The status of quantum computing versus semi-quantum computing

Round-Table ICQNM 2015

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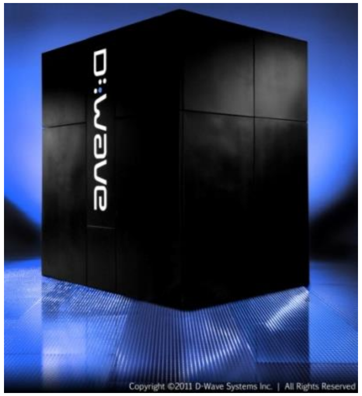
D-Wave collaborations

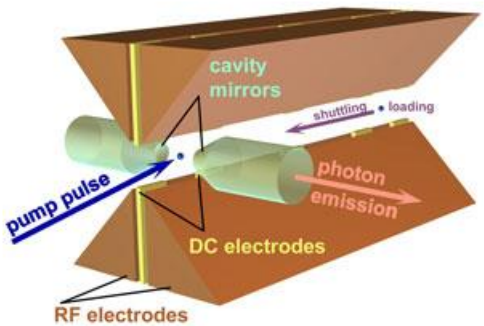
In 2011 ,**Lockheed Martin** signed a contract with **D-Wave Systems** to realize the benefits based upon a **quantum annealing processor** applied to some of Lockheed's most challenging computation problems. The contract includes the purchase of a "***128 qubit*** Quantum Computing System".

In 2013, a **"*512 qubit* system"** was sold to **Google** and **NASA**.

Researchers believe that D-Wave model is probably **not** a quantum computing model. But is it stronger than "classical"?

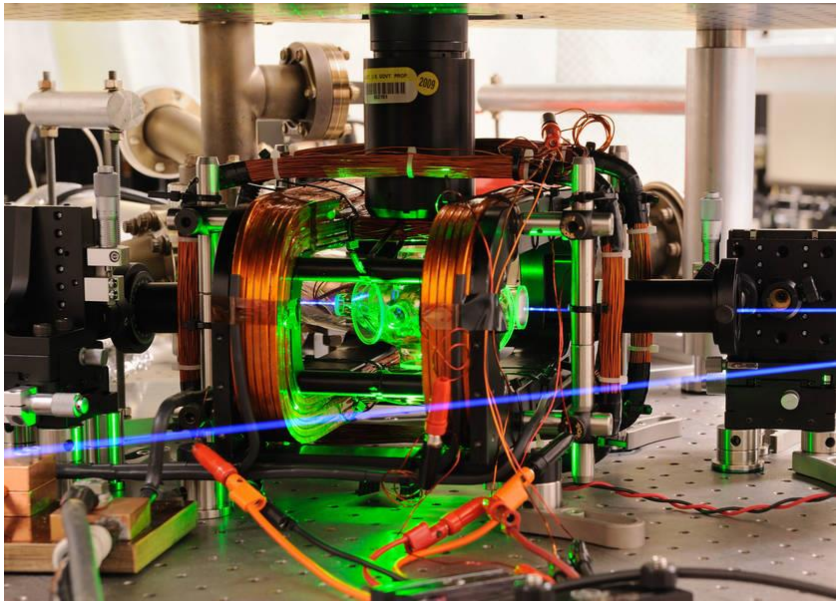


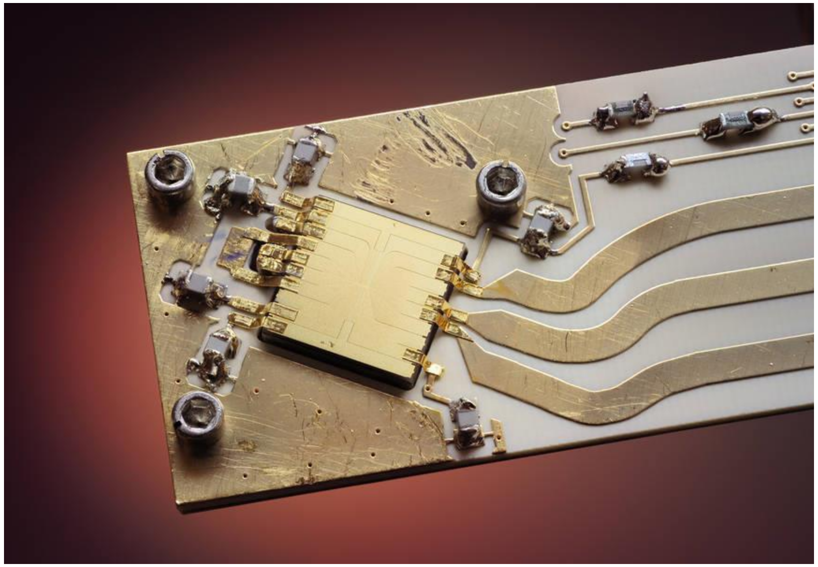
A “good” quantum computing device – ion trap



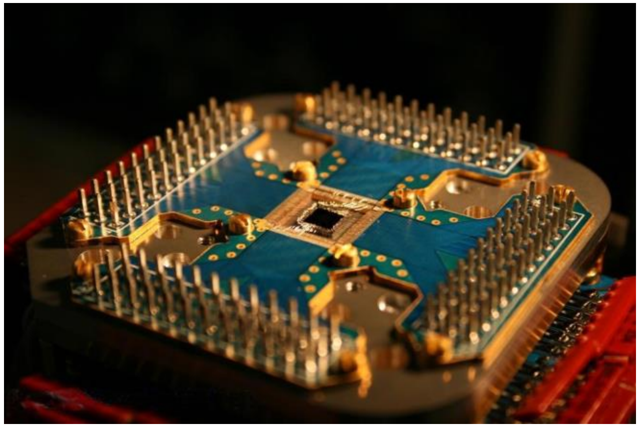
sciencedaily.com

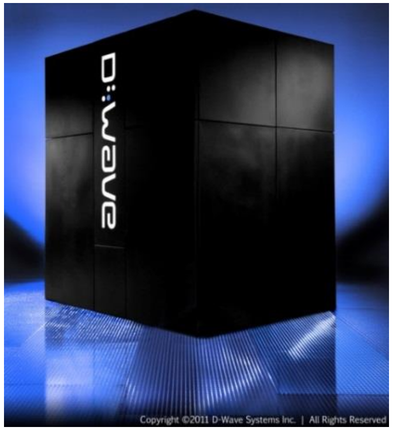
- Reached 14 qubits
- Nobel Prize and Wolf Prize

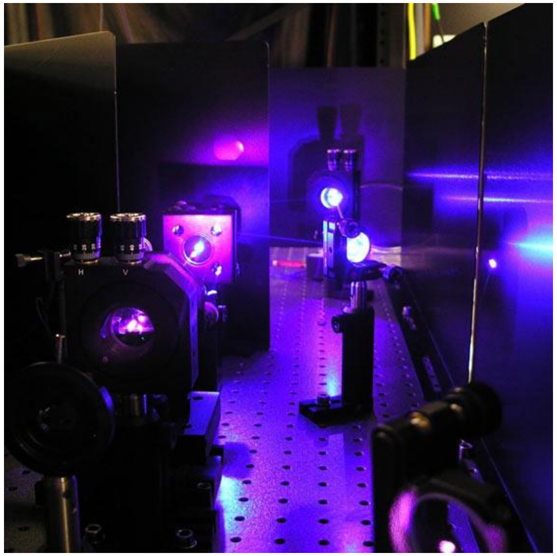




- **Josephson Junctions (the technology DWAVE is based upon): 3-5 qubits, maybe 8 (DWAVE?)**







- **Q. Optics (7-8 qubits)**

<u>Current status of fully-quantum computing</u>

- Despite the Nobel prize – **we have no clue when ion traps will reach 25 qubits**
- Despite of 20M $ DWAVE computers already sold – **we have no clue if JJ qubits are of any good**; We do know (Shin, Smith Smolin, Vazirani; 2014) that there is probably <u>no reason to believe</u> that the DWAVE model is quantum

Limited QC Models:
<u>Semi-quantum computing</u>

- D-Wave's [???]   (closely related to JJ-QC)
- One Clean Qubit   (closely related to NMR-QC)
- Linear Optics (closely related to Optics-QC)

Three Extremely Important Questions:

- What algorithms can the <u>limited</u> models run?

[OCQ – Trace estimation; LO – boson sampling]

- What kind of Quantumness/Entanglement is there?
- Do they scale much easier/better than full QC?

Quantum Key Distribution and its Applications

Round Table Discussion

ICQNM 2015, 23. – 27. August, Venice

Stefan Schauer

QKD and its Applications

- QKD provides highly (unconditional) secure communication
- Important in several fields where sensitive data is transmitted (government, research, finance, medical, military, etc.)
- Competition with classical solutions is high
  - Devices for classical cryptography are well established
  - Provide high transmission rates and “good” security

- Some applications for QKD have already been developed
  - Well-defined protocols for the communication (Q3P)
  - Integration into standard networks (quantum and classical links)
  - Integration into IPSec (keys coming from QKD)
  - Integration into applications (telephone conferences secure by QKD)

- QKD still faces several challenges before entering day-to-day life

Challenges in QKD

- Challenge 1: *Distance*
  - First implementations over a few centimeters in the lab
  - Today distance of several hundred kilometers possible
  - Losses are rather high – key rate is rather low
  - Quantum networks might be a solution

- Challenge 2: *Bandwidth*
  - Large distances don't allow a high transmission rate
    (e.g. ~3bps @ 300km, ~10bps @ 200km)
  - Photon sources and detectors are not perfect and introduce errors
  - Channels are lossy and quantum states are influenced
  - Nevertheless efficient rates are possible at a short distance
    (e.g. 450 kbps over 25km)

Challenges in QKD

- Challenge 3: *Handling*
  - QKD Systems are rather complex
  - High-end physics and sophisticated hardware involved
  - Hard to maintain in practice (configuration of the system)
  - Trend goes towards “Out-of-the-Box” systems (e.g. ID Quantique) and “QKD-on-a-Chip”

- Challenge 4: *Implementation*
  - QKD is secure in theory
  - In practice there are several physical limitations (e.g. single photon detectors, finite key length, …)
  - Several loopholes and backdoors have bee identified in the last years

QKD Networks

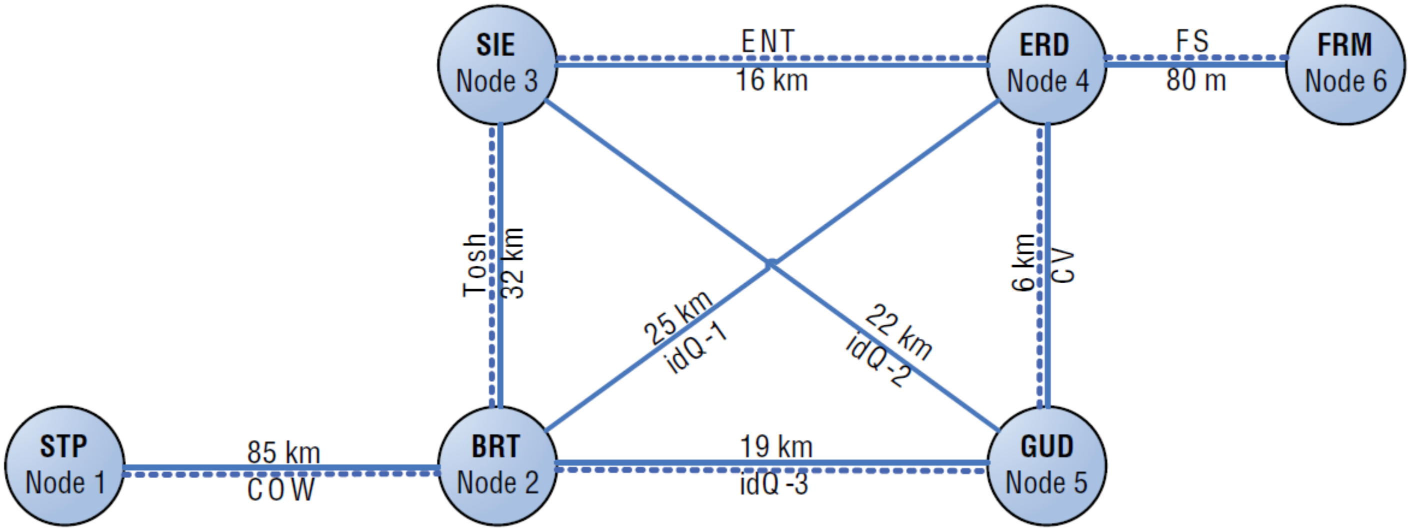
- Several installations of QKD networks
  - Vienna 2008, Switzerland 2009, Tokyo 2010, China 2016

- Nodes in the network are connected using quantum links
  - QKD is performed over these links
  - Integration of several different physical implementations
- Usually restricted to a metropolitan area
- Network serves as a backbone for “classical” users and can be accessed over specific nodes and interfaces

- Hierarchical (layered) approach to provide an abstraction for the protocols and applications on higher levels

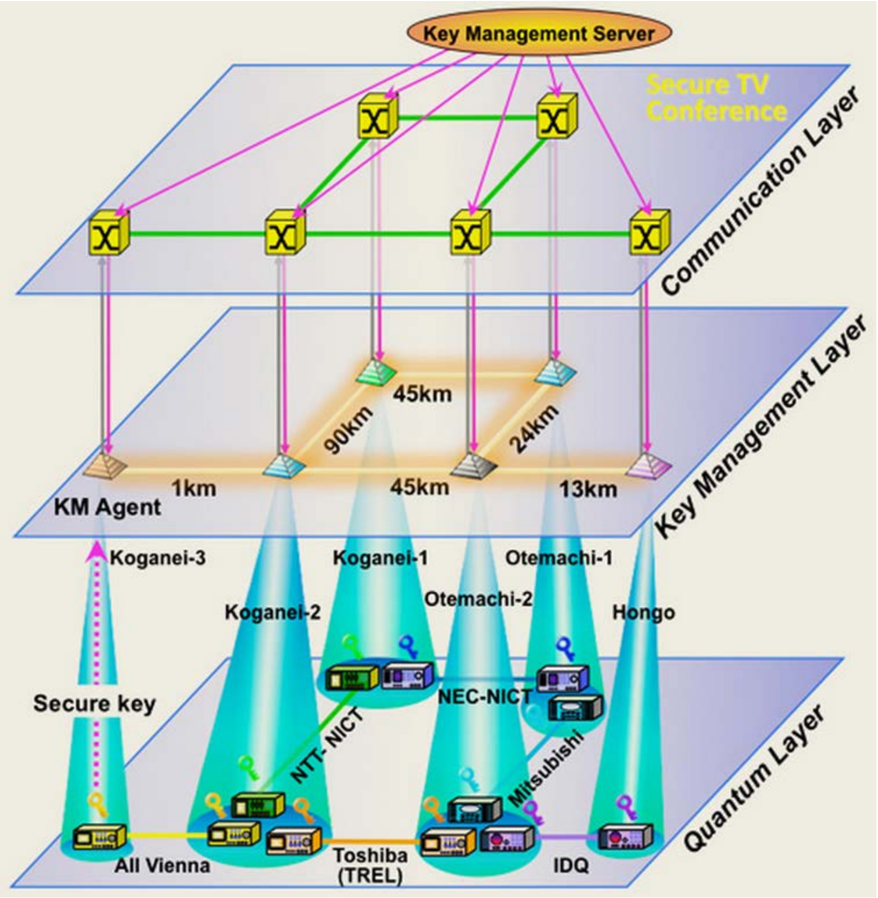
QKD Networks

- Vienna (2008):
  - First installment of a network secured by QKD
  - Six locations across Vienna
  - Largest Distance over 80km
  - Application of text, audio and video encryption



QKD Networks

- Tokyo (2010):
  - Network with distances up to 45km
  - Integration of different technologies
  - Application of a secure text, audio and video transmission



QKD Networks

- China (2016):
  - Largest QKD network so far
  - 2000km link between Beijing and Shanghai
  - Large number of nodes to connect them

- Satellite communication secured by QKD as a next step

A Quantum Computer : Dream or Reality

Thierry Ferrus

Hitachi Cambridge Laboratory

Round table on ‘Quantum : getting the momentum’

Outline

Could we (really) realise a quantum computer ?

Copenhague interpretation and no-cloning theorem

Large scale networks

A Quantum Computer : Dream or Reality

- Could we realise the computation part ?

  ➔ Coherence time, scalability, high-fidelity readout

- Could we realise a quantum memory ?

  ➔ No-cloning theorem

- Could we displace qubits over μm distances ?

  ➔ Surface acoustic waves, photonic crystals…

A Quantum Computer : Dream or Reality

- Do we need a classical circuit to operate a quantum one ?

  ➔ Pulsing and general operations

- The Copenhague interpretation : what about measurement ?

  ➔ Weak measurement is a measurement…

- What about large networks

  ➔ Repeaters, fibres, local/ flying qubits

END

A Quantum Computer : Dream or Reality

Thierry Ferrus
Hitachi Cambridge Laboratory

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