Quantum Computation

A Glimpse Into the Future of Computing

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Agenda

- Introduction
  - Richard Gordon

- Quantum $|101\rangle$
  - Dr. Collin Williams

- JPL
  - Dr. Colin Williams

- D-Wave Systems
  - Dr. Geordie Rose

- NEC Fundamental Research Labs
  - Dr. Shen Tsai

- UC Berkeley, BQIC
  - Prof. Umesh Vazirani

- HP Laboratories
  - Dr. Tad Hogg
Quantum is Sexy

Google - Millions of Search Hits

- QUANTUM
- Albert Einstein
- Bill Gates
- Max Planck
- Tom Cruise
- Pamela Anderson
- Paris Hilton
- Brad Pitt
- Julia Roberts
- Werner Heisenberg
- Quantum Computation
- Richard Feynman
- William Hung
- Erwin Schrödinger
- David Deutsch
Quantum is Inevitable

- Thanks for everything Gordon Moore … it’s been a great run

Source: Artur Ekert
Quantum is Strange

- Richard Feynman -

“If you think you understand quantum mechanics, you don’t understand quantum mechanics.

Do not [ask], if you can possibly avoid it, ‘But how can it be like that?’ because you will go ‘down the drain’ into a blind alley from which nobody has yet escaped. Nobody knows how it can be like that.”
Quantum Information is Different

• Information processing (computing) is a physical process
• Information has energy
• Information can’t travel faster than the speed of light
• Quantum information exists in parallel
• Quantum information obeys Heisenberg Uncertainty
• Quantum information is unique and can’t be copied
• Quantum information can be teleported
Quantum Computation is Everywhere

<table>
<thead>
<tr>
<th>QC Approach</th>
<th>The DiVincenzo Criteria</th>
<th>QC Networkability</th>
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<td>#1</td>
<td>#2</td>
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<tr>
<td>NMR</td>
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<td>Trapped Ion</td>
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<td>Neutral Atom</td>
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<td>Cavity QED</td>
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<td>Solid State</td>
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<td>Superconducting</td>
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<tr>
<td>Unique Qubits</td>
<td>This field is so diverse that it is not feasible to label the criteria with “Promise” symbols.</td>
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Legend:
- 🍋 = a potentially viable approach has achieved sufficient proof of principle
- 🍋 = a potentially viable approach has been proposed, but there has not been sufficient proof of principle
- 🍋 = no viable approach is known

QC ROADMAP: http://qist.lanl.gov
Quantum Computation is Hard

- Development timeline
  - Mastery will be measured in decades
  - Baby steps happening now
- Many challenges
  - Decoherence
  - Entanglement
  - Isolation
  - Error correction
  - Algorithm development

Nature: 17 June 2004
Quantum Computation is Powerful

QUANTUM ALGORITHMS

3 SAT
Graph Isomorphism
Factoring
Multiplication

Source: Artur Ekert
Quantum Computation is a Paradigm Shift

I've invented a quantum computer, capable of interacting with matter from other universes to solve complex equations.

According to chaos theory, your tiny change to another universe will shift its destiny, possibly killing every inhabitant.

Shift happens.

Fire it up.
Dr. Colin Williams

- Senior Research Scientist, Program Manager for Advanced Computing Paradigms, Information Technology Program Office, JPL, Cal Tech
  - Quantum Computing Technologies Group, 1998
- Author 5 books, including two on quantum computing
- Teacher
  - Stanford University, 2000 – 2002, Associate Professor of Computer Science
- Current research
  - Quantum algorithms for solving computationally hard problems
- Patents
  - Quantum computing circuit synthesis and mapping
  - Quantum lithography
- Ph.D. in artificial intelligence, University of Edinburgh
- M.Sc. and D.I.C. in atmospheric physics and dynamics, Imperial College, University of London
- B.Sc. in mathematical physics, University of Nottingham
Dr. Geordie Rose

• Co-founder, President and CEO of D-Wave Systems, Vancouver, Canada
• Co-inventor on 24 filed patents in the field of superconducting electronics
• Co-author eight peer-reviewed scientific articles
• 2001 Business in Vancouver 40 Under 40 award
• 2002 BCTIA award for Most Promising Start-Up
• Raised over $20M for D-Wave, including US$7.1M led by Draper Fisher Jurvetson, June 2003
• Ph.D. in theoretical physics, University of British Columbia
• B.Eng. in engineering physics, McMaster University
Dr. Shen Tsai

- Research Fellow at NEC Fundamental Research Labs
  - Leads Josephson-junction-based qubit project
  - Physics and technology of Josephson effects
  - Single-electron transport phenomena
  - Quantum coherence in superconducting tunneling systems

- Quantum breakthroughs
  - First solid-state based qubit in 1999
  - First solid-state quantum CNOT gate in 2003
  - Efficient single-shot readout in 2004

- Head of the Macroscopic Quantum Coherence Laboratory, Physical and Chemical Institute (Riken)

- Group Leader of the CREST Quantum Information Project

- Ph.D. in physics, SUNY Stony Brook, 1983
- B.S., Physics Department, UC Berkeley, 1975

- Fellow of the American Physical Society
Prof. Umesh Vazirani

• Faculty at U.C. Berkeley since 1987
  – Miller Research Professor in 2000
  – Director of BQIC - the Berkeley Center for Quantum Information and Computation

• Author
  – *An Introduction to Computational Learning Theory*, MIT Press, with Michael Kearns

• Ph.D. in computer science, U.C. Berkeley, 1985
• B.Tech in computer science, M.I.T., 1981
Dr. Tad Hogg

• Member of the Information Dynamics Group, HP Laboratories

• Quantum research
  – Applications
  – Quantum algorithm behavior visualization software
    • http://www.hpl.hp.com/shl/projects/quantum/demo
  – Survey of quantum search algorithms, IEEE Intelligent Systems, July/August 1999
    • (http://www.computer.org/intelligent/ex1999/pdf/x4009.pdf)

• Ph.D., Stanford University

• B.S., California Institute of Technology
Questions and Discussion
Qwindows 2098

Schrödinger's computer.

—I have crashed.
—I have not crashed.

—Sally O. Lee