Q-CTRL'S EXPERTISE & CAPABILITIES

THE WORLD'S LEADING EXPERTS IN QUANTUM CONTROL ENGINEERING

Q-CTRL

INTRODUCTION

At Q-CTRL we've assembled a team comprising many of the world's leading experts in quantum control engineering, with expertise spanning the dominant quantum computing hardware platforms as well as near-term applications in sensing and metrology.

Our team understands the challenges faced by hardware R&D teams, software architects, and end-users, and has a sustained publication track record demonstrating an ability to drive progress across the field of quantum technology. We solve tough challenges from experimental hardware optimization through to quantum computer architecture analyses, sensor data fusion to improved clock stabilization using machine learning.

Just imagine how much our team can help you achieve.

Explore below for highlights of our capabilities.

SUPERCONDUCTING QUANTUM COMPUTING

Our team members have led the development and operation of superconducting quantum processors, as well as the application of optimal control to these devices. We've leveraged these experiences to deliver totally new control solutions for superconducting qubits to our customers and partners.

KEY STAFF

Dr. Mirko Amico
Dr. Harrison Ball
Dr. Yuval Baum
Dr. Per Liebermann

SELECTED PUBLICATIONS

Optimal qubit control using single-flux quantum pulses
Physical Review Applied 6 (2), 024022

Optimized cross-resonance gate for coupled transmon systems
Physical Review A 97 (4), 042348

Tunable quantum entanglement of three qubits in a nonstationary cavity
Physical Review A 96 (3), 032328

Dissipative quantum entanglement dynamics of two and three qubits due to the dynamical Lamb effect
Physical Review A 98 (4), 042325

Dynamical Lamb effect in a superconducting circuit
Physical Review A 100 (1), 013841

Experimental study of Shor's factoring algorithm using the IBM Q Experience
Physical Review A 100 (1), 012305

Laplace transform approach for the dynamics of N qubits coupled to a resonator
Physics Letters A 383 (6), 487-493

Experimental study of Shor's factoring algorithm using the IBM Q Experience
Physical Review A 100 (1), 012305

Laplace transform approach for the dynamics of N qubits coupled to a resonator
Physics Letters A 383 (6), 487-493

Dynamical Lamb effect in a superconducting circuit
Physical Review A 100 (1), 013841

Dissipative quantum entanglement dynamics of two and three qubits due to the dynamical Lamb effect
Physical Review A 98 (4), 042325

Tunable quantum entanglement of three qubits in a nonstationary cavity
Physical Review A 96 (3), 032328

TRAPPED-ION QUANTUM COMPUTING

The Q-CTRL team has extensive experience in trapped-ion quantum logic and experimental hardware. Through our IARPA and ARO sponsored collaborations with the University of Sydney we have demonstrated how Q-CTRL solutions can help identify noise sources and dramatically improve the robustness and speed of Molmer-Sorensen entangling gates.

KEY STAFF

Dr. Harrison Ball
Dr. Chris Bentley
Prof. Michael J. Biercuk
Dr. Andre Carvalho
Ms. Claire Edmunds

SELECTED PUBLICATIONS

Assessing the progress of trapped-ion processors towards fault-tolerant quantum computation
Physical Review X 7 (4), 041061

Engineered two-dimensional Ising interactions in a trapped-ion quantum simulator with hundreds of spins
Nature 484 (7395), 489

Fast gates for ion traps by splitting laser pulses
New Journal of Physics 15 (4), 043006

Site-resolved imaging of beryllium ion crystals in a high-optical-access Penning trap with inbore optomechanics
Review of Scientific Instruments 90 (5), 053103

Near-ground-state transport of trapped-ion qubits through a multidimensional array
Physical Review A 84 (3), 032314

A Study on Fast Gates for Large-Scale Quantum Simulation with Trapped Ions
Scientific Reports 7, 46197

Scaling Trapped Ion Quantum Computers Using Fast Gates and Microtraps
Physical Review Letters 120 (22), 220501

Phase-modulated entangling gates robust against static and time-varying errors
arXiv:1808.10462

QUANTUM CHARACTERIZATION, VERIFICATION, AND VALIDATION

The validation of quantum hardware performance is a critical task in the development and integration of quantum firmware. Our team has focused on moving beyond simplified abstractions to understanding the practical impact of realistic hardware noise environments on the interpretation of QCVV protocols. Our emphasis on gaining actionable information about microscopic noise sources has led to new interpretations of hardware characterization routines.

KEY STAFF

Dr. Harrison Ball
Dr. Yuval Baum
Prof. Michael J Biercuk
Dr. Li Li

SELECTED PUBLICATIONS

Full reconstruction of a 14-qubit state within four hours
New Journal of Physics 18 (8), 083036

Adaptive quantum state tomography via linear regression estimation: Theory and two-qubit experiment
npj Quantum Information 3 (1), 19

Experimental demonstration of real-time adaptive one-qubit quantum-state tomography
Physical Review A 95 (1), 012129

Experimental demonstration of real-time adaptive one-qubit quantum-state tomography
Physical Review A 95 (1), 012129

The effect of noise correlations on randomized benchmarking
Physical Review A 93, 022303

Experimental quantum verification in the presence of temporally correlated noise
NPJ Quantum information 4 (1), 1-9

Dynamically corrected gates suppressing spatiotemporal error correlations as measured by randomized benchmarking
Physical Review Research 2 (1), 013156

Adaptive scheduling of noise characterization in quantum computers
arXiv preprint arXiv:1904.07225

Convergence analysis for autonomous adaptive learning applied to quantum architectures
arXiv preprint arXiv:1911.05752

NEUTRAL ATOMS FOR QUANTUM COMPUTING AND SENSING

The Q-CTRL Quantum Engineering team has built extraordinary proficiency from working in some of the world's most advanced atomic devices groups. We have a demonstrated track record of the integration of machine-learning and optimal control into neutral atom experiments to drive major performance enhancement in hardware.

KEY STAFF

Dr. Albert Benseny Cases
Dr. Chris Bentley
Dr. Andre Carvalho
Dr. Michael Hush
Dr. Nick Robins
Dr. Harry Slatyer

SELECTED PUBLICATIONS

Machine learning for quantum physics
Science 355 (6325), 580-580

Approaching the adiabatic timescale with machine learning Proceedings of the National Academy of Sciences 115 (52), 13216-13221

Multiparameter optimisation of a magneto-optical trap using deep learning
Nature Communications 9 (1), 4360

Fast machine-learning online optimization of ultra-cold-atom experiments
Scientific Reports 6, 25890

Feedback control of an interacting Bose-Einstein condensate using phase-contrast imaging
Physical Review A 82 (4), 043632

Continuous measurement feedback control of a Bose-Einstein condensate using phase-contrast imaging
Physical Review A 80 (1), 013614

Transferring orbital and spin angular momenta of light to atoms
New Journal of Physics 12 (8), 083053

Atomtronics with holes: coherent transport of an empty site in a triple-well potential
Physical Review A 82 (1), 013604

Need for relativistic corrections in the analysis of spatial adiabatic passage of matter waves
Physical Review A 85 (5), 053619

Transport of ultracold atoms between concentric traps via spatial adiabatic passage
New Journal of Physics 18 (1), 015010

Speeding up the spatial adiabatic passage of matter waves in optical microtraps by optimal control
Quantum information processing 12 (3), 1439-1467

Non-adiabatic generation of NOON states in a Tonks--Girardeau gas
New J. Phys. 18, 035012

Spatial non-adiabatic passage using geometric phases
EPJ Quantum Technology 4 (1), 3

Robust boson dispenser: Quantum state preparation in interacting many-particle systems
Physical Review A 96 (2), 023606

Interaction-induced effects on Bose-Hubbard parameters
Physical Review A 96 (6), 063611

Coherent spectral hole burning and qubit isolation by stimulated Raman adiabatic passage
Physical Review A 100 (2), 023813

Fast and robust quantum control based on Pauli blocking
Physical Review A 96 (4), 043601

Shaken not stirred: Creating exotic angular momentum states by shaking an optical lattice
J. Phys. B 49, 215003

Quantum tunneling dynamics of an interacting Bose-Einstein condensate through a Gaussian barrier
Physical Review A 98, 053629(2018)

Observation of a modulational instability in Bose-Einstein condensates
Physical Review A: Atomic, Molecular and Optical Physics 96, 4(2017) 1-5

Highly efficient optical quantum memory with long coherence time in cold atoms
Optica 3, 1(2016) 100-107

PRECISION METROLOGY, CLOCKS, AND SENSING

We are pioneers in the application of quantum control to clocks and sensors for applications in defense and aerospace. Our experiences tackle some of the toughest problems in developing high-performance devices in tight-SWAP settings. We've delivered control solutions to suppress the Dick effect in atomic clocks, narrowband controls to suppress clutter in magnetometers, and novel pulse sequences enabling nanoscale MRI. Moreover, members of our team have led ground-breaking hardware developments in novel quantum-enhanced sensors.

KEY STAFF

Prof. Michael J Biercuk
Dr. Andre Carvalho
Dr. Michael Hush
Dr. Viktor Perunicic
Dr. Nick Robins

SELECTED PUBLICATIONS

Application of optimal band-limited control protocols to quantum noise sensing
Nature Communications 8, 2189

Ultrasensitive detection of force and displacement using trapped ions
Nature Nanotechnology 5 (9), 646

A quantum spin-probe molecular microscope
Nature Communications 7, 12667

Detection of atomic spin labels in a lipid bilayer using a single-spin nanodiamond probe
Proceedings of the National Academy of Sciences 110 (27), 10894-10898

Multimode laser cooling and ultra-high sensitivity force sensing with nanowires
Nature Communications 5(2014) 4663-4663
Controlling oscillators
US Patent 9,362,929

Prediction and real-time compensation of qubit decoherence via machine-learning
Nature Communications 8, 14106

Sagnac interferometry with a single atomic clock
Physical Review Letters 115 (16), 163001

Analytically exploiting noise correlations inside the feedback loop to improve locked-oscillator performance
Physical Review E 94, 022204

Towards rotation sensing with a single atomic clock
Quantum Optics 9900, 990007

Simultaneous Precision Gravimetry and Magnetic Gradiometry with a Bose-Einstein Condensate: A High Precision, Quantum Sensor
Physical Review Letters 117, 13(2016)

A faster scaling in acceleration-sensitive atom interferometers
Europhysics Letters 105, 6(2014) 63001

Role of source coherence in atom interferometery
Physical Review A: Atomic, Molecular and Optical Physics 89, 2(2014) 023626

A Bose-condensed, simultaneous dual-species Mach-Zehnder atom interferometer
New Journal of Physics 16, 2014(2014) 073035/ 1-15

Atom lasers: Production, properties and prospects for precision inertial measurement
Physics Reports: Review Section of Physics Letters 529, 3(2013) 265-296

Precision atomic gravimeter based on Bragg diffraction
New Journal of Physics 15(2013)

From apples to atoms: measuring gravity with ultra cold atomic test masses
Preview 164(2013) 30-33

Precision measurement with cold atoms
Physics 5, 26(2012) 1-3

Cold-atom gravimetry with a Bose-Einstein condensate
Physical Review A: Atomic, Molecular and Optical Physics 84, 3(2011) 5

APPLIED QUANTUM CONTROL ENGINEERING AND MACHINE LEARNING

Various members of our team have made foundational contributions to quantum control engineering as a discipline. This spans open quantum-system dynamics, open-loop control and dynamic error suppression, feedback control, and input-output theory. We also possess deep expertise in machine learning applied to control engineering with experience spanning robotics and quantum coherent devices.

KEY PERSONNEL

Dr. Harrison Ball
Prof. Michael J Biercuk
Dr. Andre Carvalho
Mr. Sean Howell
Dr. Michael Hush
Dr. Li Li
Dr. Junkai Zeng

SELECTED PUBLICATIONS, OPEN-LOOP CONTROL

Optimized dynamical decoupling in a model quantum memory
Nature 458 (7241), 996

Experimental noise filtering by quantum control
Nature Physics 10, 825-829

High-order noise filtering in nontrivial quantum logic gates
Physical Review Letters 109, 020501

Dynamical decoupling sequence construction
as a filter-design problem
Journal of Physics B: Atomic, Molecular and Optical Physics
44 (15), 154002

Arbitrary quantum control of qubits in the presence
of universal noise
New Journal of Physics 15, 095004

Robustness of composite pulses to time-dependent control noise
Physical Review A 90, 012316

Reducing sequencing complexity in dynamical
quantum error suppression by Walsh modulation
Physical Review A 84 (6), 062323

Walsh-synthesized noise filters for quantum logic
EPJ Quantum Technology 2 (1), 11

Fastest pulses that implement dynamically
corrected single-qubit phase gates
Physical Review A 98 (1), 012301w

General solution to inhomogeneous dephasing
and smooth pulse dynamical decoupling
New Journal of Physics 20 (3), 033011

Geometric formalism for constructing arbitrary
single-qubit dynamically corrected gates
Physical Review A 99 (5), 052321

Concepts of quantum non-Markovianity: a hierarchy
Physics Reports, 759, 1-51 (2018)

Experimental control of the transition from Markovian
to non-Markovian dynamics of open quantum systems
Nature Physics 7, 931-934 (2011)

Canonical form of master equations and
characterization of non-Markovianity
Phys. Rev. A 89 042120

Experimental generation of an eight-photon
Greenberger Horne Zeilinger state
Nature Communication 2, 546, 2011

Concepts of quantum non-Markovianity: a hierarchy
Physics Reports 759, 1-51

Experimental control of the transition from Markovian
to non-Markovian dynamics of open quantum systems
Nature Physics

Experimental generation of an eight-photon
Greenberger–Horne–Zeilinger state
Nature Communications 2, 546

Canonical form of master equations
and characterization of non-Markovianity
Physical Review A 89 (4), 042120

Experimental validation of quantum steering
ellipsoids and tests of volume monogamy relations
Physical Review Letters 122 (7), 070402

Boson–boson pure-dephasing model
with non-Markovian properties
Physics Letters A 383 (2-3), 127-135

APPLIED QUANTUM CONTROL ENGINEERING AND MACHINE LEARNING

KEY PERSONNEL

Dr. Harrison Ball
Dr. Yuval Baum
Prof. Michael J Biercuk
Dr. Andre Carvalho
Mr. Sean Howell
Dr. Michael Hush
Dr. Li Li
Dr. Junkai Zeng

SELECTED PUBLICATIONS, CLOSED-LOOP STABILIZATION

Machine learning for predictive estimation
of qubit dynamics subject to dephasing
Physical Review Applied 9 (6), 064042

Ignorance is bliss: General and robust cancellation
of decoherence via no-knowledge quantum feedback
Physical Review Letters 113 (2), 020407

Robustness of system-filter separation for the
feedback control of a quantum harmonic oscillator
undergoing continuous position measurement
Physical Review A 87 (1), 013626

Feedback tracking control of non-Markovian quantum
systems IEEE Transactions on Control Systems Technology
25 (5), 1552-1563

Coherently tracking the covariance matrix
of an open quantum system
Physical Review A 92 (1), 012115

Non-Markovian coherent feedback control
of quantum dot systems
Quantum Science and Technology 2 (1), 014002

Selected Publications, Quantum Dynamics:
Decoherence and multipartite entanglement
Physical Review Letters 93 (23), 230501

Optimal dynamical characterization of entanglement
Physical Review Letters 98 (19), 190501

Generic map from non-Lindblad to Lindblad master equations
Physical Review A 91 (3), 032113

Scalable quantum field simulations of conditioned systems
Physical Review A 80 (1), 013606

Gaussian representation of extended quantum states
Physics Letters A 376 (1), 19-23

The Pointer Basis and Feedback Stabilization
of Quantum systems
New J. Phys. 16 113026

The pointer basis and the feedback stabilization
of quantum systems
New Journal of Physics 16 (11), 113026

THE IMPACT OF NOISE & CONTROL IN QUANTUM COMPUTER ARCHITECTURE

The interface of quantum control with other layers of the quantum computing stack presents some of the most profound opportunities to advance quantum computing in the NISQ era. Our team has led the exploration of control in the development of quantum computer architectures, from the physical to the logical layers.

KEY STAFF

Dr. Harrison Ball
Prof. Michael J Biercuk
Dr. Andre Carvalho
Ms Claire Edmunds
Dr Michael Hush
Dr Junkai Zeng

SELECTED PUBLICATIONS

Designing a practical high-fidelity
long-time quantum memory
Nature Communications 4, 2045

Functional basis for efficient physical layer
classcal control in quantum processors
Physical Review Applied 6 (6), 064009

The role of master clock stability
in quantum information processing
Nature Quantum Information 2, 16033

Quantum–classical interface based
on single flux quantum digital logic
Quantum science and technology 3 (2), 024004

Scaling Trapped Ion Quantum Computers
Using Fast Gates and Microtraps
Physical Review Letters 120 (22), 220501

Near-ground-state transport of trapped-ion
qubits through a multidimensional array
Physical Review A 84 (3), 032314

Dynamically corrected gates suppress
spatio-temporal error correlations as
measured by randomized benchmarking
arXiv:1909.10727

Adaptive scheduling of noise characterization
in quantum computers
arXiv:1904.07225