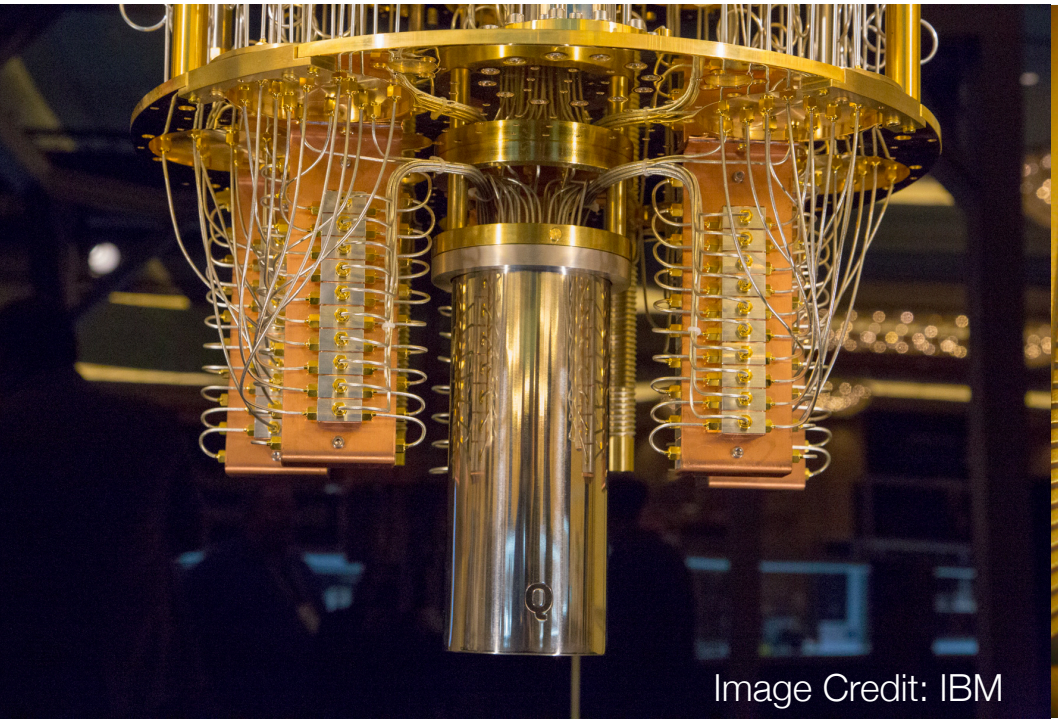
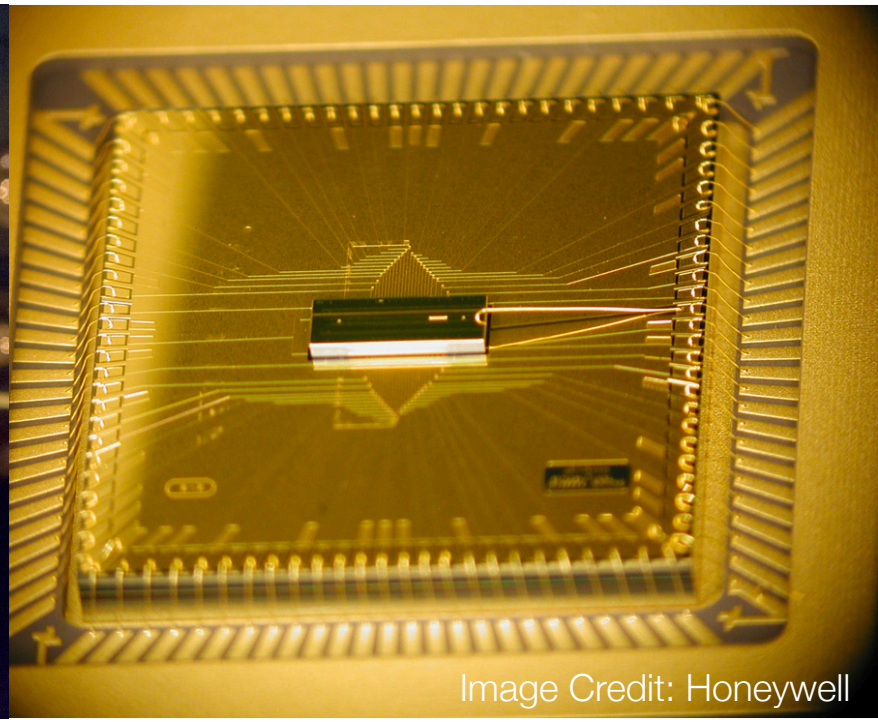
Technologies that have demonstrated algorithms

Superconducting qubits



Trapped ion qubits



Surface codes approach with superconducting qubits

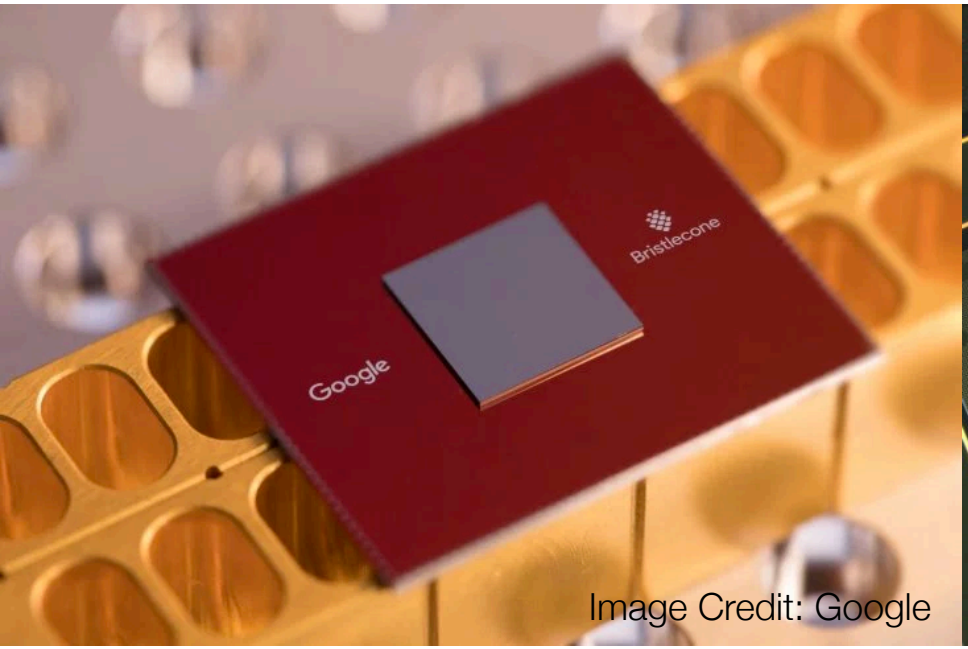


Image Credit: Google

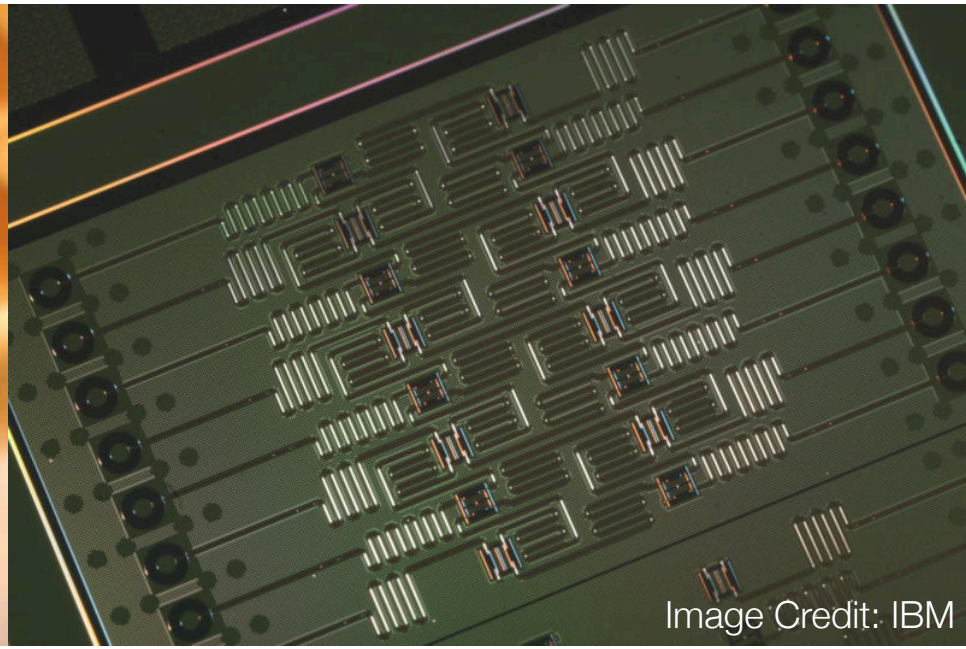
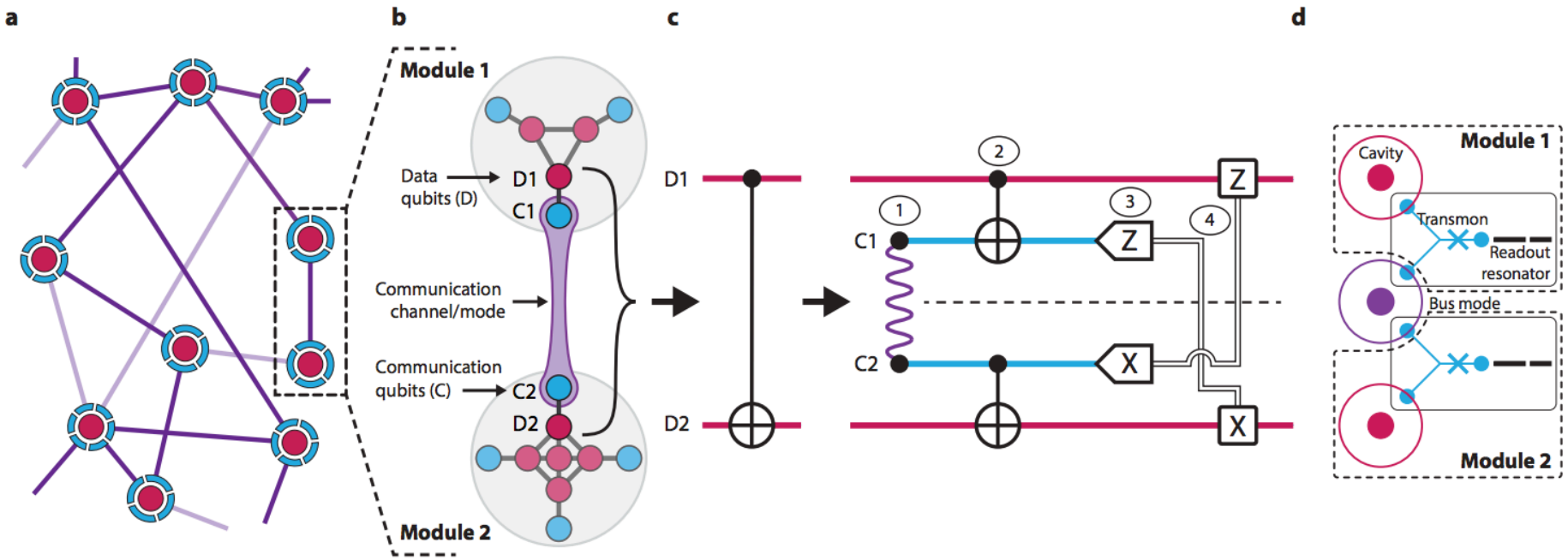


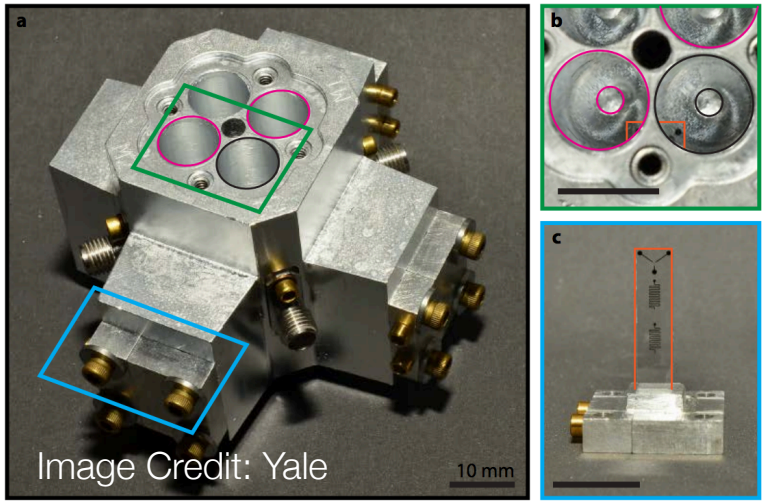
Image Credit: IBM

- Approach taken by major industry players: IBM, Google, Rigetti
- Internal testing on 72- and 50-qubit machines ongoing, nearest neighbor coupling
- Demonstrated ~20-qubit machines with all qubits >30us coherence, single qubit fidelities around 99.99% and two-qubit gate fidelities near 99%
- Entering era where claims of quantum supremacy must be considered

Modular approach with superconducting circuits

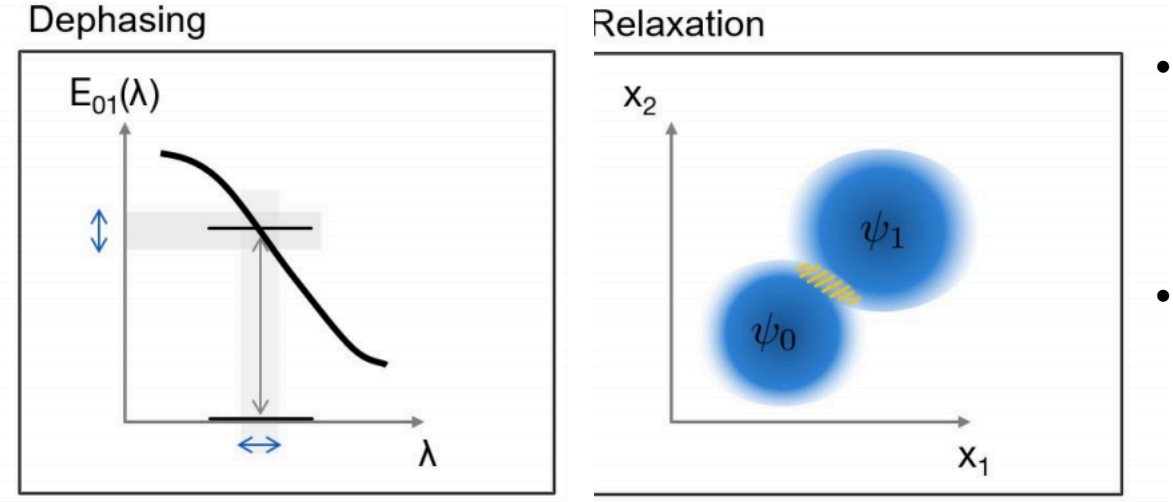


- Hardware efficient cat-code in each module
- Teleport gates between modules
- Approach taken by Yale/QCI

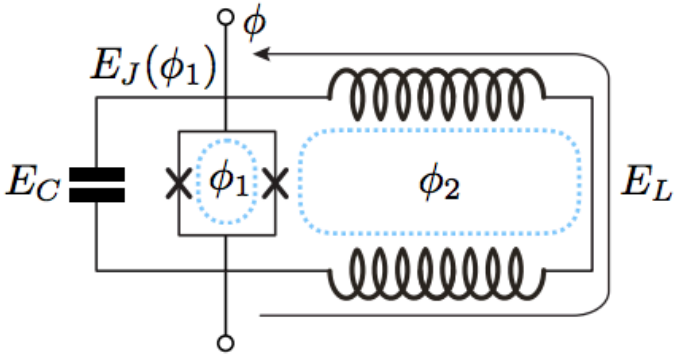


arXiv:1801.05283

Novel superconducting qubits

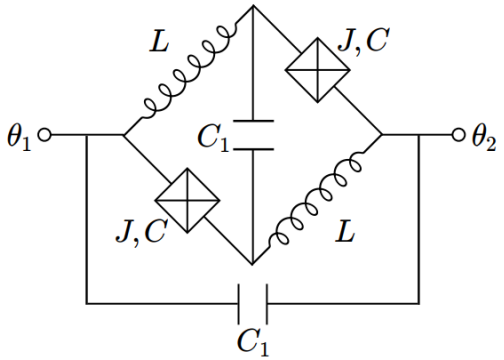


- Until recently, progress focused on improving dephasing: tranmson qubit
- New focus on fundamental protection from relaxation while maintaining low dephasing



Phys. Rev. Lett. 120, 150503 (2018)

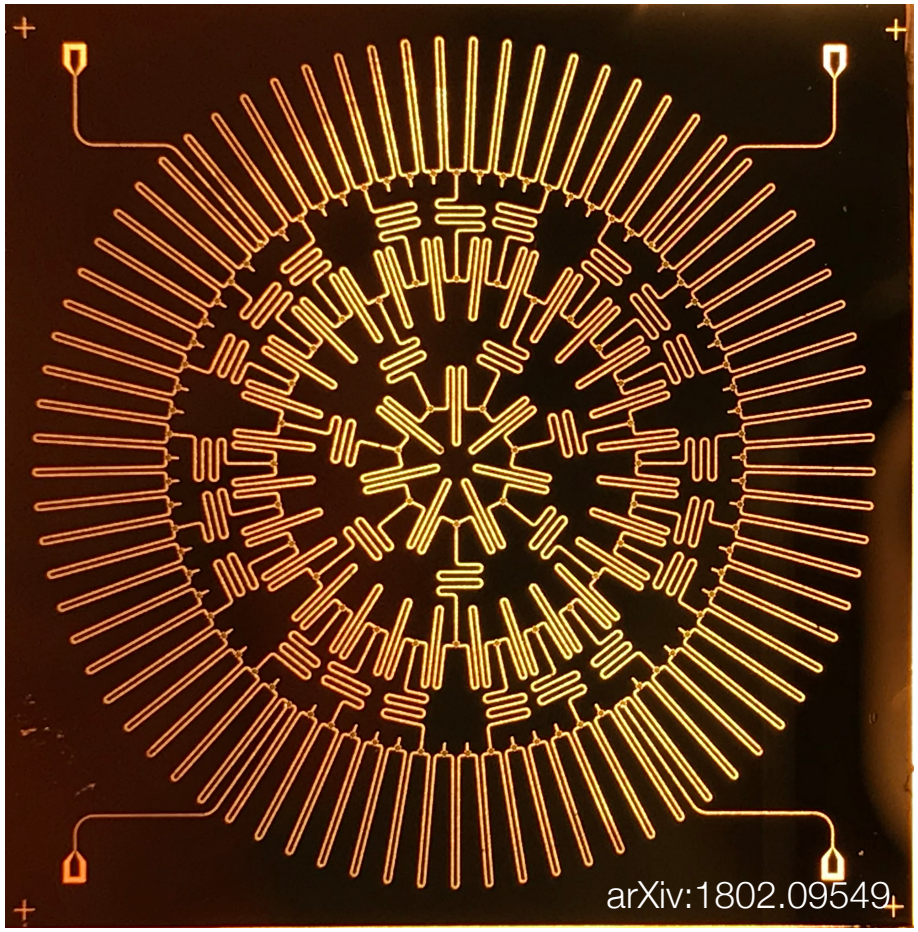
Inductively shunted transmon gives relaxation times approaching 10ms



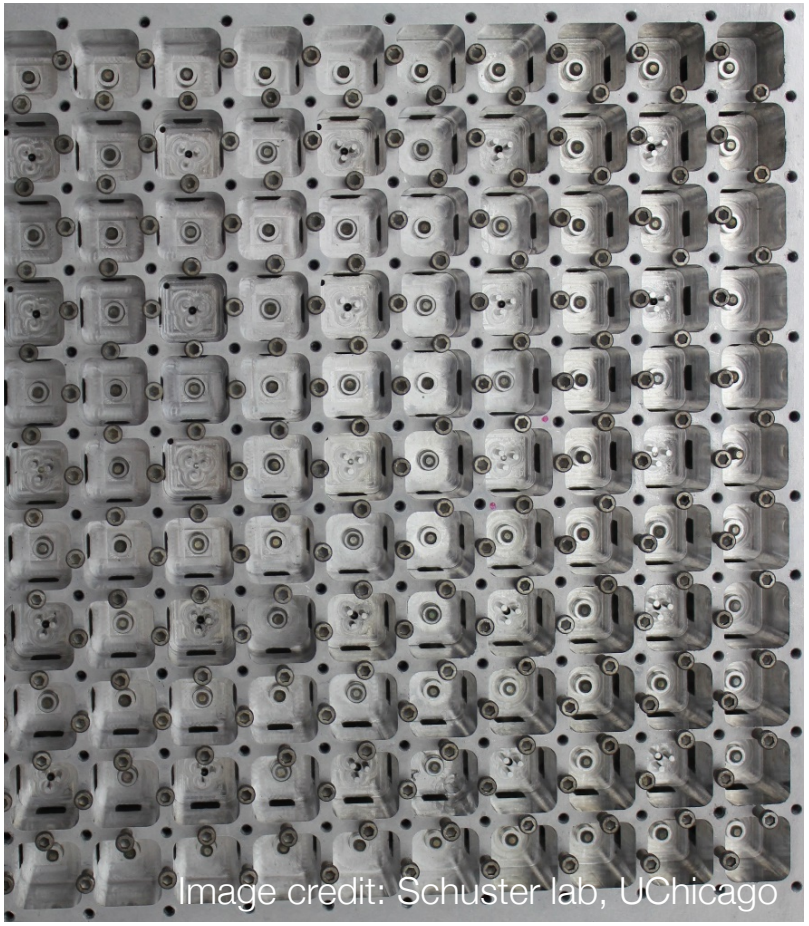
Phys. Rev. A 87, 052306 (2013)

"zero-pi" device gives relaxation and dephasing times appraoching 10ms in simulation

Application specific quantum computing



Simulation of a particles on a hyperbolic graph



Simulation of photons in an artificial magnetic field, photonic Weyl semimetals, and other novel materials

Are there near term problems of interest that can be encoded in an ASQC?

Challenges and opportunities ahead

- Qubit size: high coherence qubits are ~100um in size
  - Packaging modes cause unwanted crosstalk as size increases
  - Blend of modular and surface code approaches?

- Cost per channel (qubit) is very high
  - Is there a way to use classical hardware more efficiently?
  - Can we find automatic or hardware efficient error corrrecting codes?

- Fabrication tolerances and automatic calibration
  - How do you efficiently tune a large quantum system?
  - Are there gates that are robust against fabrication disorder?
  - Are there ways to use something like modelocking to make qubits identical?

- Is there a *useful* near-term algorithm?