FM 78: Quantum Computation: Hardware Platform III

Time: Thursday 14:00–15:30 Location: 1199

Invited Talk FM 78.1 Thu 14:00 1199

Quantum Information Processing using Trapped Atomic Ions and MAGIC — Theeraphot Sriarunothai[1], Sabine Wölk[4], Gouri S. Giri[5], Nicolai Friis[2], Vedran Dunjko[3], Hans J. Briegel[4], Patrick Barthel[1], Patrick Huber[1], and •Christof Wunderlich[1] — [1]Siegen University, Germany — [2]Austrian Academy of Sciences, Vienna, Austria — [3]Leiden University, Netherlands — [4]Innsbruck University, Austria — [5]Düsseldorf University, Germany

Using ion traps that allow for long-range magnetic gradient induced coupling (MAGIC) [1], laser light can be replaced by long-wavelength radiation in the radio-frequency (RF) regime, thus facilitating scalability.

Using a freely programmable quantum computer (QC) based on MAGIC, we report on a proof-of-principle experimental demonstration of the deliberation process in the framework of reinforcement learning [2]. This experiment at the boundary between quantum information science and machine learning shows that decision making for reinforcement learning is sped up quadratically on a QC as compared to a classical agent.

Then we report on 2-qubit RF gates that are robust against variations in the secular trap frequency and Rabi frequency. In future traps such gates will increase speed and fidelity of multi-qubit gates.

[1] C. Piltz et al.,Science Advances **2**, e1600093 (2016).
[2] Th. Sriarunothai et al., Quantum Sci. Technol.**4**, 015014 (2019).

FM 78.2 Thu 14:30 1199

Local entangling operations on two arbitrary ions in a string of ions — •Michael Meth[1], Marc Bussjäger[1], Alexander Erhard[1], Lukas Postler[1], Roman Stricker[1], Martin Ringbauer[1], Thomas Monz[1,2], and Rainer Blatt[1,3] — [1]Universität Innsbruck, Institut für Experimentalphysik, Technikerstraße 25, Innsbruck — [2]Alpine Quantum Technologies GmbH — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences

We present a scheme for local entangling operations on two arbitrary ions in a string of currently up to 16 ions. Two acousto-optic deflectors are used to address a single or multiple ions at once, performing parallel quantum gate operations on several quantum bits (qubits) with independent phase control. The deflectors are aligned such that induced frequency shifts are cancelled along the trap axis regardless of the addressed ions. Mølmer-Sørensen (MS) gates are implemented to create entanglement between two arbitrary qubits via coupling to the common motion of the ion string. In conjunction with single qubit gates a universal set of gates is formed. For an arbitrary set of two ions in a string of four the entangling gate fidelities are measured to be comparable with collective MS gates on all qubits and no significant loss in performance has been observed for longer strings. This method can be extended from two qubits to subsets of arbitrary lengths. Simulations of improved optical setups show an addressable range of several hundreds of micrometers, which corresponds to more than 50 qubits.

FM 78.3 Thu 14:45 1199

Towards large-scale microwave quantum devices with trapped ions — •Amado Bautista[1,2], Henning Hahn[1,2], Giorgio Zarantonello[1,2], Jonathan Morgner[1,2], and Christian Ospelkaus[1,2] — [1]Leibniz University of Hannover, Welfengarten 1, 30176 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Currently quantum computing with trapped ions is reaching an unprecedented maturity towards a practical realization of a scalable platform. The field requires also a significant effort on reaching a scalable hardware. Here we present recent advances on the development of a novel method for the realization of large-scale quantum devices [1]. First, I will detail on the trap fabrication and show preliminary results on the characterization of a multilayer ion trap with integrated 3D microwave circuitry [2] towards the implementation of high-fidelity quantum logic control on $^9Be^+$ ions. We demonstrate ion trapping, simple microwave control on a laser cooled $^9Be^+$ ion held at a distance of 35 μm, characterize the magnetic field around the trap center based on our 2D near-field model [3]. Finally, I will discuss new routes and potential new integrated devices in which the multilayer method can be exploited.

[1] A. Bautista-Salvador et al. New J. Phys., 21, 043011 (2019) [2] H. Hahn et al. ArXiv181202445 (2018) [3] M. Wahnschaffe et al. Appl. Phys. Lett., 110, 034103 (2017)

FM 78.4 Thu 15:00 1199

Near-field microwave quantum logic with ^{9}Be$^+$ ions — Henning Hahn[2,1], Giorgio Zarantonello[1,2], Marius Schulte[3], Jonathan Morgner[1,2], Amado Bautista-Salvador[2,1], Klemens Hammerer[3], and •Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]PTB, Bundesallee 100, 38116 Braunschweig — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover

Near-field microwave fields allow the implementation of an integrated entangling gate mechanism for trapped-ion qubits in surface-electrode trap arrays [1]. We present a tailored near-field microwave conductor structure which has recently allowed us [2] to realize an entangling gate operation between two $^9Be^+$ ion qubits using long-lived field-independent "clock" states. We establish a gate error budget through comparison to numerical simulations and find that the gate operation is at present not limited by any mechanism inherent to the method, and all leading order infidelity contributions can be dealt with using straigt-forward technical measures that have already been implemented for other (laser and microwave based) implementations. We discuss further methods which we hope will reduce the infidelity significantly and give an outlook towards the extension to multi-zone trap arrays.

[1] C. Ospelkaus *et al.*, Nature **476**, 181 (2011)
[2] H. Hahn *et al.*, arXiv:1902.07028 [quant-ph] (2019)

FM 78.5 Thu 15:15 1199

Ion trap fabrication at PTB — •André P. Kulosa, Alexandre Didier, Malte Brinkmann, and Tanja E. Mehlstäubler — QUEST Institute, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Ion traps are the heart of quantum computers and simulators based on laser-cooled ions, but also a key essential of quantum clocks and precision spectroscopy. Here we report on progress and future prospects of the ion trap fabrication in the QUEST Institute at PTB. As a consequence of the quantum initiative call from the German Federal Government, the BMBF supports the transfer of quantum technology from research to industry enabling the second quantum revolution. Within the BMBF-funded *opticlock* project, our technology platform will be used to demonstrate a compact Yb^+ ion optical clock replacing hydrogen masers as a future frequency reference. In a second funded project, *IDEAL*, we investigate integrated optics on diamond wafer chip traps enabling robust and compact interaction of laser light with the ions for the next generation of ion traps.

In the frame of its mission as governmental body to support German science and industry, PTB placed the corner stone for a Quantum Technology Competence Center (QTZ). The newly founded QTZ will focus on transfer of PTB's expertise in quantum technology from science to application in collaboration with partners from industry and academia. For this purpose, our ion trap technology will be made accessible to external users in a new user facility providing lab infrastructure.