bildung von optischaktiven Zentren in Festkörpern mit hoher Effizienz.

[1] Jacob et al., Phys. Rev. Lett. 117, 043001 (2016)