Convergence: The Promise and Reality of AI & Quantum

November 14, 2022

Quantum Limited Sensing with Superconducting Circuits

Kevin O'Brien

MIT EECS

MIT CSAIL Computer Science & Artificial Intelligence Laboratory

MIT Center for Quantum Engineering

Superconducting qubit measurement

- Superconducting qubits have an energy of ~3×10^{-24} Joules.
- In a fridge at 10 thousands of a degree above absolute zero.
- Ideally measure qubit state with >99% accuracy.
- Amplifiers with ultra low noise and broad bandwidth needed to measure many qubits at once.

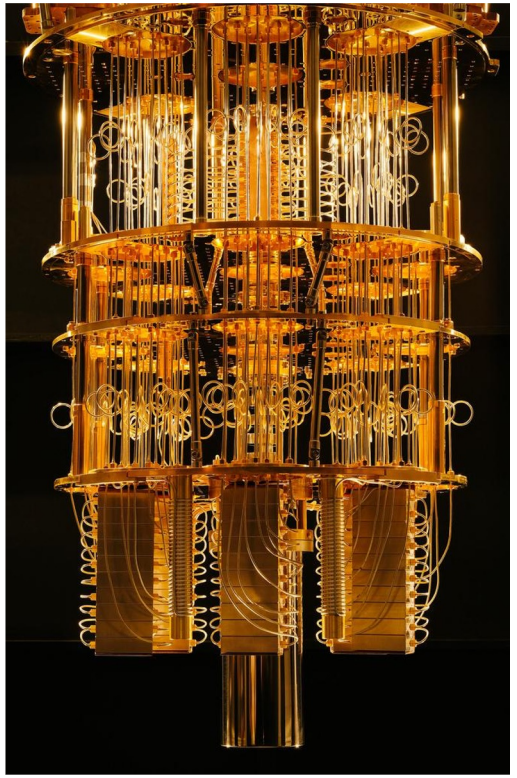
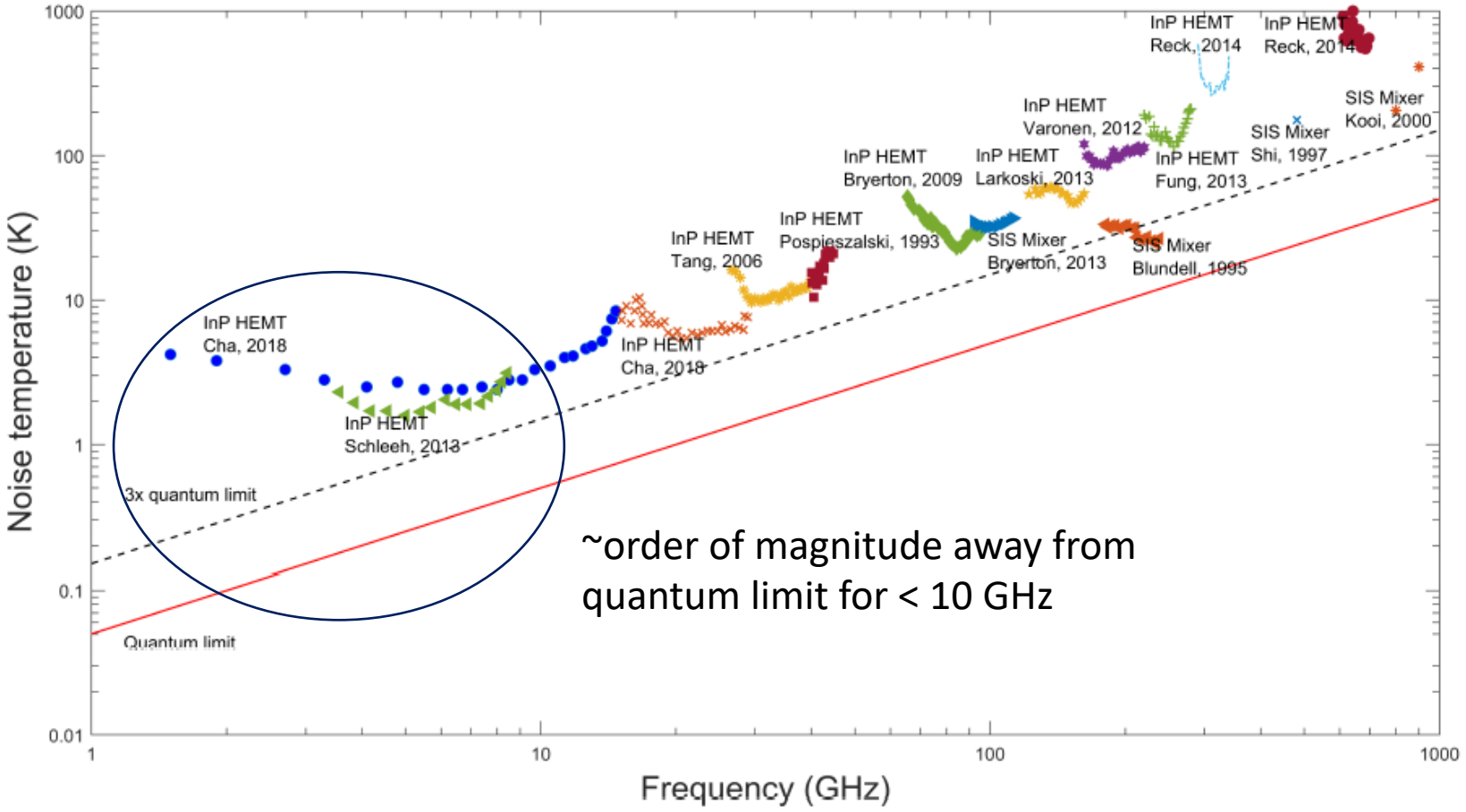
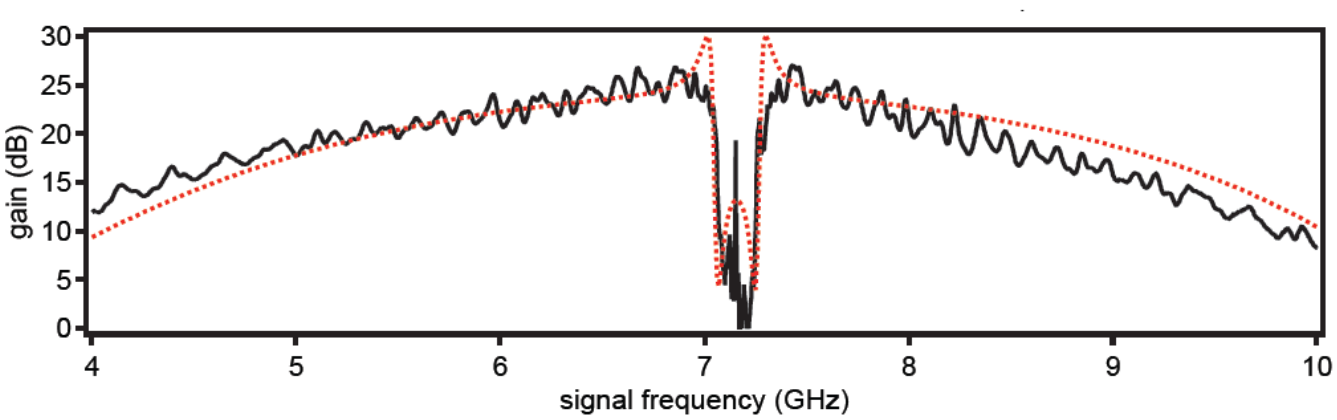


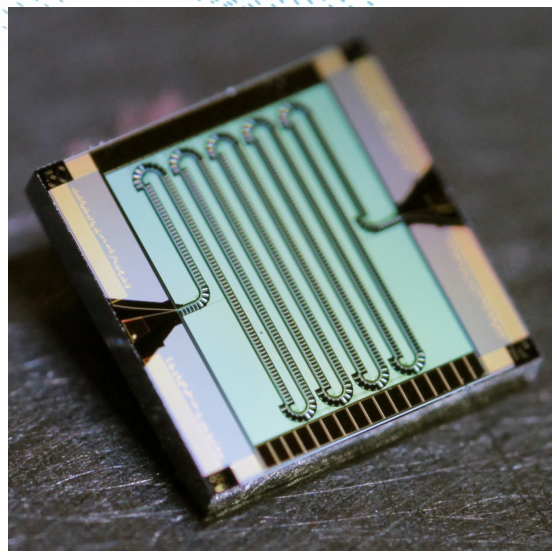
Image credit: IBM Q

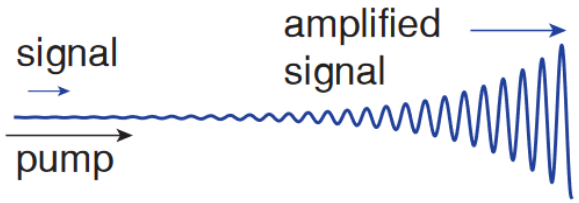
Transistor based amplifiers have too much noise



Superconducting Josephson traveling wave parametric amplifiers (JTWPA)



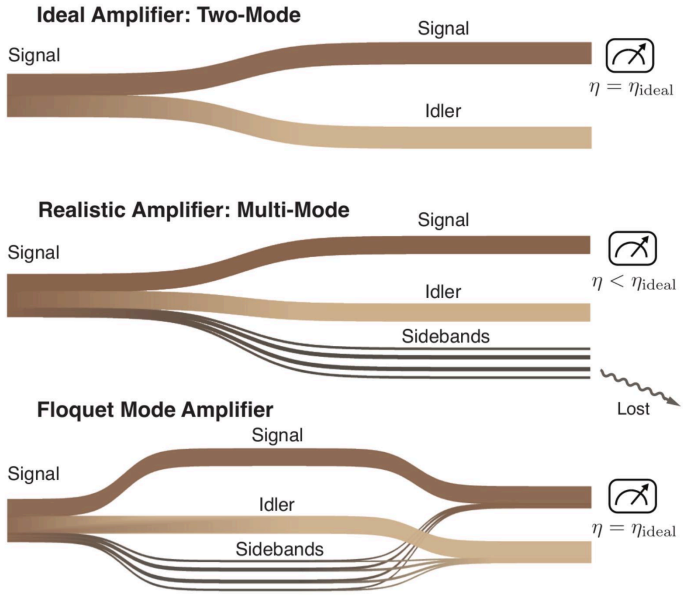


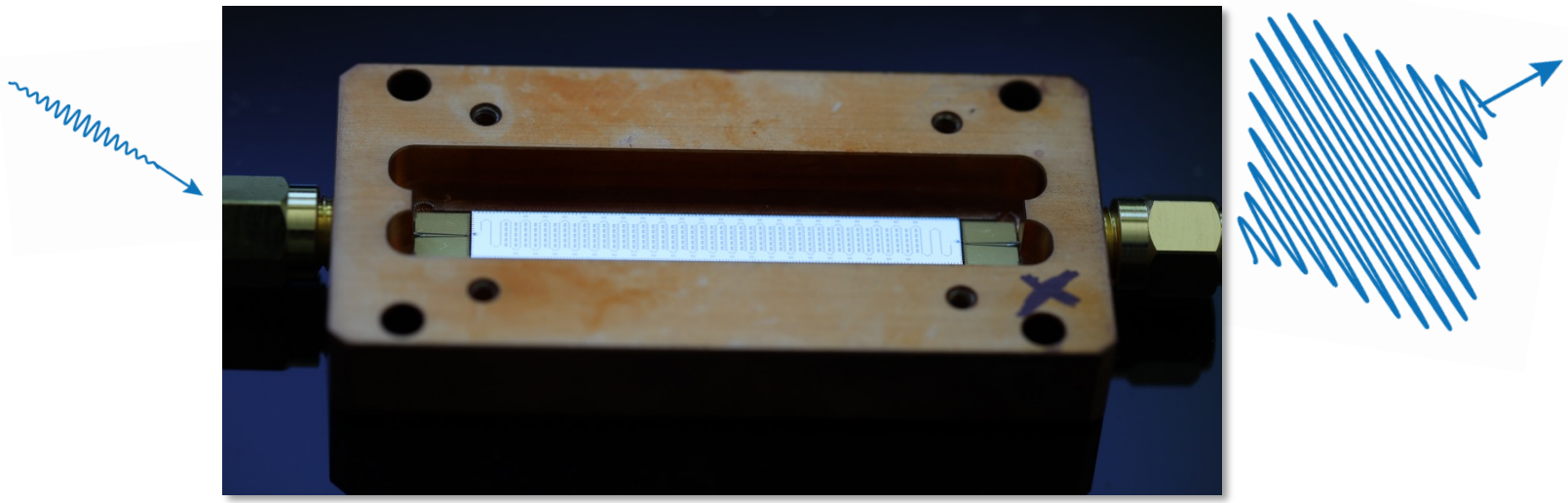


- Developed in collaboration with Lincoln Lab. Fabricated at Lincoln.
- >300 distributed worldwide.
- High gain, broad bandwidth.
- Noise performance within a factor of 2 of the quantum limit
- Can we do better?

Macklin et al. Science (2015)

Floquet mode Josephson traveling wave parametric amplifiers

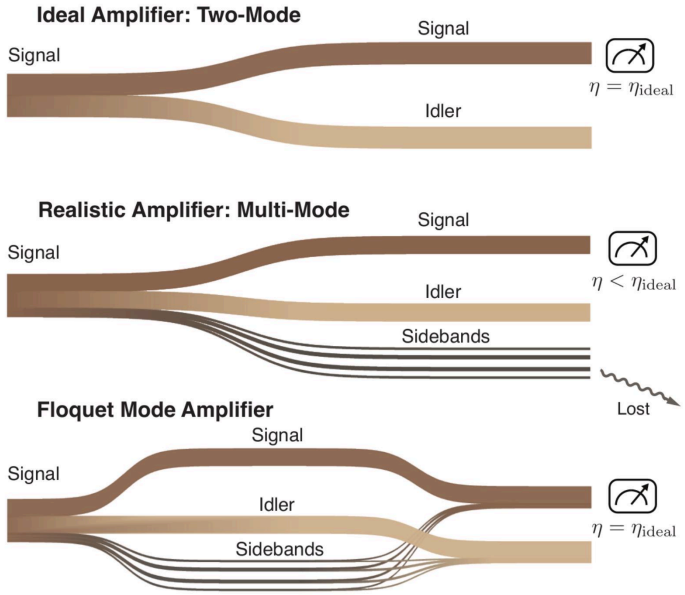


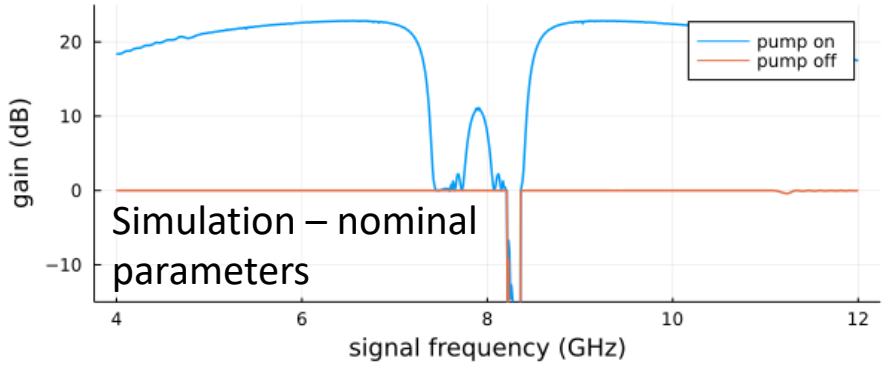


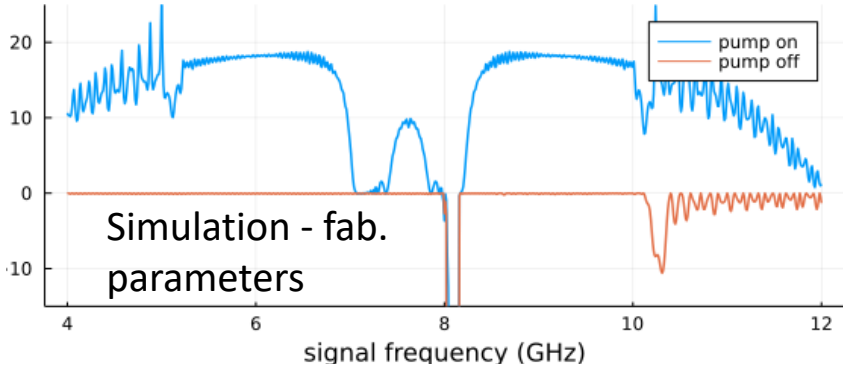
- Noise performance in previous JTWPAs limited by dissipation and generation of other frequencies (sidebands)
- New amplifier design and fabrication processes mitigates both
- Noise performance within 99% of quantum limited predicted

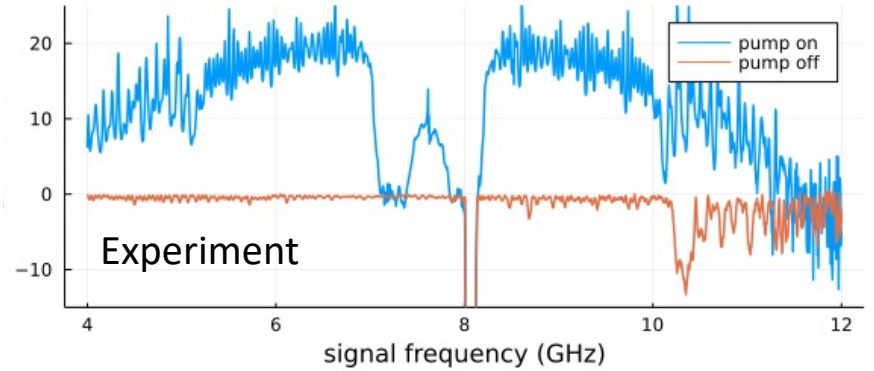
K. Peng et al. (unpublished)

Floquet mode Josephson traveling wave parametric amplifiers





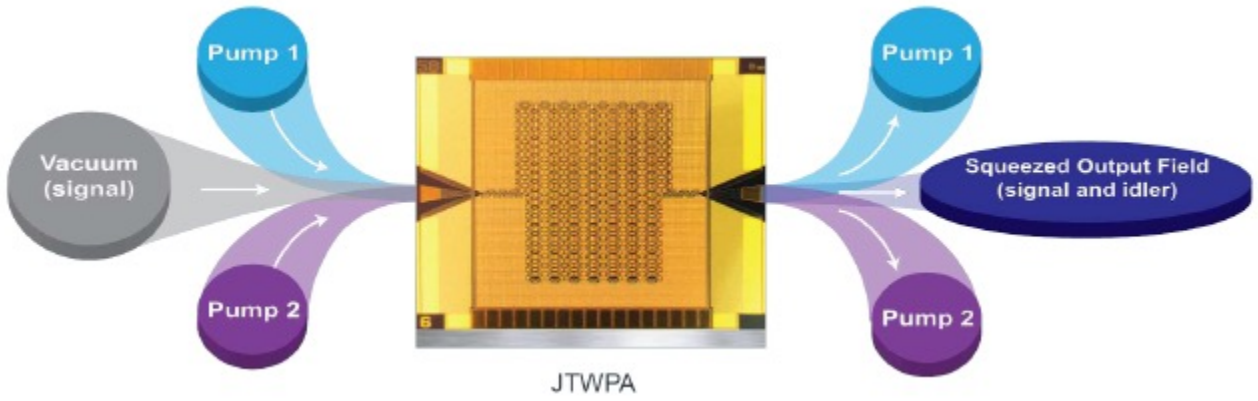


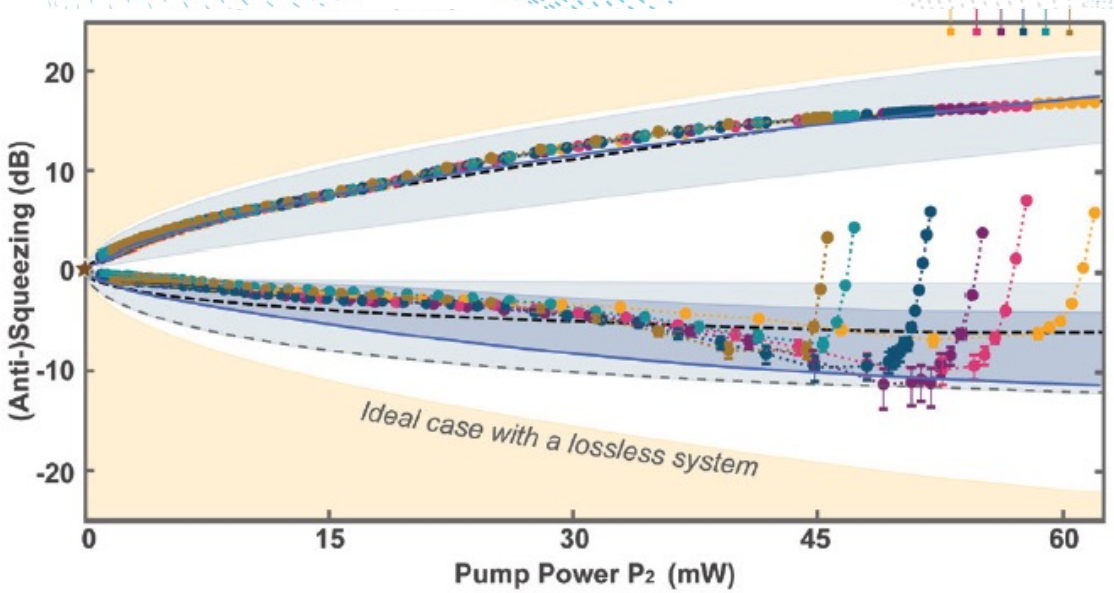


- Noise performance in previous JTWPAs limited by dissipation and generation of other frequencies (sidebands)
- New amplifier design and fabrication processes mitigates both
- Noise performance within 99% of quantum limited predicted

K. Peng et al. (unpublished)

Squeezing the quantum vacuum





- Squeezing the quantum vacuum enables noise performance better than the standard quantum limit.
- Demonstrated state of the art squeezing over a record bandwidth.
- Applications in particle physics (collaboration with Formaggio group in MIT Physics)

J. Qiu et al. (O'Brien and Oliver groups)
Accepted to Nature Physics

MIT CSAIL Computer Science & Artificial Intelligence Laboratory

MIT Center for Quantum Engineering

Convergence: The Promise and Reality of AI & Quantum

November 14, 2022

Quantum technologies have real world impact both in quantum computing and other fields

Design

Fab.

Kevin O’Brien

MIT CSAIL Computer Science & Artificial Intelligence Laboratory

MIT Center for QuantumEngineering