QI 27: Quantum Error Correction

Time: Thursday 11:00–12:30 Location: HS VIII

Invited Talk QI 27.1 Thu 11:00 HS VIII

Fault-tolerant compiling of quantum algorithms — •Dominik Hangleiter — Simons Institute, UC Berkeley

As we are entering the era of early quantum fault-tolerance, the question how to most efficiently make use of fault-tolerant quantum resources comes into focus. This question is addressed by fault-tolerant compiling, meaning a codesign of an error-correcting code, an algorithm, and the physical hardware. I will introduce this idea using two examples. First, I will describe the fault-tolerant compilation of a family of IQP circuits implemented transversally using quantum Reed-Muller codes in reconfigurable atom arrays. This yields a path towards fault-tolerant quantum advantage. Second, I will sketch an encoding in which coherent implementations of classical arithmetic—a crucial but highly expensive building block of quantum algorithms—can be achieved naturally in a reconfigurable architecture, which can give savings for certain tasks.

QI 27.2 Thu 11:30 HS VIII

Experimental measurement and a physical interpretation of quantum shadow enumerators — •Daniel Miller[1,2], Kyano Levi[1], Lukas Postler[3], Alex Steiner[3], Lennart Bittel[1], Gregory A.L. White[1], Yifan Tang[1], Eric J. Kuehnke[1], Antonio A. Mele[1], Sumeet Khatri[1,4,5], Lorenzo Leone[1], Jose Carrasco[1], Christian D. Marciniak[3], Ivan Pogorelov[3], Milena Guevara-Bertsch[3], Robert Freund[3], Rainer Blatt[3,6], Philipp Schindler[3], Thomas Monz[3,7], Martin Ringbauer[3], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Institute for Theoretical Nanoelectronics (PGI-2), Forschungszentrum Jülich, 52428 Jülich, Germany — [3]Universität Innsbruck, Institut für Experimentalphysik, Technikerstrasse 25, 6020 Innsbruck, Austria — [4]Department of Computer Science, Virginia Tech, Blacksburg, Virginia 24061, USA — [5]Virginia Tech Center for Quantum Information Science and Engineering, Blacksburg, Virginia 24061, USA — [6]Institut für Quantenoptik und Quanteninformation, Österreichische Akademieder Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria — [7]Alpine Quantum Technologies GmbH, 6020 Innsbruck, Austria

We show that Rains shadow enumerators are the same as triplet probabilities in two-copy Bell sampling. We measure them in experiments.

QI 27.3 Thu 11:45 HS VIII

Leading Order Measurement-Free Quantum Error Correction Optimized for Rydberg Atoms — •Katharina Brechtelsbauer[1], Sebastian Weber[1], Friederike Butt[2,3], David F. Locher[2,3], Santiago Higuera Quintero[1], Markus Müller[2,3], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Stuttgart, Germany — [2]Institute for Quantum Information, RWTH Aachen University, Aachen, Germany — [3]Institute for Theoretical Nanoelectronics (PGI-2), Forschungszentrum Jülich, Jülich, Germany

Large scale quantum computation requires the implementation of quantum error correction. As different platforms come along with different challenges it can be helpful to design error correction protocols and logical gate sets considering the features of the specific platform. For example, in the case of neutral atom platforms where measurements are slow, measurement-free error correction schemes offer a great alternative to feed-forward correction. Furthermore, for neutral atom platforms two- and multiqubit gates are expected to be the dominating source of noise and careful design of the gates allows to further reduce the noise model to Pauli-Z errors. In this work, we show that for such a biased noise model the measurement-free error correction protocol of the seven-qubit Steane code can be reduced. Furthermore, we develop a measurement-free universal gate set that is fault tolerant with respect to the assumed noise model. In addition, we sketch possible implementations on neutral atom platforms.

QI 27.4 Thu 12:00 HS VIII

Characterization of errors in a CNOT between surface code patches — •Bálint Domokos[1], Áron Márton[1], and János K. Asbóth[1,2] — [1]Budapest University of Technology and Economics — [2]HUN-REN Wigner Research Centre for Physics

As current experiments already realize small quantum circuits on error corrected qubits, it is important to fully understand the effect of physical errors on the logical error channels of these fault-tolerant circuits. Here, we investigate a lattice-surgery-based CNOT operation between two surface code patches under phenomenological error models. (i) For two-qubit logical Pauli measurements – the elementary building block of the CNOT – we optimize the number of stabilizer measurement rounds, usually taken equal to d, the size (code distance) of each patch. We find that the optimal number can be greater or smaller than d, depending on the rate of physical and readout errors, and the separation between the code patches. (ii) We fully characterize the two-qubit logical error channel of the lattice-surgery-based CNOT. We find a symmetry of the CNOT protocol, that results in a symmetry of the logical error channel. We also find that correlations between X and Z errors on the logical level are suppressed under minimum weight decoding.

QI 27.5 Thu 12:15 HS VIII

Optimal number of stabilizer measurement rounds in an idling surface code patch — •Janos Asboth[1] and Aron Marton[2] — [1]Budapest University of Technology and Economics — [2]RWTH Aachen University

Logical qubits can be protected against environmental noise by encoding them into a highly entangled state of many physical qubits and actively intervening in the dynamics with stabilizer measurements. In this work [1], we numerically optimize the rate of these interventions: the number of stabilizer measurement rounds for a logical qubit encoded in a surface code patch and idling for a given time. We model the environmental noise on the circuit level, including gate errors, readout errors, amplitude and phase damping. We find, qualitatively, that the optimal number of stabilizer measurement rounds is getting smaller for better qubits and getting larger for better gates or larger code sizes. We discuss the implications of our results to some of the leading architectures, superconducting qubits, and neutral atoms.

[1] arXiv:2408.07529