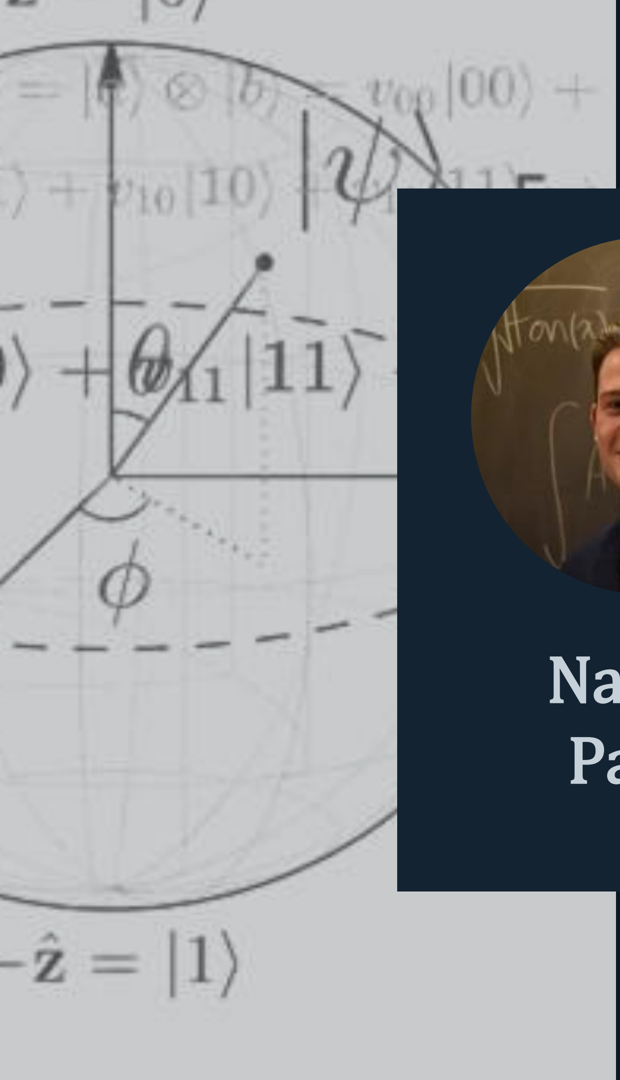


Nathan Pacey

About Me

linkedin.com/in/nathan-pacey

npacey01.wixsite.com/website

github.com/NathanPaceydev

youtube.com/@nathanpacey

Education

M.Sc. Quantum Science and Engineering

EPFL

Specialization in Quantum Information and Computation

Research interests in Quantum Surface Codes, QML, QEC, Quantum Algorithms and Fundamental Quantum Theory

B.A.Sc Engineering Physics and Computing

Queen's University

Stockdale, P. Excellence Award in Physics

Thesis on Developing Machine Learning Algorithms for American Style Stock Options

Capstone on Development of a Web Application for Automated Clean Energy Feasibility Studies Using Global Data Sources

Research Experience

Queen's University

CERN

IQC Institute for Quantum Computing

University of Waterloo

EPFL

Industry Experience

Magna

Minute School

Vision Spatial Technologies

Lockheed Martin

Encircle

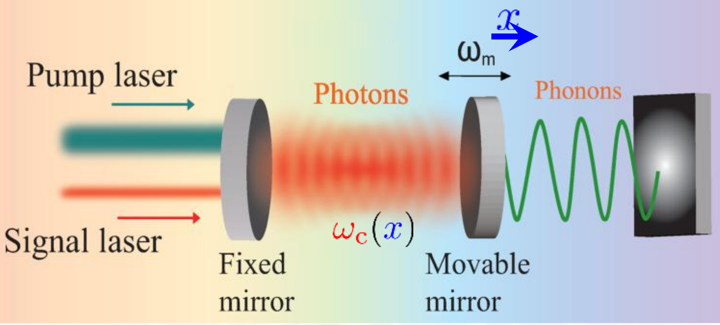
Optomechanical Pair-Coherent State Generation

Schrodinger's Optomechanical Cats: Pairing up for Quantum Computing

Nathaniel James Pacey

Supervising Professor Bradley Hauer

University of Waterloo Electrical and Computer Engineering
and Institute for Quantum Computing



Li, Jinjin, et al. Entropy, vol. 15, no. 2, 2013, pp. 434-444

Advantages of Mechanical Systems

1 Noise-Biased Error Correction

Mechanical systems offer the potential for noise-biased error correction within a compact footprint.

2 Long Lifetimes

Mechanical qubits Have the potential to exhibit longer coherence times, enabling longer quantum operations.

3 Minimal Crosstalk

The low crosstalk between mechanical qubits allows for high-fidelity operations and the scaling of the system.

Pair Coherent States

$$\gamma = \frac{\epsilon_{ab}}{i\kappa_{ab}/2}$$

$$|\gamma, \delta\rangle = \mathcal{N} \sum_{n=0}^{\infty} \frac{\gamma^{n+\delta/2}}{\sqrt{n!(n+\delta)!}} |n+\delta\rangle_a |n\rangle_b$$

$$\delta = a^\dagger a - b^\dagger b$$

Improved Error Correction

- Pair cat codes detect and correct a broader range of errors than single cat codes. Robust to single photon loss

Enhanced Fault Tolerance

- Greater resistance to noise and correlated errors
- Reduced physical qubits for error corrected logical qubits

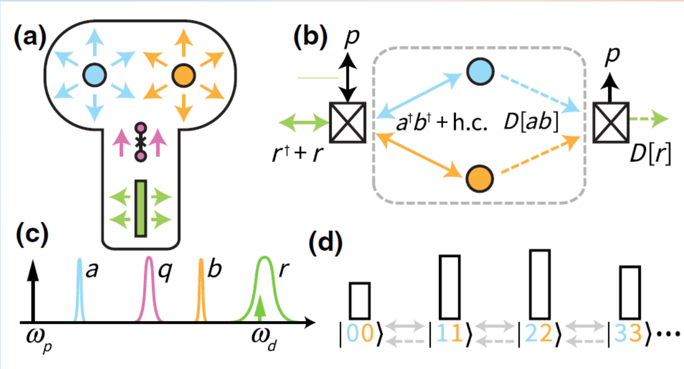
Increased Stability and Performance

- Better long-term coherence for quantum computing and communication

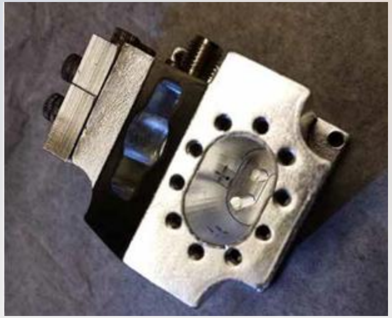
$$\dot{\rho} = -\frac{i}{\hbar}[H, \rho] + \kappa_{ab} L[ab]\rho \qquad \frac{H}{\hbar} = \epsilon_{ab}^* ab + \epsilon_{ab} a^\dagger b^\dagger$$

Chen Wang Lab at
the University of Massachusetts-Amherst

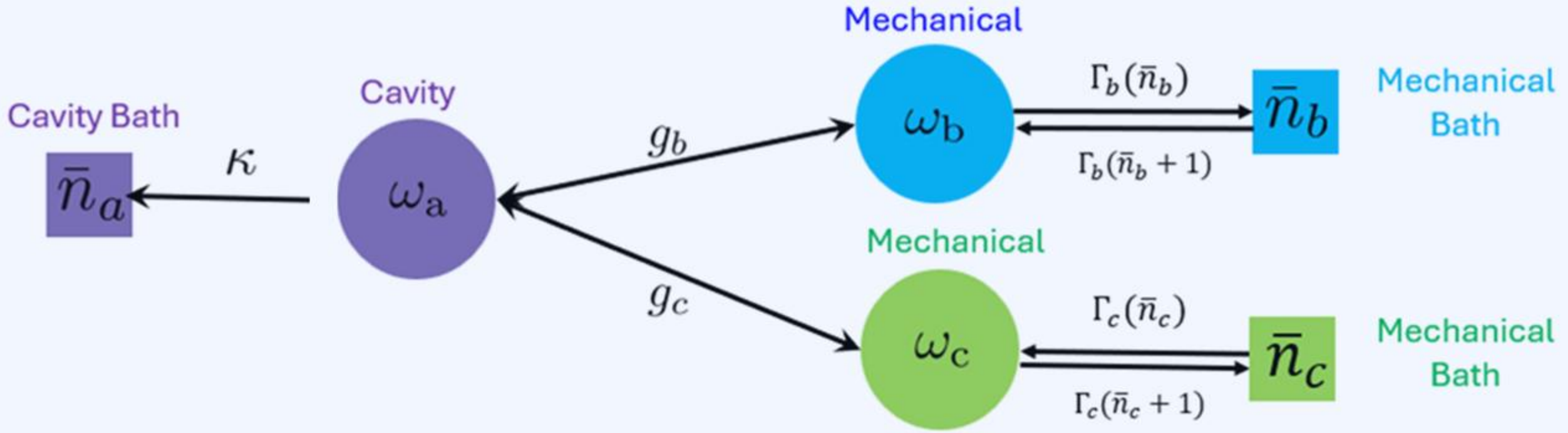
Gertler *et al.*, *PRX* **4**, 020319 (2023)



Experimental Fidelity: $\mathcal{F} = 41.5 \pm 1.3\ \%$

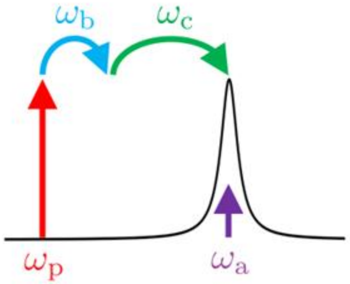


Double Mechanical Mode Optomechanical System



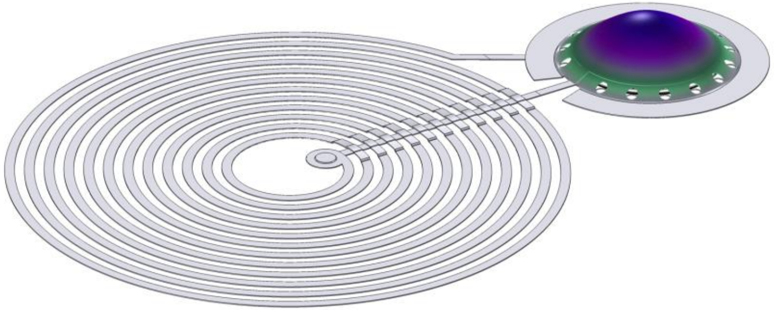
$$\dot{\rho} = -\frac{i}{\hbar}[H,\rho] + \kappa L[a]\rho + \Gamma_b(\bar{n}_b + 1)\, L[b]\rho + \Gamma_b \bar{n}_b L[b^\dagger]\rho + \Gamma_c(\bar{n}_c + 1)\, L[c]\rho + \Gamma_c \bar{n}_c L[c^\dagger]\rho$$

$$\frac{H}{\hbar} = \omega_a a^\dagger a + \omega_b b^\dagger b + \omega_c c^\dagger c + a^\dagger a[g_b(b + b^\dagger) + g_c(c + c^\dagger)]$$
$$+ \varepsilon_d a^\dagger e^{i\omega_d t} + \varepsilon_d^* a e^{-i\omega_d t} + \varepsilon_p a^\dagger e^{i\omega_p t} + \varepsilon_p^* a e^{-i\omega_p t}$$



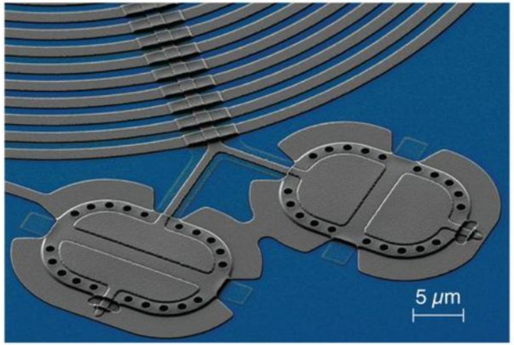
Experimental Realization

Vacuum Gap Capacitors of Two Types



Teufel *et al.*, *Nature* ***475***, 359 (2011)

1: Two Mechanical Resonators



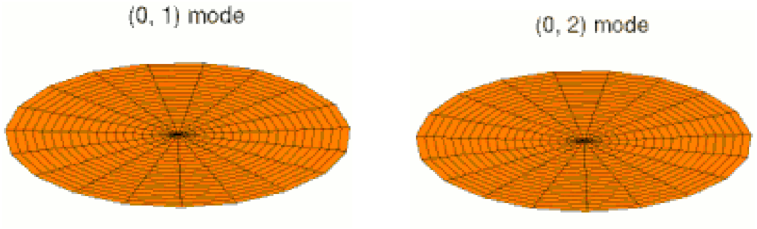
Kotler *et al.*, *Science* **372**, 622 (2021)

- Individual frequencies (more tunable) but share a single cavity mode
- Coupling shared between mechanical modes
- Can cause parasitic coupling

2: Two mechanical Modes of a Single Resonator

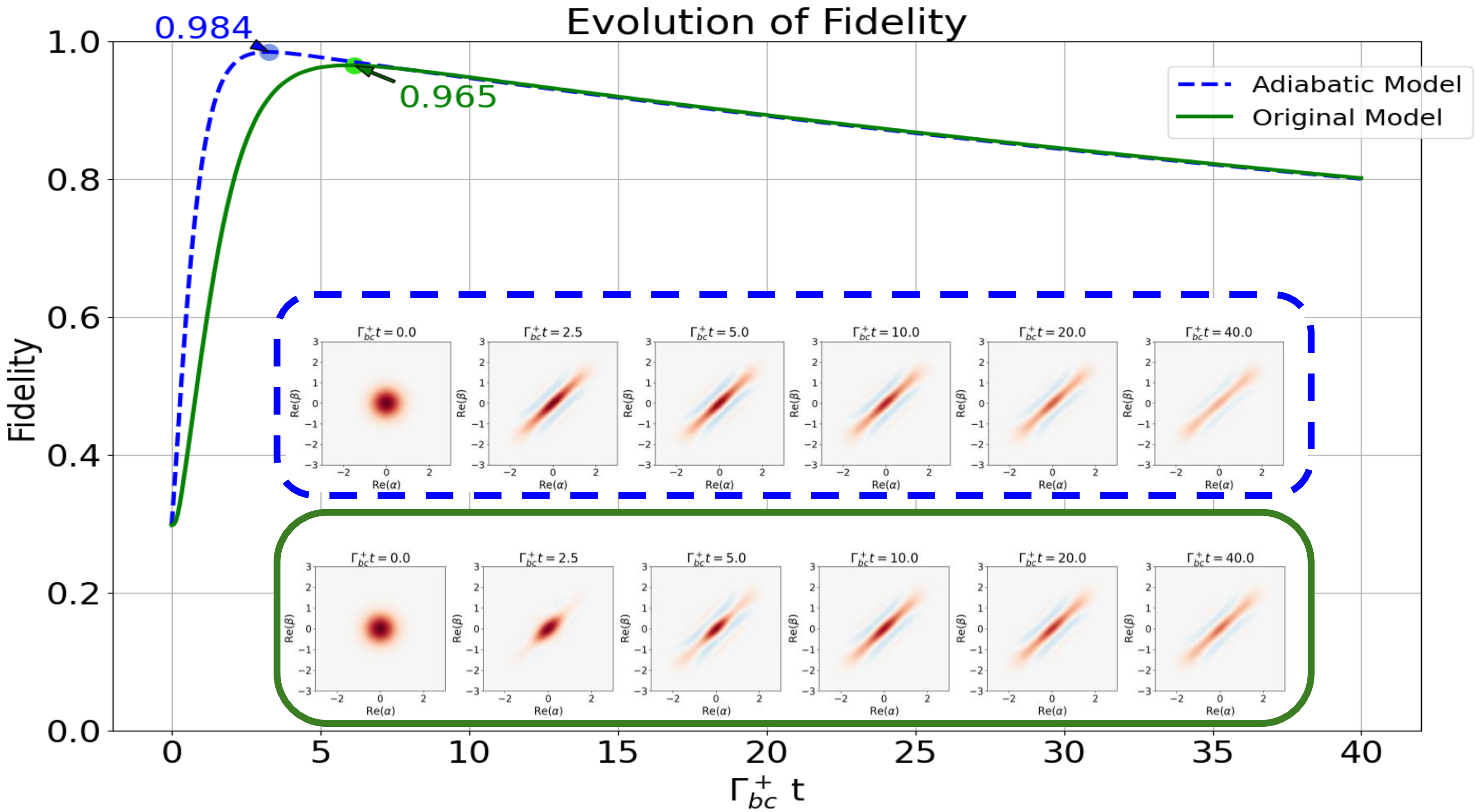
- More constrained in frequency for a given geometry
- **Choose this option** with a constant circular membrane mode ratio

$$\frac{\omega_b}{\omega_c} = 2.3$$



Simulation Fidelity

Pair Coherent State: $\boldsymbol{\delta = 0}$



When Nathan isn't doing Physics, what is he up to?