Experimental Quantum Computing Progress
in a Pre-Quantum World

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Status Update
Trapped-Ion Qubits

- **Single Qubit Gates**
  - Speed: 12 µs (Oxford 2014a)
  - Fidelity: 99.9999% (Oxford 2014a)

- **Number of Single Qubit Gates**
  - 2000 (Oxford 2014a)

- **Two Qubit Gates**
  - Speed: 100µs (Oxford 2014b)
  - Fidelity: 99.9% (Oxford 2014b)

- **Qubit Numbers**
  - Seven fully controlled (Innsbruck 2014)
  - Singles and pairs common (NIST, Univ. Maryland, Sandia, Duke,...)

References:
Innsbruck 2014: Science 345 p302
High-Fidelity Preparation, Gates, Memory, and Readout of a Trapped-Ion Quantum Bit


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<table>
<thead>
<tr>
<th>preparation/readout operation</th>
<th>error</th>
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<tbody>
<tr>
<td>stretch state $S_{1/2}^{4,+4}$ preparation</td>
<td>$&lt; 1 \times 10^{-4}$</td>
</tr>
<tr>
<td>transfer to qubit (3 or 4 m.w. $\pi$-pulses)</td>
<td>$1.8 \times 10^{-4}$</td>
</tr>
<tr>
<td>transfer from qubit (4 m.w. $\pi$-pulses)</td>
<td>$1.8 \times 10^{-4}$</td>
</tr>
<tr>
<td>shelving transfer $S_{1/2}^{4,+4} \rightarrow D_{5/2}$</td>
<td>$1.7 \times 10^{-4}$</td>
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<td>time-resolved fluorescence detection</td>
<td>$1.5 \times 10^{-4}$</td>
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<tr>
<th>single-qubit gate error source</th>
<th>mean EPG</th>
</tr>
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<tr>
<td>microwave detuning (4.5 Hz)</td>
<td>$0.7 \times 10^{-6}$</td>
</tr>
<tr>
<td>microwave pulse area ($5 \times 10^{-4}$)</td>
<td>$0.3 \times 10^{-6}$</td>
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<tr>
<td>off-resonant effects</td>
<td>$0.1 \times 10^{-6}$</td>
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Status Update

Silicon Qubits

- Single Qubit Gates \text{(UNSWa)}
  - Speed: 30\mu s
  - Fidelity: 99.9%
- Number of Single Qubit Gates \text{(UNSWa)}
  - 400
- Two Qubit Gates \text{(UNSWb)}
  - Speed: 130ns
  - Fidelity: 99%
- Qubit Numbers \text{(UNSWb)}
  - Two max
  - Only a few labs have demonstrated silicon qubits

References:
UNSWa: J. Phys. Cond. Matt. 27 154205
UNSWb: arXiv:1411.5760
Device Geometry for Confining Single Electrons
Silicon Qubits – U. New South Wales

Two-Qubit Characterization
Silicon Qubits – U. New South Wales
Significant Impact of Enriched Silicon

Implanted $^{31}\text{P}$ Electron Spin Qubit in $^{28}\text{Si}$

- P-atom implanted Electron Spin Qubit
- Natural Silicon, 5% $^{29}\text{Si}$
- Pla et al., Nature (2012)
- Rabi oscillations $T_2^* = 55 \text{ ns}$

J. Muhonen et al., arXiv:1402.7140; to appear in Nature Nanotechnology
Status Update

Superconducting Qubits

- Single Qubit Gates (UCSBa 2014)
  - Speed: 20ns
  - Fidelity: 99.9%
- Number of Single Qubit Gates:
  - 350 (UCSBa 2014)
- Two Qubit Gates (UCSBB 2014)
  - Speed: 40ns
  - Fidelity: 99.4%
- Qubit Numbers (UCSBB 2014)
  - Nine fully controlled
  - Singles and pairs common

References:
UCSBA 2014: Nature 508 p500
UCSBB 2014: Nature 519 p66

Courtesy IBM - Superconducting Qubits

Courtesy University of Chicago
Superconducting Qubits
University of Chicago

Superconducting Qubit Chip – Close Up

Flux tuning line

Qubit A

Qubit B

Readout / Control lines

200μm

Courtesy of University of Chicago
David Schuster Group
University of Chicago

Superconducting Qubit Chip – Zoom In

Qubit Geometry

Flux tuning line

Josephson junction

200µm

~0.1µm

Courtesy of University of Chicago
David Schuster Group
University of Chicago

Experimental Setup

~20cm

Photo Courtesy of University of Chicago
David Schuster Group
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