Quantum Systems for Information Technology

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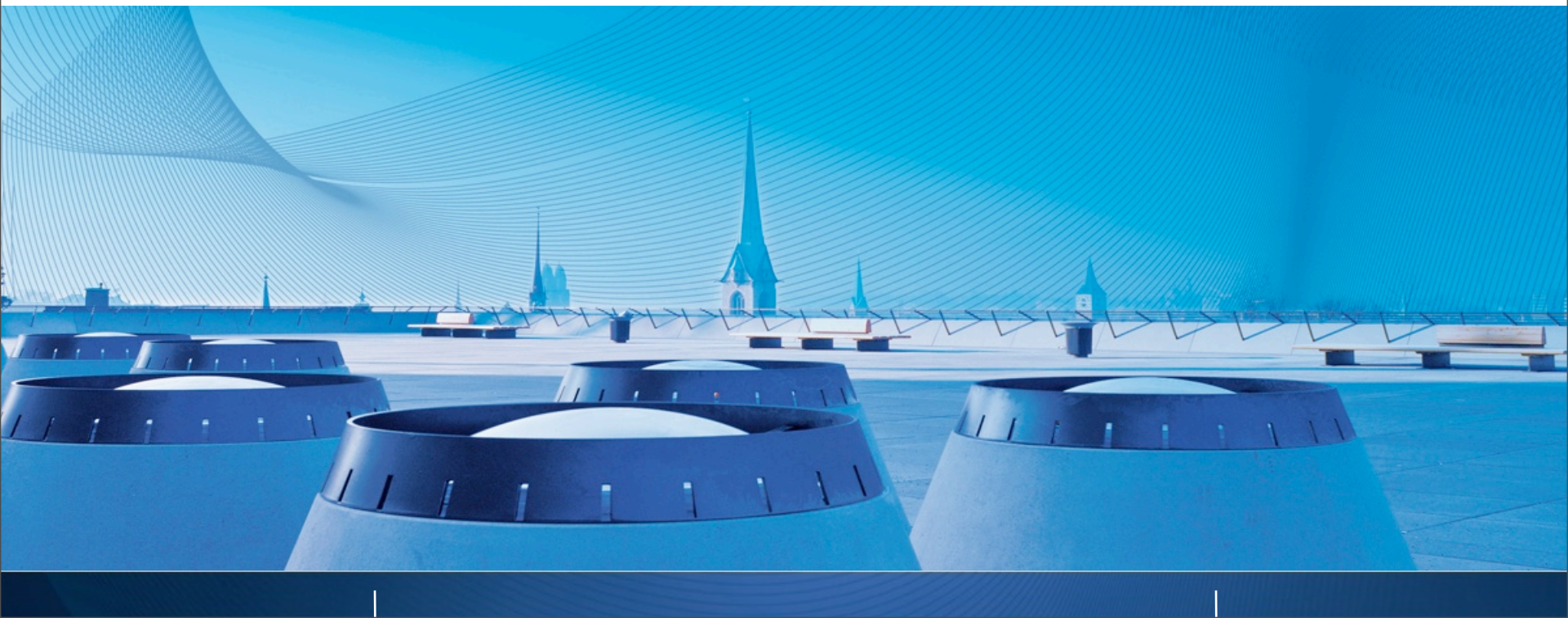
Deterministic quantum teleportation of atomic qubits

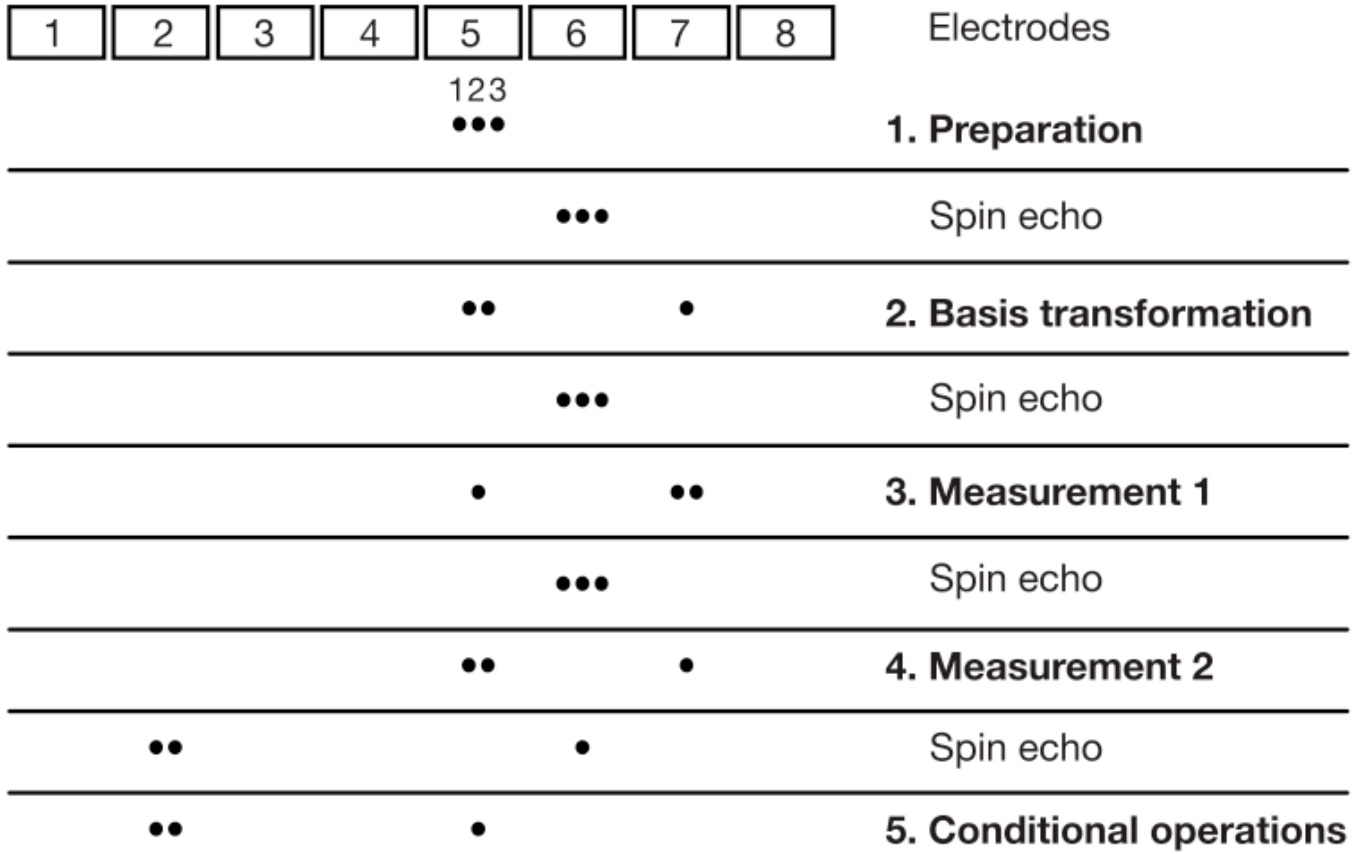
Presented by Daniel Bechstein



Overview

- Using 3 $^{9}Be^{+}$ Ions
- Qubit 1 and 3 entangled
- Qubit 2 to be teleported onto 3

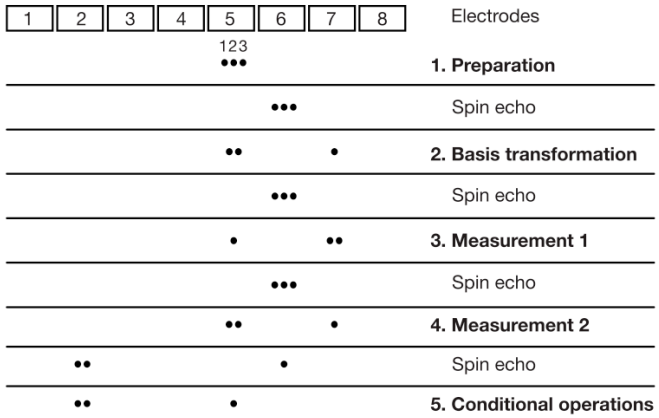
Process flow in Ion traps



- Spin echo pulses used for longer coherence times

Initial State Preparation

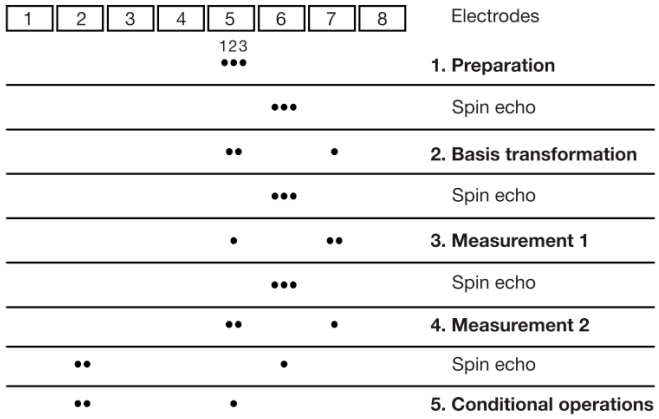
- Initial state: $|\Phi\rangle = |S\rangle_{1,3} \otimes |\psi\rangle_2$
- S is Singlet $|S\rangle_{1,3} \equiv |\uparrow\rangle_1 |\downarrow\rangle_3 - |\downarrow\rangle_1 |\uparrow\rangle_3$



- Prepared by 2 spin echo sequences

Basis transformation

- Use phase gate on qubits 1 and 2



- Single qubit rotation through Raman transitions

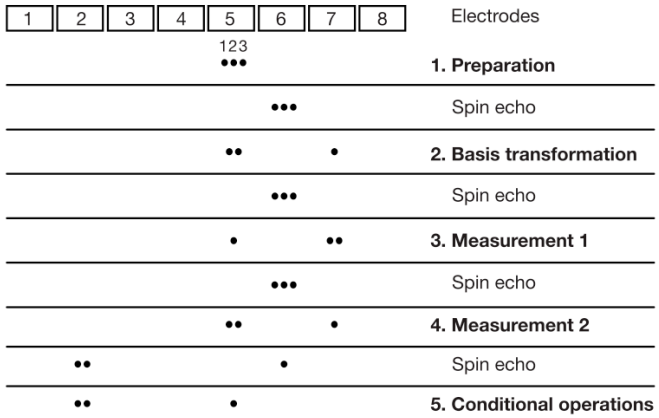
$$R(\theta,\phi) = \cos(\theta/2)I + i\sin(\theta/2)\cos(\phi)\sigma_x + i\sin(\theta/2)\sin(\phi)\sigma_y$$

- Qubit state (Bell state of qubit 1,2 and unitary rotation of 3)

$$|\uparrow\uparrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)\sigma_x|\psi\rangle_3 + |\uparrow\downarrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)\sigma_y|\psi\rangle_3$$
$$+i|\downarrow\uparrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)I|\psi\rangle_3 - |\downarrow\downarrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)\sigma_z|\psi\rangle_3$$

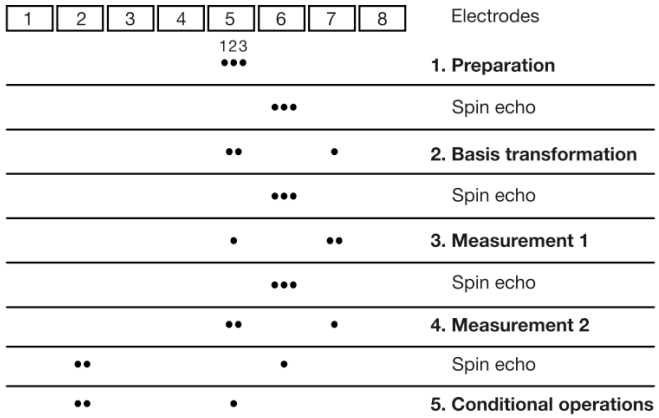
Bell state measurement

- Through fluoresence
- Measure qubit 1
- Measure qubit 2 (1+2)
  - Better fidelity when measuring qubits 1 and 2 together
  - Qubit 1 is brought in $|\uparrow\rangle$



Conditional operations

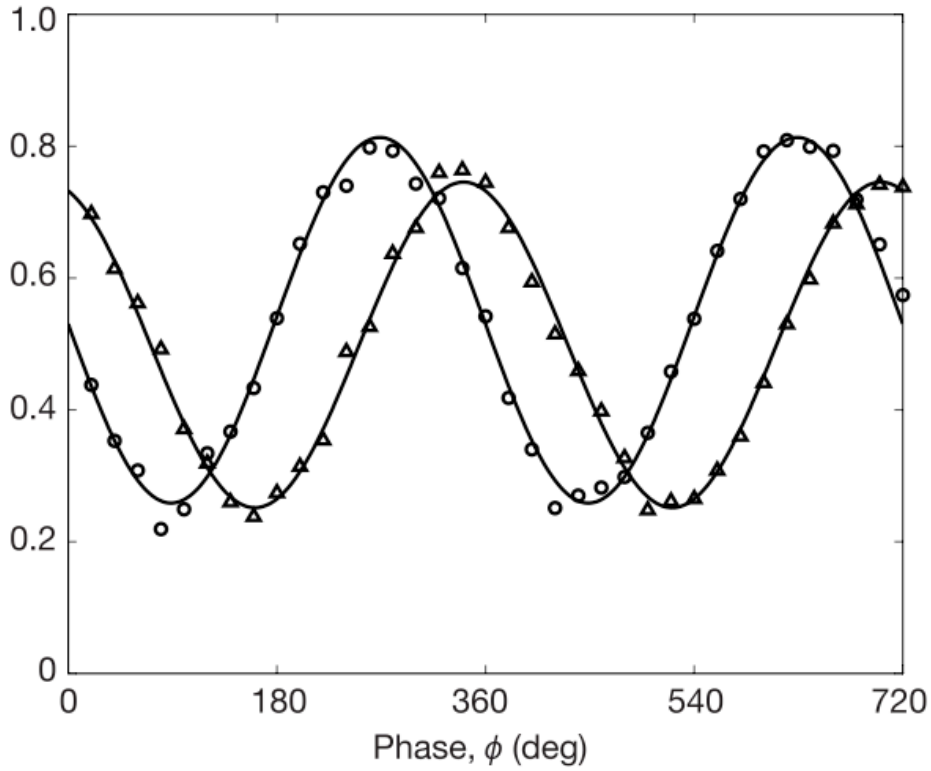
- Apply unitary operations depending on measurement results on qubit 3



$$|\uparrow\uparrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)\sigma_x|\psi\rangle_3+|\uparrow\downarrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)\sigma_y|\psi\rangle_3$$
$$+i|\downarrow\uparrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)I|\psi\rangle_3-|\downarrow\downarrow\rangle_{1,2}\otimes R(\pi/2,-\pi/2)\sigma_z|\psi\rangle_3$$

Ramsey Fringes

- Phase from first π/2 pulse on qubit 2
- Two curves have different phase in second pulse



Summary

- Fidelity Process 78%
- On demand Quantum Teleportation (using entanglement) works as fidelity over 2/3
- Entanglement is kept when moving ions

Thank you for your attention