Quantum Computing

△ Shor's algorithm: exponentially faster solve factoring problem

△ bloch sphere representation.

Bloch sphere representation [edit]

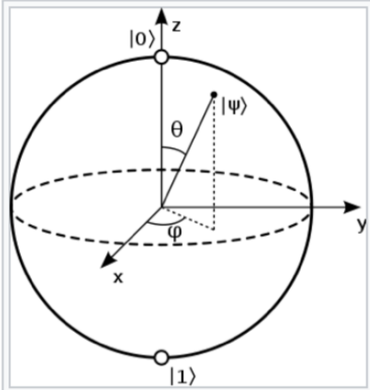
It might, at first sight, seem that there should be four degrees of freedom in $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$, as α and β are complex numbers with two degrees of freedom each. However, one degree of freedom is removed by the normalization constraint $|\alpha|^2 + |\beta|^2 = 1$. This means, with a suitable change of coordinates, one can eliminate one of the degrees of freedom. One possible choice is that of Hopf coordinates:

$$\alpha = e^{i\psi} \cos\frac{\theta}{2},$$
$$\beta = e^{i(\psi+\phi)} \sin\frac{\theta}{2}.$$

Additionally, for a single qubit the overall phase of the state $e^{i\psi}$ has no physically observable consequences, so we can arbitrarily choose α to be real (or β in the case that α is zero), leaving just two degrees of freedom:

$$\alpha = \cos\frac{\theta}{2},$$
$$\beta = e^{i\phi} \sin\frac{\theta}{2},$$

where $e^{i\phi}$ is the physically significant *relative phase*.



Bloch sphere representation of a qubit. The probability amplitudes for the superposition state, $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$, are given by $\alpha = \cos\left(\frac{\theta}{2}\right)$ and $\beta = e^{i\phi}\sin\left(\frac{\theta}{2}\right)$.

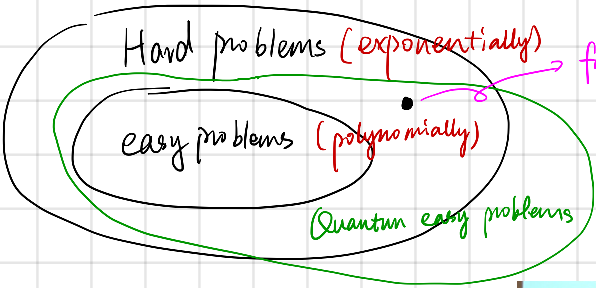
△ Quantum Circuit 中的 $\boxed{\nearrow}$: measurement

△ Classical: AND, OR, NOT, XOR

Quantum: { Hadamard, CNOT } ⇒ Superposition + Entanglement

△ application { Cryptography, Chemistry, ML }

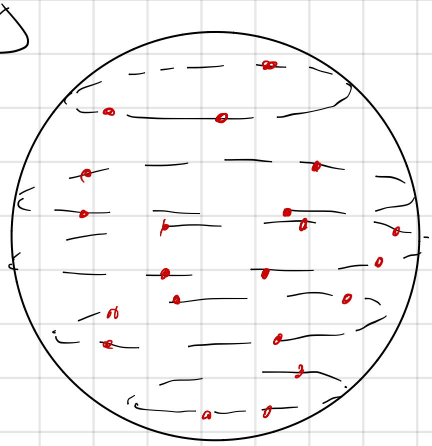
△

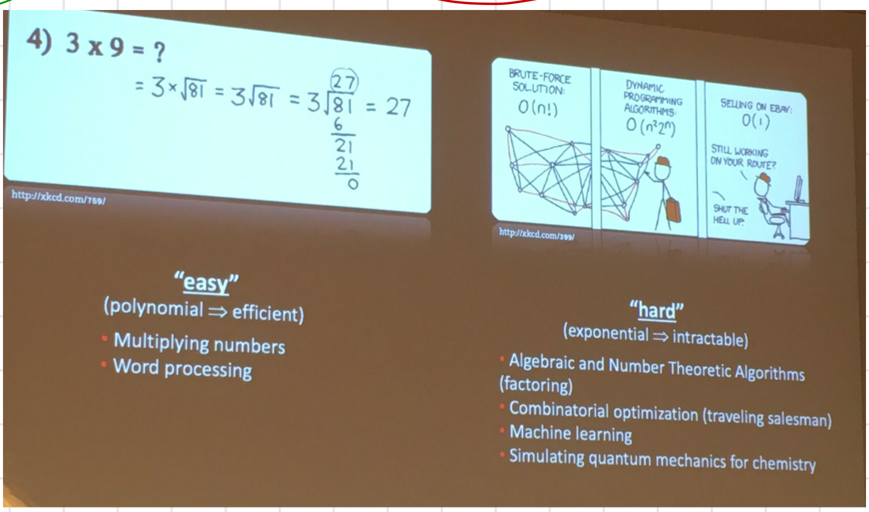


最好的现存的 factorization algorithm

$2^{\log n \cdot \log\log n}$

△

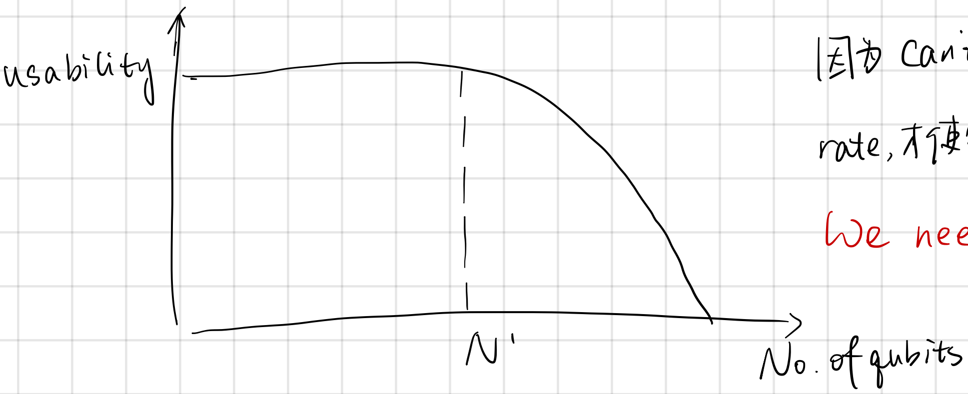




△ Fault-tolerance Quantum Computer

quantum annealing 量子退火

△ A Quantum Computer's power depends on more than just adding qubits —— error rate



因为 can't get rid of error rate, 才使得没法增加 qubits.

We need to increase N'.

现在大概 50 or so

△ Quantum Science → Quantum ready (Now) → Quantum Advantage (3 to 10 years)

△ Chemistry with QC:

- H_2: 2 qubits
- LiH: 4 qubits
- BeH_2: 6 qubits
- Caffeine (咖啡因): we can represent it using around 160 qubits.

△ HHL algorithm

$A \to A^{-1}$

$O(N^3) \Rightarrow$ computational cost of 矩阵求逆

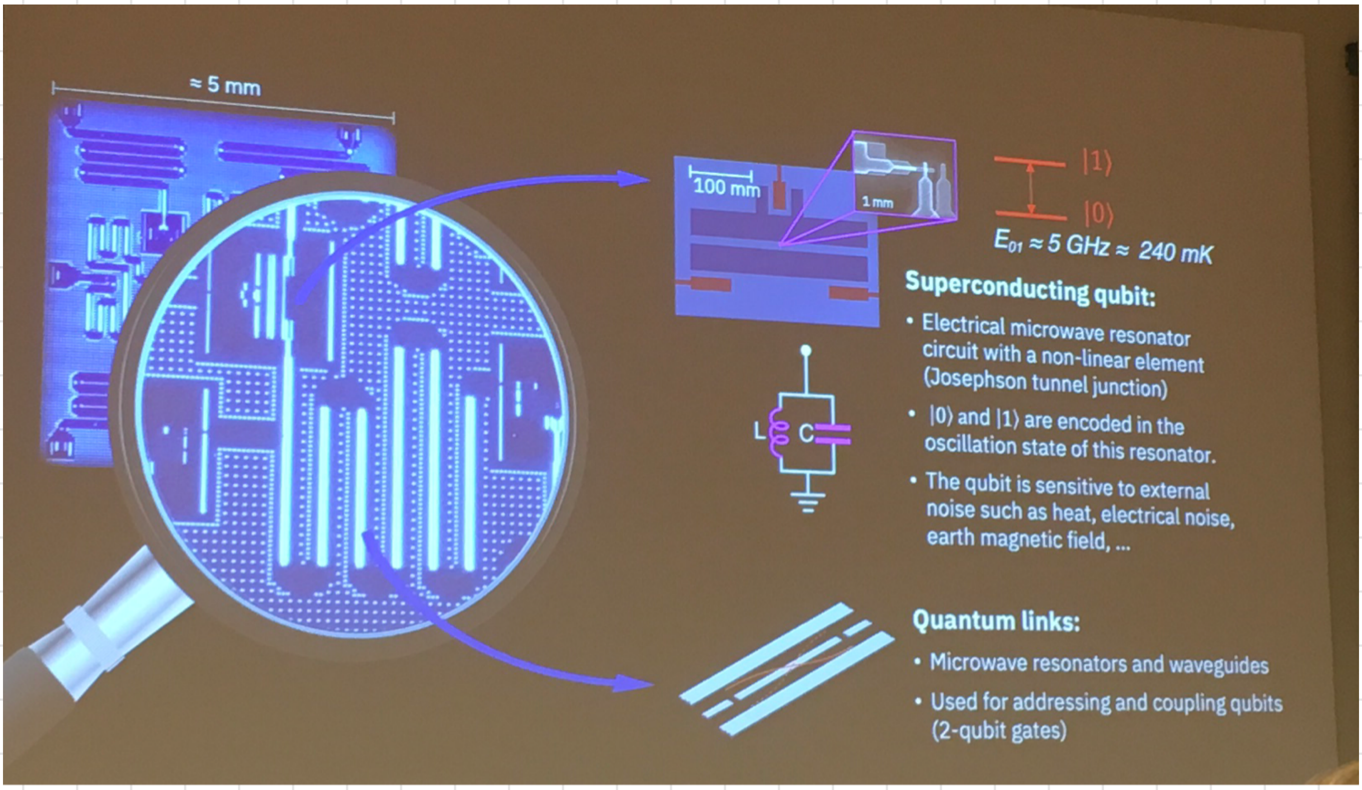
$\Downarrow$

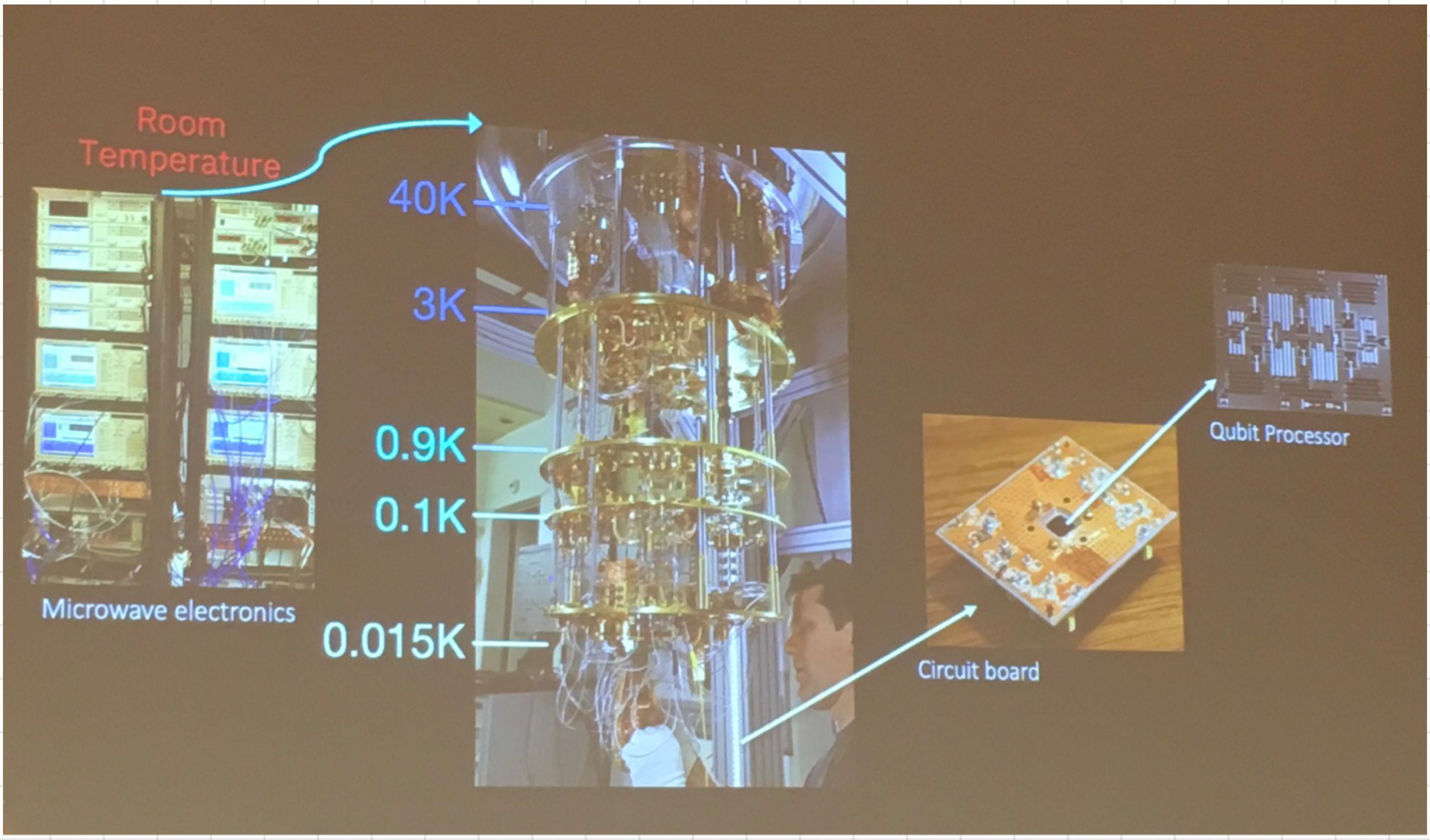
$O(\log N)$

可用于 ML, self-learning ML

△ No quantum memory yet.

△ Quantum Computer 的结构.





○ { Quantum register : qubits
Classical register : bits