What is a quantum computer?

Many diverse technologies

- Annealers
- Ion traps
- Neutral atoms
- Photons
- Quantum dots
- Superconducting

Annealers

- Pioneered by D-Wave
- Google's original theory focus

Image courtesy of D-Wave Quantum Inc

Annealers

- An array of qubits with many body couplers that impose constraints
- Latest system has 5000+ qubits
- No scalable QEC protocol

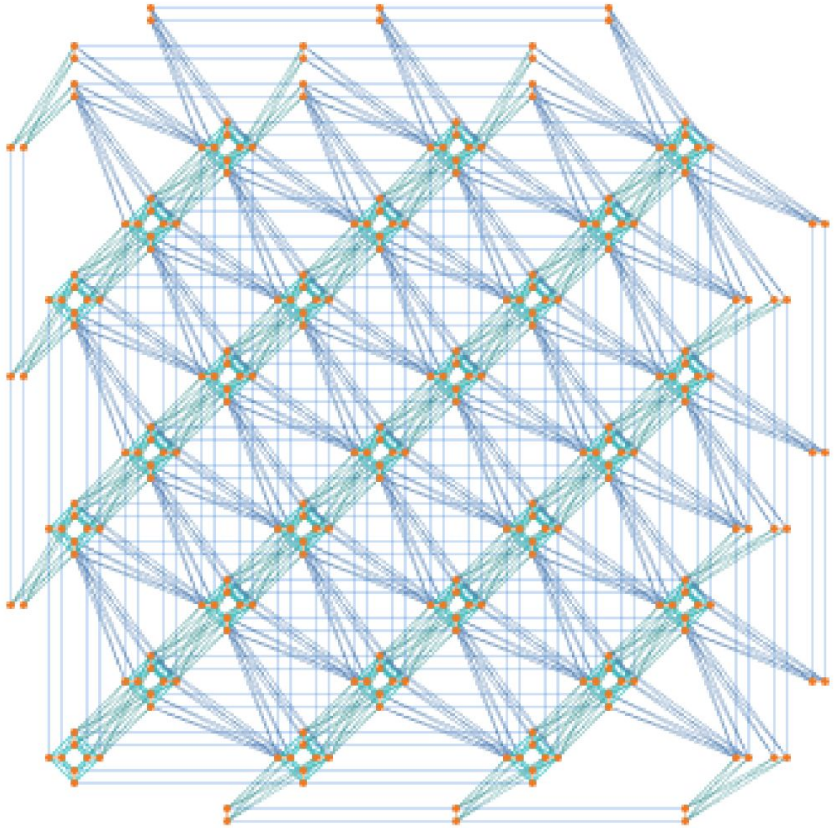
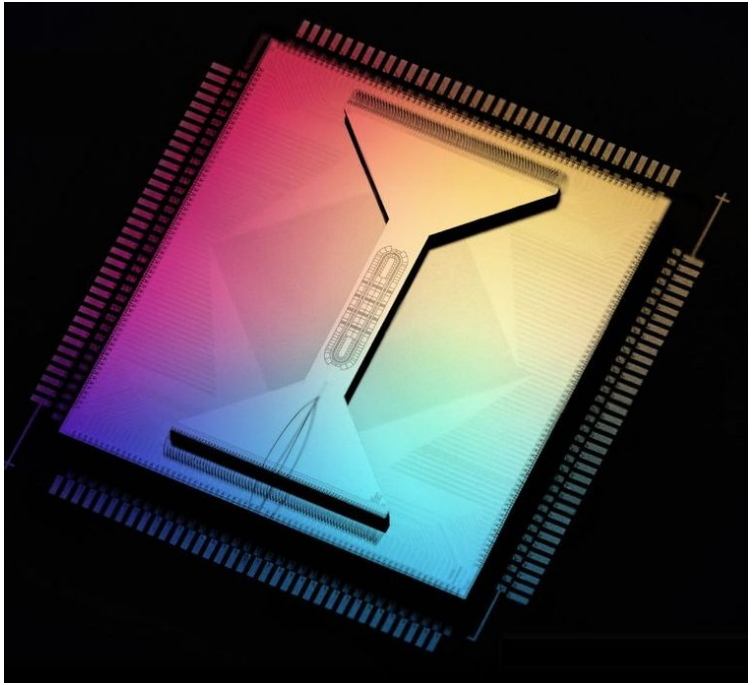


Image courtesy of D-Wave Quantum Inc.

Ion traps

- Many groups investigating
- Surface with segmented electromagnetic tracks to trap and shuttle ions
- Lasers and microwaves used to manipulate the states of the ions
- Some of the highest fidelity quantum gates



Quantinuum H2

https://www.quantinuum.com/hardware/h2

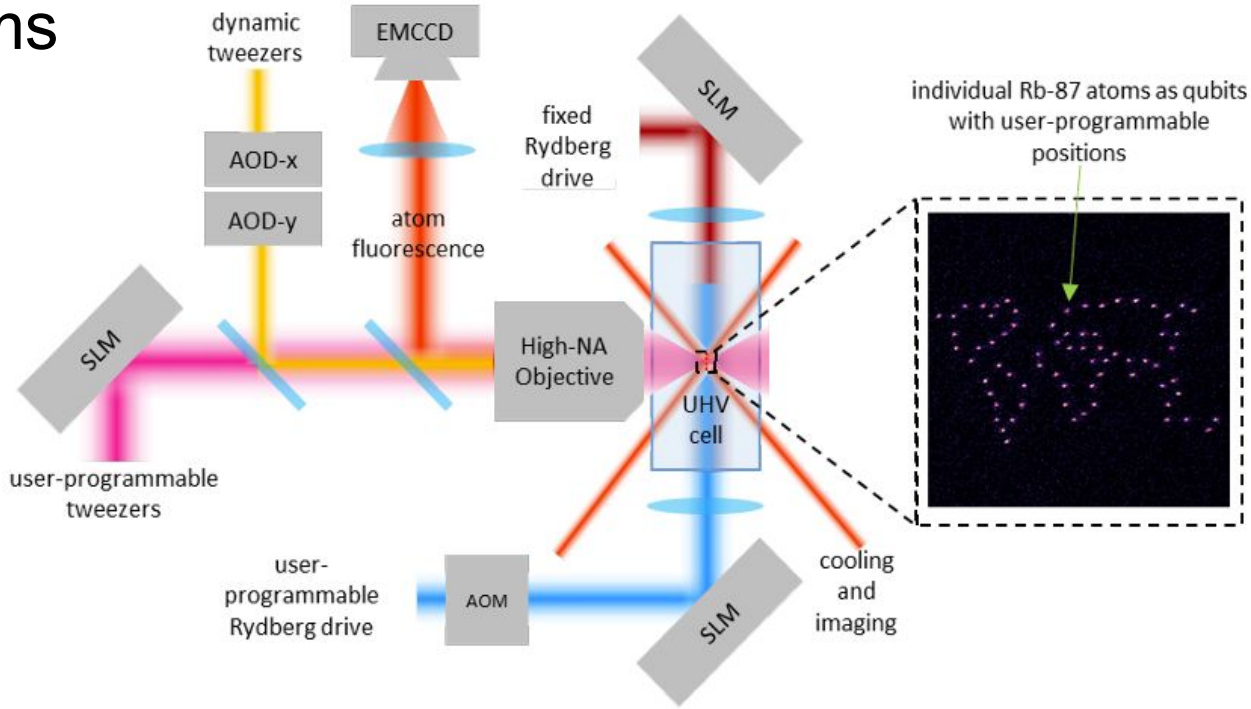
Neutral atoms

- There are many neutral atom companies:
  - QuEra
  - Pasqal
  - ColdQuanta
  - Atom Computing
  - Planqc
  - M Squared

Figure 1.1 The exterior of Aquila, a "field-programmable qubit array" (FPQA) operated as an analog Hamiltonian simulator that implements quantum computations with up to 256 neutral-atom qubits.

https://arxiv.org/abs/2306.11727

Neutral atoms

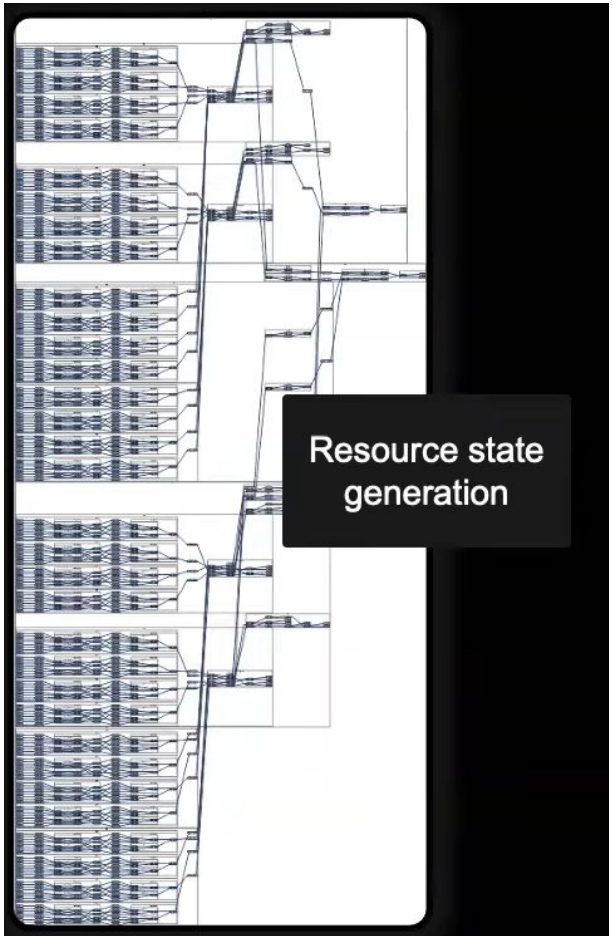


- Atoms in a vacuum trapped by lasers
- Largest gate-based quantum computations

https://arxiv.org/abs/2306.11727

Photonic

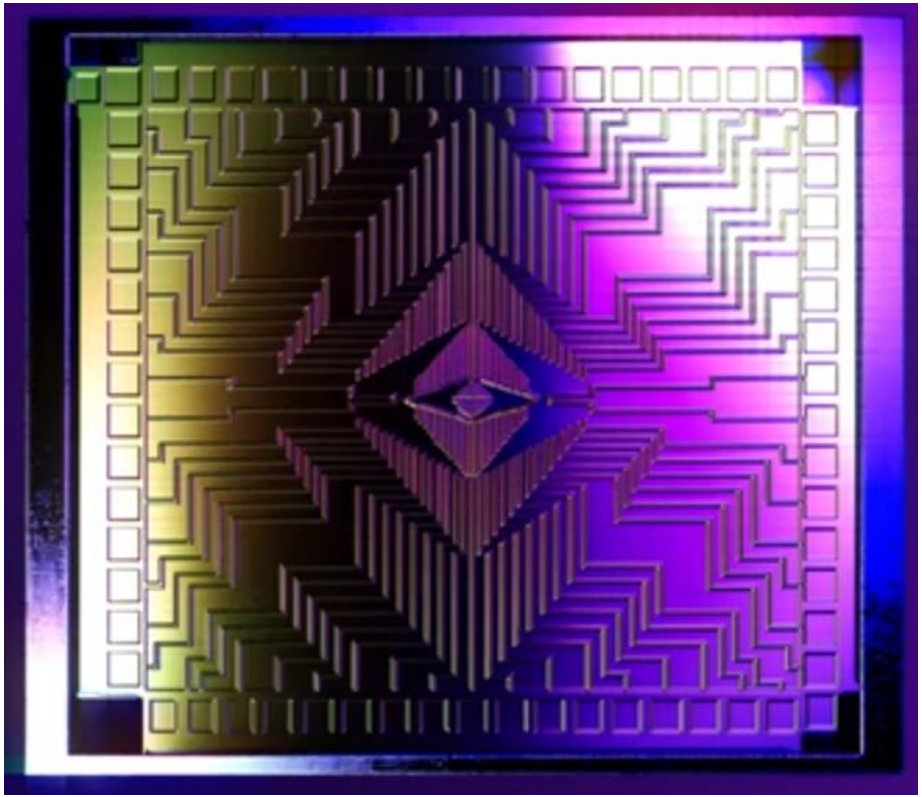
- PsiQuantum
- Generate photons on chip
- Probabilistically entangle them
  - Discard failures
  - Assemble successes into a growing state
- Progressively measure the state to drive computation



PsiQuantum, https://www.youtube.com/watch?v=62Y7uT26hzo

Quantum dots

- Intel / QuTech
- 12 qubit device
- Qubits are individual electrons held in place with electrostatic fields and manipulated by microwaves



https://www.intel.com/content/www/us/en/research/quantum-computing.html

Quantum dots

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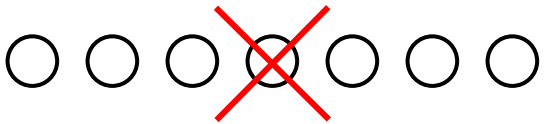
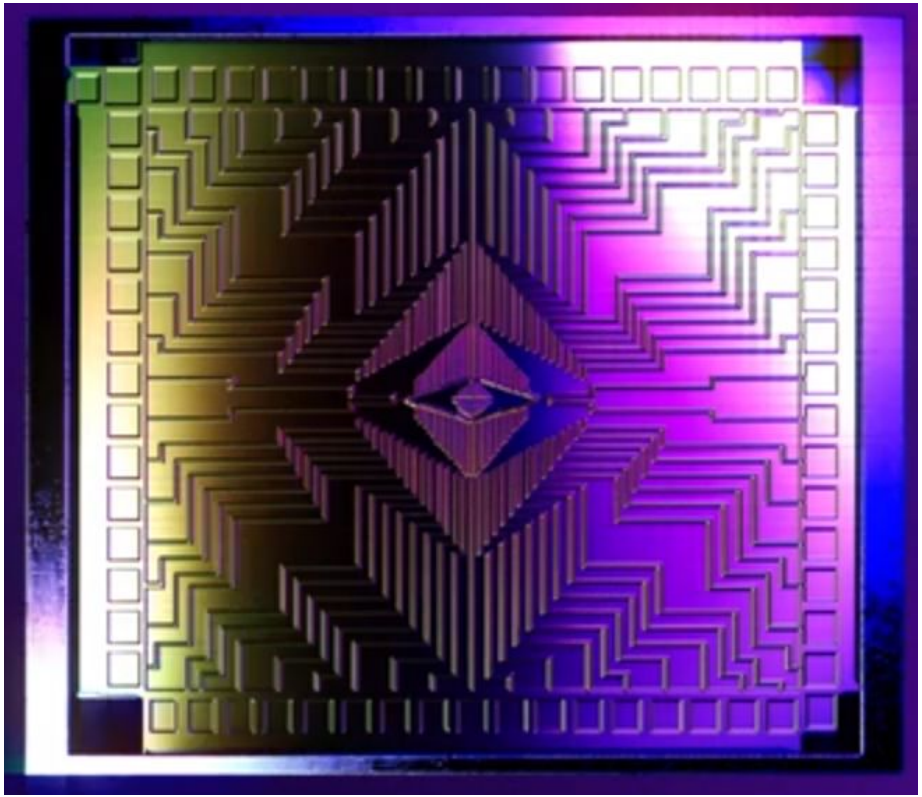
- Single broken qubit breaks computer in two

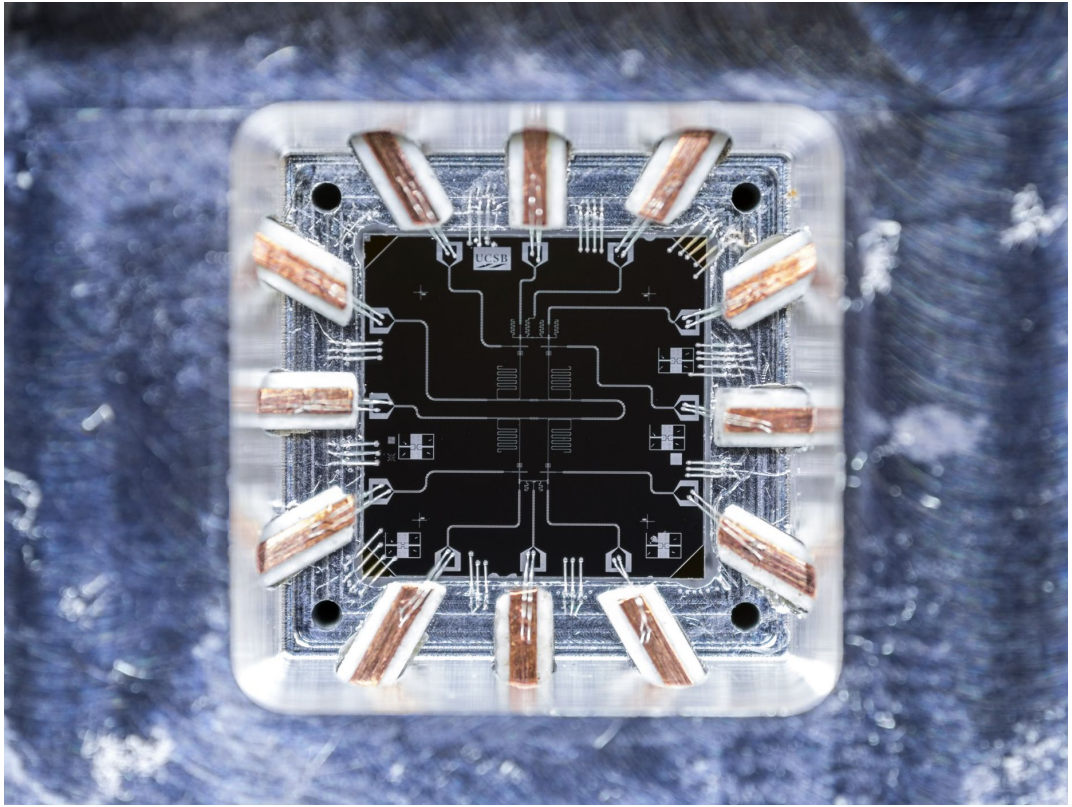




https://www.intel.com/content/www/us/en/research/quantum-computing.html

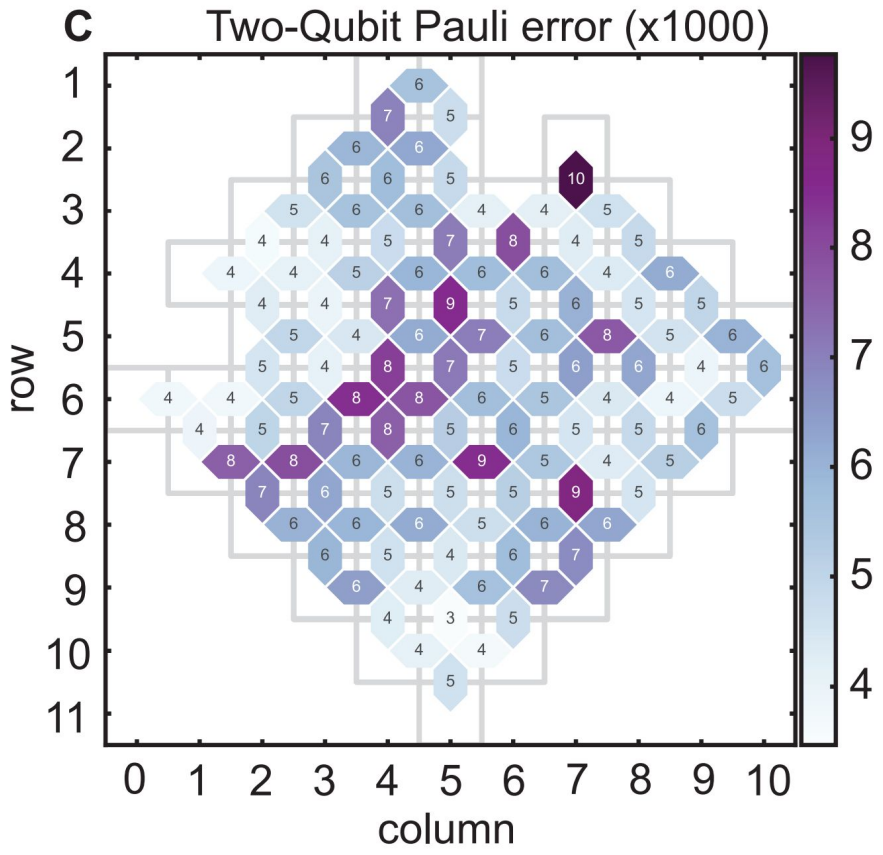
Superconducting

- Focus at Google
  - IBM
  - USTC
  - Many others
- Qubits are tunable frequency resonant circuits
  - think guitar string
- We use the ground state and first excited state to represent |0> and |1>
- Manipulate the data with microwaves and by changing resonant frequencies



Superconducting

- Flagship chips in principle have 72 qubits
- Don't have 100% yield
  - some qubits and couplers unusable



Data from an early test chip

Superconducting

- Chip lives at the bottom of a cryogenic fridge at 10 mK
- Microwaves generated in racks of control electronics
- 2D arrays of qubits will be the focus of this course
- Next video: quantum states and circuits