TT 13: Quantum Computing (joint session TT/DY)

Time: Wednesday 11:15–13:00 Location: H7

TT 13.1 Wed 11:15 H7

Probing the critical current coupling of defects in Josephson junctions — •Alexander Konstantin Neumann[1], Benedikt Berlitz[1], Alexey V. Ustinov[1,2,3], and Jürgen Lisenfeld[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]National University of Science and Technology MISIS, Moscow 119049, Russia — [3]Russian Quantum Center, Skolkovo, Moscow 143025, Russia

Material defects form a major source of decoherence in state of the art superconducting quantum bits. It has been a long standing question whether defects residing in the tunnel barrier of Josephson junctions modify their critical current. We investigate this with spectroscopic measurements and QuTiP simulations on individual defects strongly coupled to a transmon qubit. By observing avoided level crossings at driving amplitudes allowing for multi-photon transitions, we quantify the strength of the critical current coupling. Moreover, we find an effective direct interaction between the defect and the qubit's readout resonator, providing an additional decoherence channel.

TT 13.2 Wed 11:30 H7

Cavity mediated quantum gate between distant charge qubits — •Florian Kayatz, Jonas Mielke, and Guido Burkard — Department of Phyiscs, University of Konstanz, Konstanz, Germany

Gate based quantum computers require high fidelity single-qubit and two-qubit gates to allow for arbitrary multi-qubit operations that are needed to perform a quantum algorithm. Ideally, one has "all-to-all" connectivity, i.e. an architecture with two-qubit gates between any desired pair of qubits. Notably, short-ranged interactions such as capacitive coupling and the exchange interaction cannot be harnessed to implement two-qubit gates between distant qubits. We investigate whether a high-fidelity iSWAP gate between distant charge qubits can be implemented by using a microwave resonator as an intermediate system mediating the interaction. In particular, we consider charge qubits formed by a single electron confined in a Si double quantum dot that are coupled to a microwave resonator via electric dipole coupling. We theoretically demonstrate that, in the dispersive regime, the photons can mediate an iSWAP gate. We then calculate the gate fidelity in the presence of the dominant noise sources, quasi-static charge noise, resonator damping and phonon induced charge relaxation, and find a very limited gate fidelity.

TT 13.3 Wed 11:45 H7

Crosstalk analysis for single-qubit and two-qubit gates in spin qubit arrays — •Irina Heinz and Guido Burkard — University of Konstanz, Konstanz, Germany

Scaling up spin qubit systems requires high-fidelity single-qubit and two-qubit gates. Gate fidelities exceeding 98% were already demonstrated in silicon based single and double quantum dots, whereas for the realization of larger qubit arrays crosstalk effects on neighboring qubits must be taken into account. We analyze qubit fidelities impacted by crosstalk when performing single-qubit and two-qubit operations on neighbor qubits with a simple Heisenberg model. Furthermore we propose conditions for driving fields to robustly synchronize Rabi oscillations and avoid crosstalk effects. In our analysis we also consider next to nearest neighbor crosstalk and show that double synchronization leads to a restricted choice for the driving field strength, exchange interaction, and thus gate time. Considering realistic experimental conditions we propose a set of parameter values to perform a nearly crosstalk-free CNOT gate and so open up the pathway to scalable quantum computing devices.

TT 13.4 Wed 12:00 H7

Spin shuttling in a silicon double quantum dot — •Florian Ginzel[1], Adam R. Mills[2], Jason R. Petta[2], and Guido Burkard[1] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]Department of Physics, Princeton University, Princeton, New Jersey 08544, USA

The transport of quantum information between different nodes of the device is crucial for a quantum processor. In the context of spin qubits, this can be realized by coherent electron spin shuttling between quantum dots. Here we theoretically study a minimal version of spin shuttling between two quantum dots (QDs) occupied by one electron [1]. We analyze the possibilities and limitations of spin transport during a detuning sweep in a silicon double QD. This research is motivated by recent experimental progress [2,3]. Spin-orbit interaction and an inhomogeneous magnetic field play an important role for spin shuttling and are included in our model. Interactions that couple the position, spin and valley degrees of freedom open avoided crossings in the spectrum allowing for diabatic transitions and interfering paths. The outcomes of single and repeated spin shuttling protocols are explored by means of numerical simulations and an approximate analytic model based on the Landau-Zener model. We find that fast high-fidelity spin-shuttling is feasible for optimal choices of parameters or protected by constructive interference.

[1] Ginzel et al., Phys. Rev. B 102, 195418 (2020)
[2] T. Fujita et al., npj Quantum Information 3, 22 (2017)
[3] A. R. Mills et al., Nat. Comm. 10, 1063 (2019)

TT 13.5 Wed 12:15 H7

Simulating hydrodynamics on NISQ devices with random circuits — •Jonas Richter and Arijeet Pal — Department of Physics and Astronomy, University College London, UK

We show that pseudorandom circuits, recently implemented in Google's seminal "quantum supremacy" experiment, are not just abstract tools to outperform classical computers, but in fact form tailor-made building blocks to simulate certain aspects of quantum many-body systems on noisy intermediate-scale quantum computers. Specifically, we propose an algorithm consisting of a random circuit followed by a trotterized Hamiltonian time evolution to study transport properties in the linear response regime, which we numerically exemplify for one- and two-dimensional quantum spin systems. While the algorithm operates without an overhead of bath or ancilla qubits for initial-state preparation and measurement, our numerics further suggest that it is comparatively robust against systematic Trotter errors and noisy gates.

[1] J. Richter and A. Pal, Phys. Rev. Lett. 126, 230501 (2021)

TT 13.6 Wed 12:30 H7

Adaptive variational NISQ quantum algorithms for dynamics and excited states preparation — Yongxin Yao[1,2], Niladri Gomes[1,2], Feng Zhang[1,2], Cai-Zhuang Wang[1,2], Kai-Ming Ho[1,2], Thomas Iadecola[1,2], and •Peter P. Orth[1,2] — [1]Ames Laboratory, Ames, Iowa, USA — [2]Iowa State University, Ames, Iowa, USA

Simulating quantum dynamics of interacting many-body systems is one of the main potential applications of quantum computing, since the growth of entanglement makes such simulations exponentially hard on classical devices. The shallow circuit requirement of current QPUs limits algorithms based on Trotter product formulas to simulate early time dynamics. Here, we present an adaptive approach to construct a variational wave function ansatz for accurate quantum dynamics simulations based on McLachlan's variational principle [1]. The key idea is to dynamically expand the variational ansatz along the time-evolution path such that the McLachlan distance, which is a measure of the simulation accuracy, remains below a set threshold. We apply this adaptive variational quantum dynamics simulation approach (non)integrable quantum spin models and find the circuits to contain up to two orders of magnitude fewer CNOT gates than those obtained from first-order Trotter expansion. We also present results on development of an adaptive VQE-X algorithm for preparation of highly excited states in many-body models [2].

[1] Yao et al., PRX Quantum 2, 030307 (2021)
[2] Zhang et al., arXiv:2104.12636 (2021)

TT 13.7 Wed 12:45 H7

Simulating a discrete time crystal over 57 qubits on a quantum computer — •Philipp Frey and Stephan Rachel — School of Physics, University of Melbourne, Parkville, VIC 3010, Australia

We simulate the dynamics of a spin-1/2 chain with nearest neighbor Ising interactions, quenched disorder and periodic driving over 57 qubits on a current quantum computer. Based on the dynamics of local spin depolarisation we observe discrete time crystalline (DTC) behaviour due to many body localisation (MBL). We probe random initial states along with fully polarised states and compare the cases of vanishing and finite disorder to distinguish MBL from pre-thermal dynamics. In order to extract the signal from the noisy data produced by current quantum computer devices, we develop a strategy for error mitigation and show that the results are robust under variations of the parameters introduced in this scheme. A transition between DTC and a thermal phase is observed via critical fluctuations in the sub-harmonic frequency response of the system, as well as a significant speed-up of spin depolarisation. Our findings are consistent with previous numerical simulations, but represent the realization of a DTC with largest system size to date.