CP-01-01

Developing modular microwave trapped-ion quantum computers for operation with millions of qubits

Winfried K. Hensinger

Sussex Centre for Quantum Technologies, Department of Physics and Astronomy, University of Sussex / Brighton BN1 9QH, United Kingdom/Universal Quantum Ltd, Brighton BN1 6SB, UK. 3

Abstract

Microwave technology poses a significant opportunity to scale trapped ion quantum computers to system sizes that support utility scale quantum computation within the fault-tolerant regime.

I will present progress on making microwave quantum gates faster with errors much below the fault-tolerant threshold by creating much larger magnetic field gradients. We have successfully developed a new generation of ion microchips capable of generating large magnetic field gradients in excess of 100 T/m. I will show progress on realizing high-fidelity gates with these new chips.

Current quantum computers can only operate with around 100 quantum bits while most disruptive industry applications would require quantum computers that can process millions of quantum bits. I will discuss a recent achievement, the demonstration of electric fields links between ion microchips as well as successful transport of ion qubits between microchips that should enable the construction of quantum computers with millions of quantum bits. I report the demonstration of a quantum matter-link in which ion qubits are transferred between adjacent quantum computer modules [1]. Ion transport between adjacent modules is realised at a rate of 2424 s^{-1} and with an infidelity associated with ion loss during transport below 7×10^{-8}.

Furthermore, I will show that the link does not measurably impact the phase coherence of the qubit.

Finally I will discuss the enhanced connectivity in our transport based trapped ion quantum computer and discuss the creation of a decoder enabling transversal logical quantum gates.

I will also discuss the path forward to build practical trapped ion quantum computers. This includes the underlying research within our research group at the University of Sussex; an engineering focussed approach to construct practical machines at spin-out company Universal Quantum; work with future quantum computing users to develop applications and use cases in order to fast track the demonstration of disruptive industry applications.

[1] A High-Fidelity Quantum Matter-Link Between Ion-Trap Microchip Modules, M. Akhtar, F. Bonus, F. R. Lebrun-Gallagher, N. I. Johnson, M. Siegele-Brown, S. Hong, S. J. Hile, S. A. Kulmiya, S. Weidt & W. K. Hensinger, A high-fidelity quantum matter-link between ion-trap microchip modules. Nature Communications 14, 531 (2023)