CMOS Emerging Technologies Workshop: Short-Term Realization of a Commercial Quantum Computer

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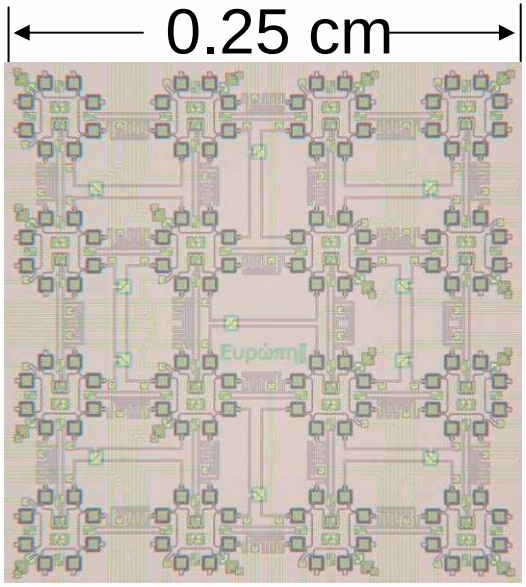
D-Wave Builds Quantum Computers

Blue Gene/L supercomputer
Courtesy IBM



Prototype quantum processor
Courtesy D-Wave

What is a Quantum Computer?

A quantum computer is any **computing device** that makes direct use of **quantum mechanical phenomena**, such as superposition and entanglement, to **solve computational problems**.

Not a replacement for classical computers – quantum computing is a complementary technology

Why is a Quantum Computer Useful?

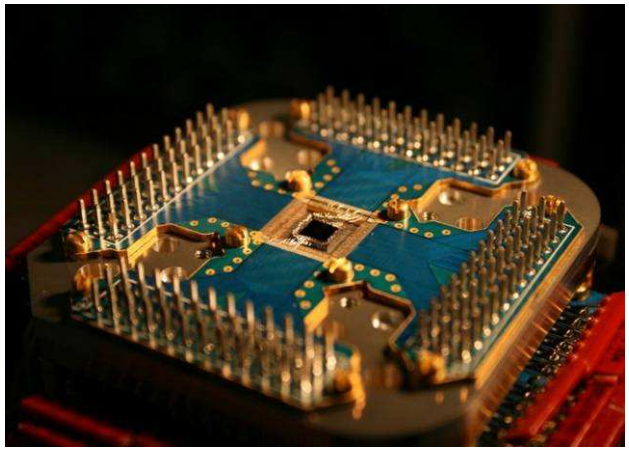
The fundamental laws necessary for the mathematical treatment of a large part of physics and the whole of chemistry are thus **completely known**, and the difficulty lies only in the fact that application of these laws lead to equations that are **too complex to be solved**.

– Paul Dirac
1933 Nobel Laureate in Physics

Quantum Computing

Classically intractable calculations can be performed on quantum computers with only 50 qubits

- Consumes 6MW of power
- 1700 miles of network cables
- Cost: $300M + ~$30M/year



- Runs on 6V batteries
- 100 square feet
- Cost: *a lot less*

D-Wave
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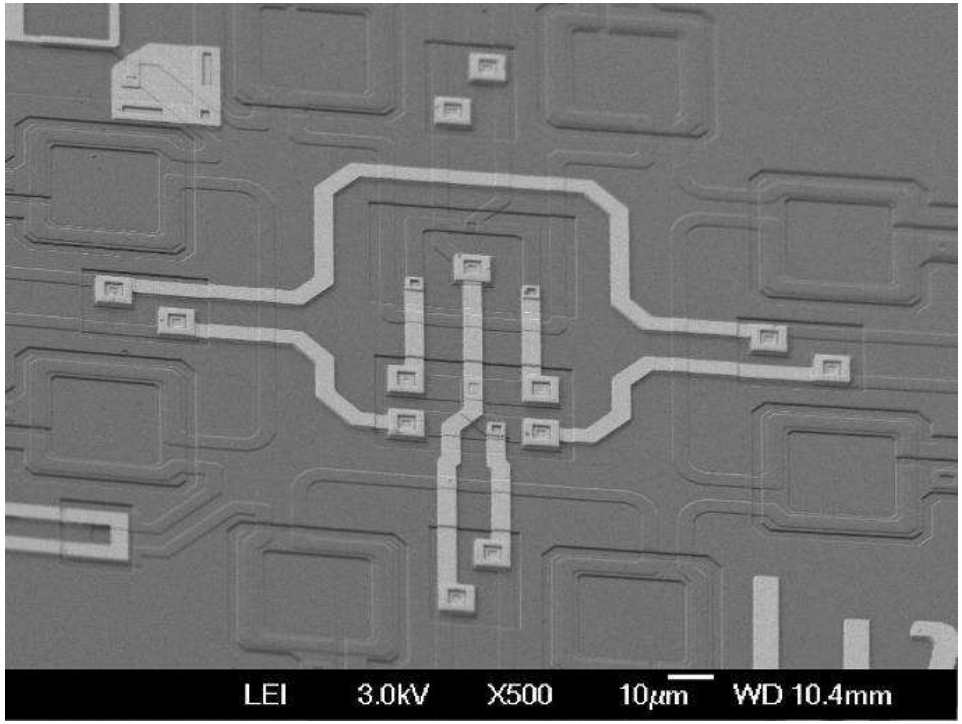
A Short-Term Quantum Processor

Superconductor integrated circuits made with **established semiconductor fabrication** technology

- 0.25 micron minimum circuit feature size
- 10^3 - 10^5 tunnel junctions for processing power untouchable by classical approaches



SEM of D-Wave quantum bit

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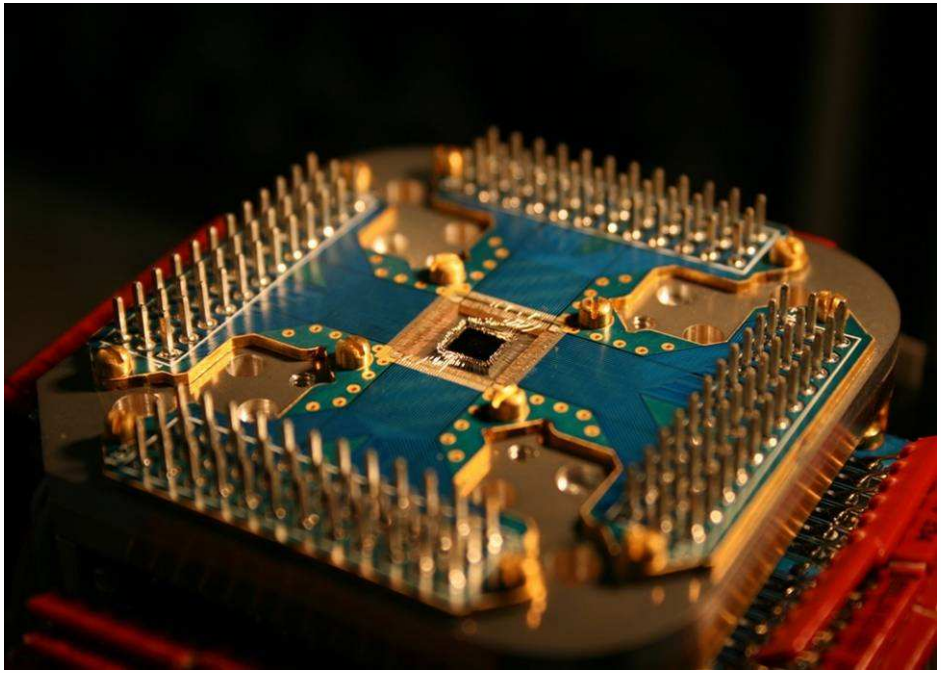
A Short-Term Quantum Processor

Hardware system is engineered using established components

- Dilution refrigeration
- Electronics and filtering



Quantum processor and chip packaging (above). Hardware system including ultra-low temperature filtering assembly (right).

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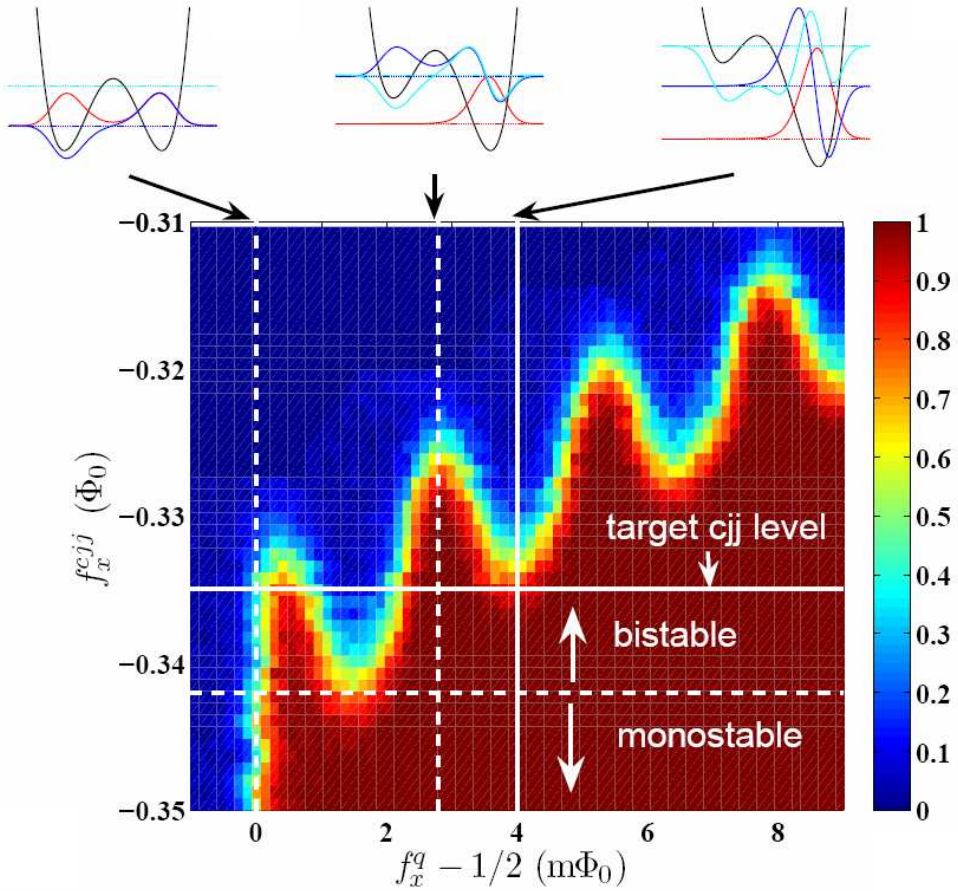
A Short-Term Quantum Processor

Identify and harness most robust quantum phenomena to process information



Operating parameters and quantum tunneling in a quantum bit.

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‘Shotgun’ Quantum Processor Development

Modeling is difficult and inaccurate; most successful approach is to build many prototypes with increasing complexity and performance feedback into design

Requires:

- Infrastructure to rapidly move through design, fabrication, testing, and deployment
- Low-volume but fast lot run-time fabrication and inexpensive masks to enable short design spins
- Building a clearer picture of quantum resources and processing power through performance tests

Summary

- Quantum processing is complementary to ‘classical’ processing
- Accessing robust quantum phenomena to accelerate information processing
- Leveraging established technology to maximize likelihood of success
- Shotgun quantum processor development