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A Brief Comparison:

Ion-Trap and Silicon-Based Implementations of Quantum Computation

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MN1

Motivation

- Many Proposed Technologies
  - All work toward the same goal
  - some experimentally verified
  - Generalize the key constraints and capabilities
- Purpose For Ion-Traps
  - Ion Traps are somewhat scalable
  - Decoherence-Free Subspace (DFS) encoding
  - Ballistic transport
  - Experimentally feasible

Slide 2

MN1 Comparison Motivation

* There are indeed many technologies that have been proposed for the realization of a quantum computer. Some technologies have even been experimentally verified to perform quantum computation.
* In fact so much different research has been done toward one common goal, that it is a given that with time some technologies simply won't work, some will be too expensinve, different applications may require a different technologie,
and undoubtedly so, there will be a winner.
* It is for this reason, that it worth while for
scientists to begin exploring in more quantified detail some of the key differences of the models in effort to concentrate toward few possible winners.

* In this paper we have provide a rough comparison between two technologies - Kane and Ion traps.

marlies, 6/4/2003

MN2

Brief Roadmap

- Recall The Skinner-Kane Model
- Ion-Trap Model
  - DFS encoding
  - Ballistic transport
- Fault-Tolerant Computation

Slide 3

MN2 Brief Overview:

1. Why Compare Ion Traps and Kane,
   * We have done much research into the Kane technology.
   * Kane is based on Slicon, and Ion-Traps have a prospect of silicon
   *

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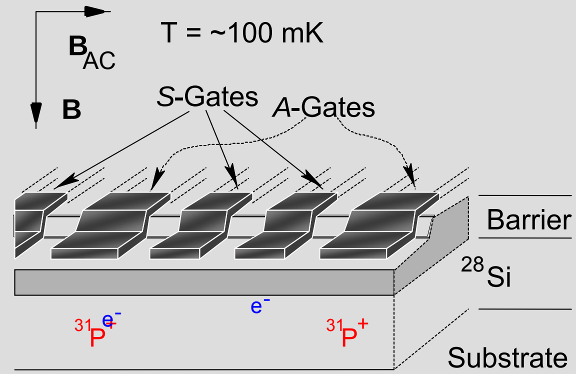
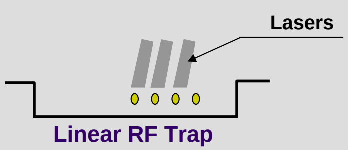
Skinner-Kane (SK)



Skinner 02'

Ion-Traps



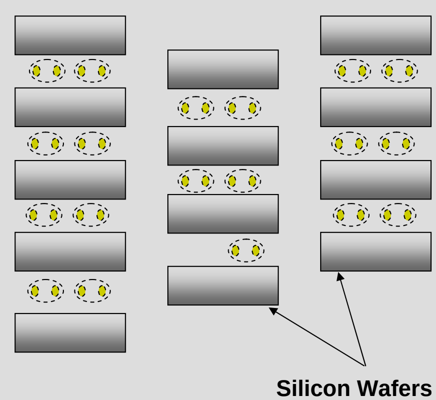
- Qubits are held in the hyperfine interaction between the nuclear and electronic spin.
- Gates: light induced coupling.
- Information exchange is done by Coulombic Interactions between ions and an ion head.
- Problems with this approach.

Cirac and Zoller, 95'

Inter-Connected Ion Traps

QCCD :

Quantum Charge-Coupled Device



Kielpinski 02'

$|\downarrow\rangle + \alpha|\uparrow\rangle$ **: collective dephasing**

$$|\downarrow\rangle = |\downarrow\uparrow\rangle \;\; \textit{and} \;\; |\uparrow\rangle = |\uparrow\downarrow\rangle$$

$$\alpha|\downarrow\uparrow\rangle + \alpha|\uparrow\downarrow\rangle$$

Fault-Tolerant Error Correction

- Qubits Must be Encoded To Protect States
- Errors Must Be Uncorrelated
- Kane - avoidance, Ions - prevention

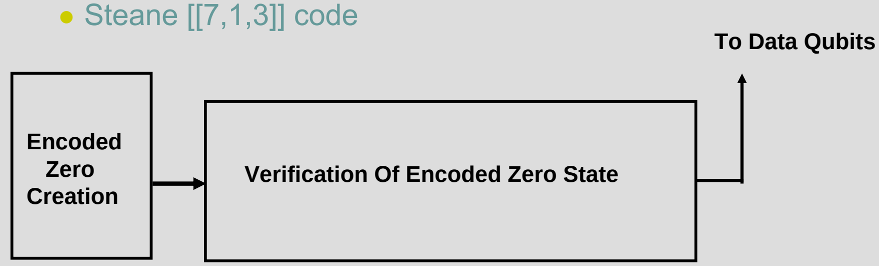
Lowest Level Encoding

- Ion Traps
  - DFS encoding
  - Corrected through SM gate pulses
- Skinner Kane Model
  - Steane [[7,1,3]] code

Steane 96'

Second Level Encoding

- Ion Traps
  - Steane [[7,1,3]] code

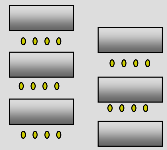


- Skinner Kane Model
  - Steane [[7,1,3]] X [[7,1,3]] code

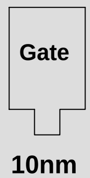
Upper Level Codes are Recursive to the Lower Levels

Architectural Features

- **Ion-Traps**
  - High Parallelism
  - Trapping electrodes need not be very large
  - Ions must be at least 10μm apart

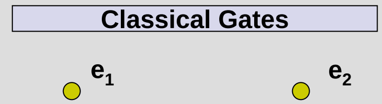


- **Skinner Kane**
  - qubits are 15-100 nm apart
  - T < 1K (Big Problem for Classical Gates)

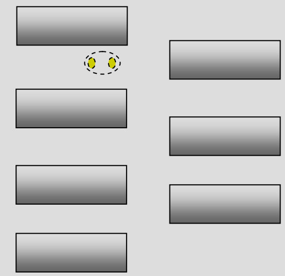


Transport – Static *vs.* Dynamic

- Skinner-Kane (Static)
  - Neighbor-to-Neighbor Swaps – 0.15m/s



- Ion-Traps (Dynamic)
  - Ballistic Transport – 10m/s



Quick Analysis

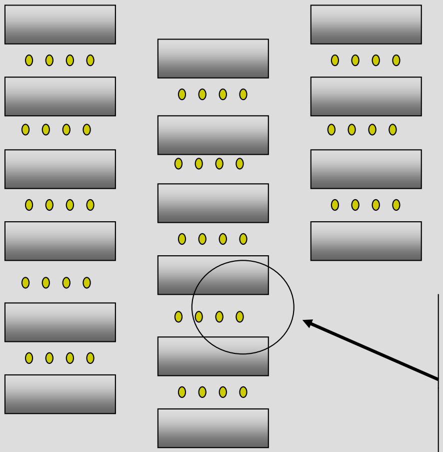
Operator	Silicon	Ion-Trap
SWAP	0.57 μs	6 μs
Transport	0.15 m/s	10 m/s
Entangl.	4 μs	1 μs
CNOT	3.2 μs	2 μs
Rotation	≤ 0.3 μs	≤ 24 μs
Hadamard	0.1 μs	1.5 μs

*** Ion Total Cost : ~ 400 μs**
*** Skinner-Kane Cost: ~ 4500 μs**

Conclusion

- Alternative Approaches to Error Correction
- Future Work

Ion-Traps



QCCD

Quantum
Charge-Coupled
Device

Cross View (Silicon Wafers)