Sandia National Laboratories

QSCOUT

Quantum Scientific Computing Open User Testbed

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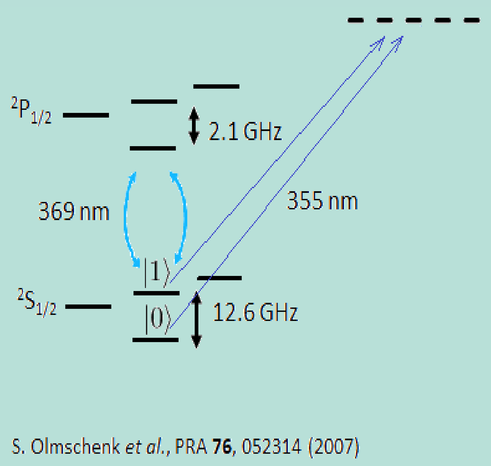
QSCOUT 1.0 and 1.1

Testbed system designed for open user access to support scientific applications



S. Olmschenk *et al.*, PRA **76**, 052314 (2007)

- Room temperature system
- Testbed based on Ytterbium-171 trapped ions
- Single chain of 2-11 qubits, with hardware support of up to 32 qubits
- Full connectivity between ions using radial vibrational modes
- Individual addressability with 355 nm Raman beams
- Provides unique parameterized single and two-qubit gate sets

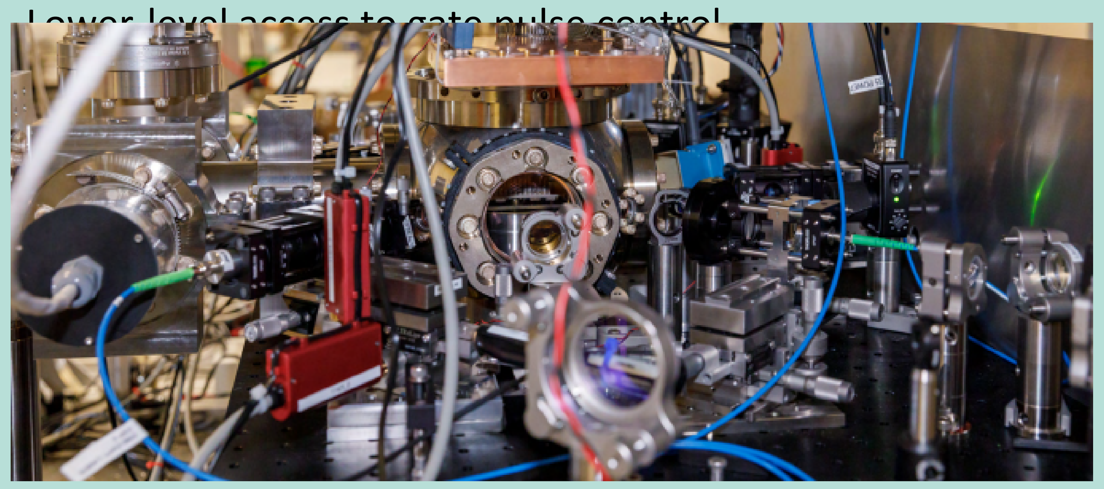
Single qubit gates (99.5% gate fidelities)

$$R_\phi(\theta),\ X_{\pi/2},\ Y_{\pi/2},\ Z_\phi,\ H,\ T$$

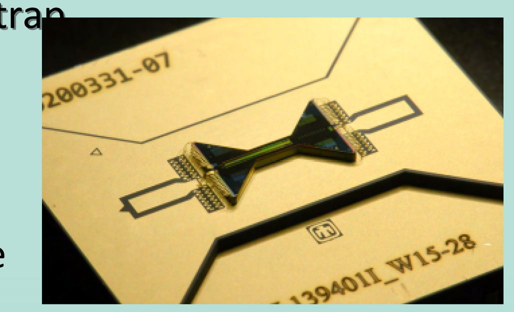
Two-qubit gates (98% gate fidelities)

$$MS(\theta,\phi) = e^{-i\frac{\theta}{2}(\cos(\phi)\sigma_x + \sin(\phi)\sigma_y)^{\otimes 2}},$$

- Lower-level access to gate pulse control



Sandia custom-designed Peregrine trap



- Micro-fabricated linear ion surface trap
- Surface heating rates:

24.2 ± 2.2 q/s at room temperature on transverse mode (2.3 MHz) at 5 degree trap rotation

Example capabilities:

- Simulation of quantum dynamics for system of interest
- Characterization of the system by intentional addition of coherent and incoherent noise, simulated crosstalk manipulation and adjustment of lower-level pulses
- Investigation of various benchmarking techniques including random-analog verification, cross-entropy benchmarking, and gate set tomography

Interested? Please talk to us for access!

Jaqal & JaqalPaw

A custom-designed quantum assembly language for more explicit and transparent qubit control

- Parameterized single-qubit rotation gates that can be rotated about any axis on the equatorial plane of the Bloch sphere
- Parameterized single-qubit Z gates that act as a phase advance on subsequent waveforms
- Mølmer-Sørensen gates between any two pairs of ions, with user-defined phase and rotation angle

For Jaqal specifications, refer to **arXiv: 2003.09382**

JAQAL

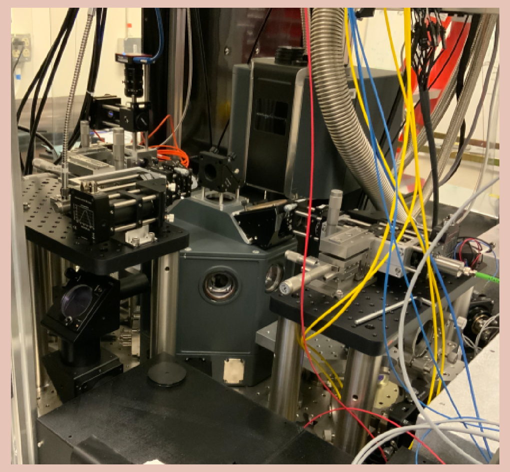
A suite that is used to define pulses and waveforms for Jaqal to be run on the QSCOUT hardware

- The lower level counterpart to Jaqal that describes gates in terms of waveforms
- Can be ported to other platforms that aim for high customizability

For JaqalPaw specifications, visit the qscout website.

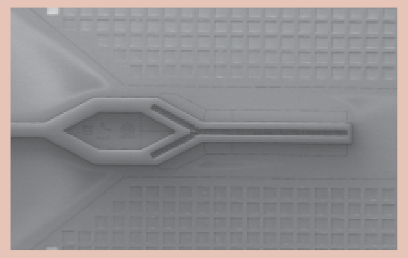
QSCOUT 2.0

Cryo (call for proposals – ***OPEN NOW!***)

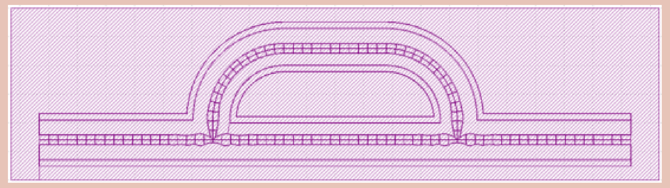


- Offering cryogenic cooling down to 8 K
- Reduced ion motional heating – major source of decoherence
- Better vacuum conditions and lower energy collisions

Shuttling for partial chain measurements (call for proposal – early spring 2023)



- a Y-trap design that shuttles ions out of the detection region, allowing for the detection of others anywhere in the chain



- Ion bus creating multiple trapping zones for ion connectivity comparison

2021 R&D 100 WINNER

In 2021, QSCOUT became an R&D 100 winner for the unique low-level access to programming control and gate execution!

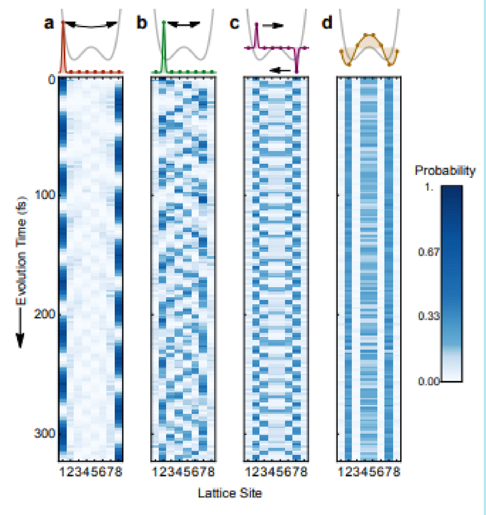
*For more information, visit the QSCOUT website **https://qscout.sandia.gov** or email **qscout@sandia.gov**.*

View QSCOUT's most recent annual progress report on the QSCOUT website using this QR code:

Round 1 User Projects

Simulating quantum chemical proton-coupled electron transfer dynamics

Indiana University

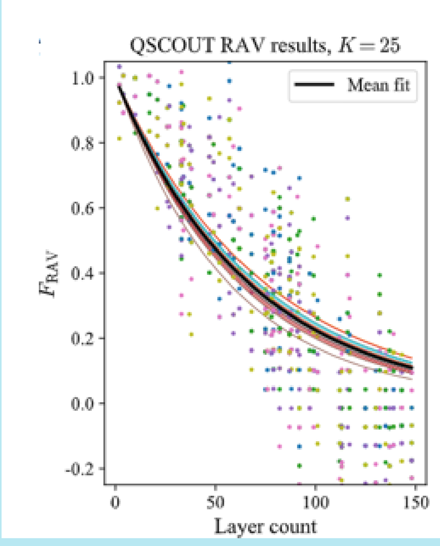


This project proposed the mapping of an Ising-type Hamiltonian to a discrete nuclear lattice Hamiltonian with site specificity. QSCOUT experimentally emulated the quantum chemical dynamics and vibrational properties of $DMANH^+$ within spectroscopic accuracy.

arXiv: 2204.08571

Efficient verification of continuously parameterized quantum gates

University of California, Berkeley



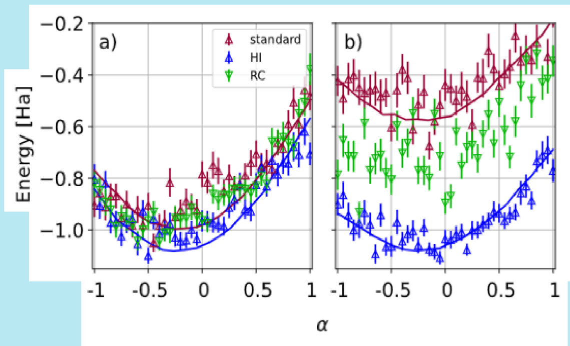
This project used the randomized analog verification (RAV) technique to investigate the efficient verification of continuously parameterized gates. These results were compared to cross-entropy benchmarking, with the RAV technique demonstrating fidelity estimates with less variance.

arXiv: 2205.13074

Characterizing and mitigating coherent errors using hidden inverses

Oak Ridge National Laboratories

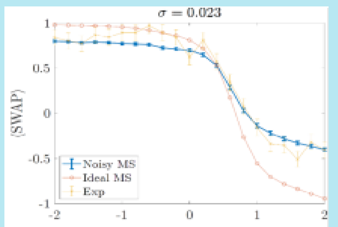
This project demonstrated how the use of coherent noise mitigation techniques – both randomized compiling and hidden inverse gates – could be used to characterize the types of noise present in the experimental system. These techniques were further investigated by the intentional introduction of coherent and incoherent errors.



arXiv: 2205.14225

Digital simulation of adiabatic evolution

University of New Mexico

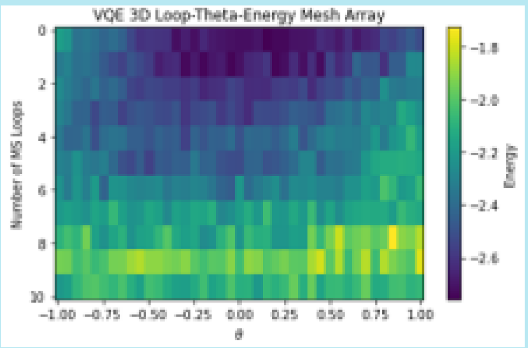


This project studies a digitized simulation of an adiabatic evolution, with an interpolating Hamiltonian that provides a wide range of adiabatic conditions. Work is in progress to improve results and understand the effects of noise on the simulation.

Exploring extrapolation techniques to reduce VQE error

Tufts University

This *Jaqal exemplar* project explores various extrapolation techniques to reduce error in VQE algorithms.



Round 2 User Projects

Indiana University
Continuing quantum chemical nuclear dynamic simulations with more chemical accuracy and including a generalized mapping to molecules with asymmetric potentials

London Centre for Nanotechnology
Simulating the quantum evolution of quantum circuits using tensor network algorithms to run and optimize its performance

Super Tech / Cold Quanta
Perform low-level control and performance benchmarking that can optimize circuits by using native gates and noise awareness models

Lawrence Livermore National Laboratories
Perform high-fidelity two-qubit gates in the presence of large amounts of simulated crosstalk, emulating the effects of larger individual addressing beams

Johns Hopkins University
Perform characterization and mitigation studies of temporally-correlated amplitude control noise to improve gate fidelity

IBM
Measure quantum volume circuits and determine how different noise sources affect various verification and validation metrics

References:

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