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Physics for Computation: Using Novel Devices to Solve Hard Problems

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Quantum systems are hard to simulate.
Quantum computing is hard to do.
What about small quantum devices?

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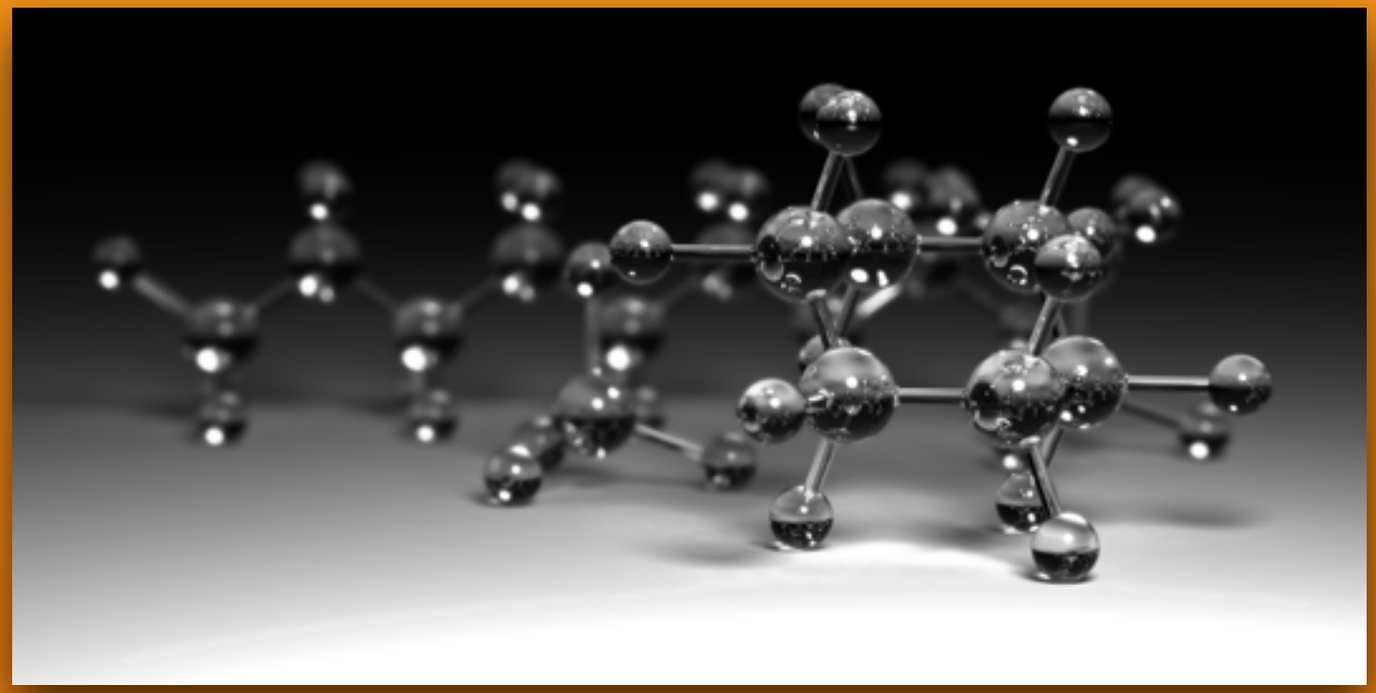
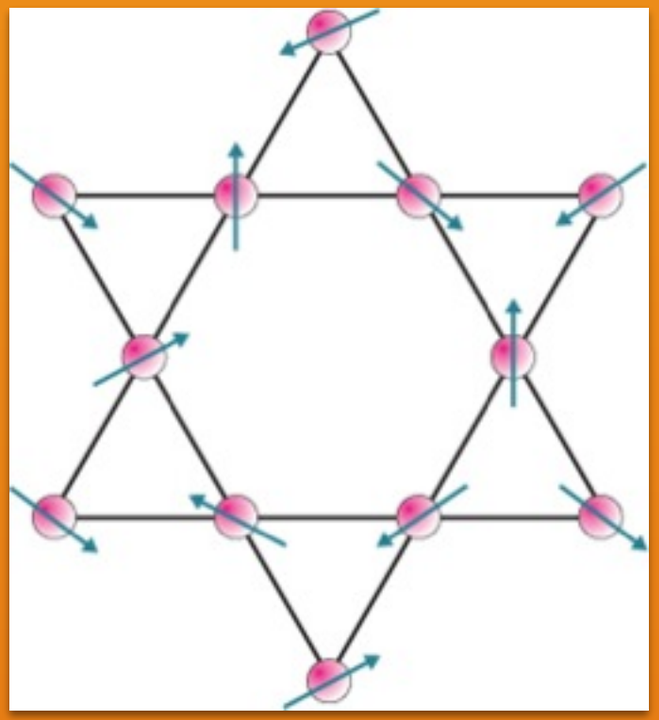
Simulating quantum systems helps us understand quantum phenomena.

Examine origins of high temperature superconductivity



Calculate molecular properties

Simulating quantum systems on supercomputers is slow.

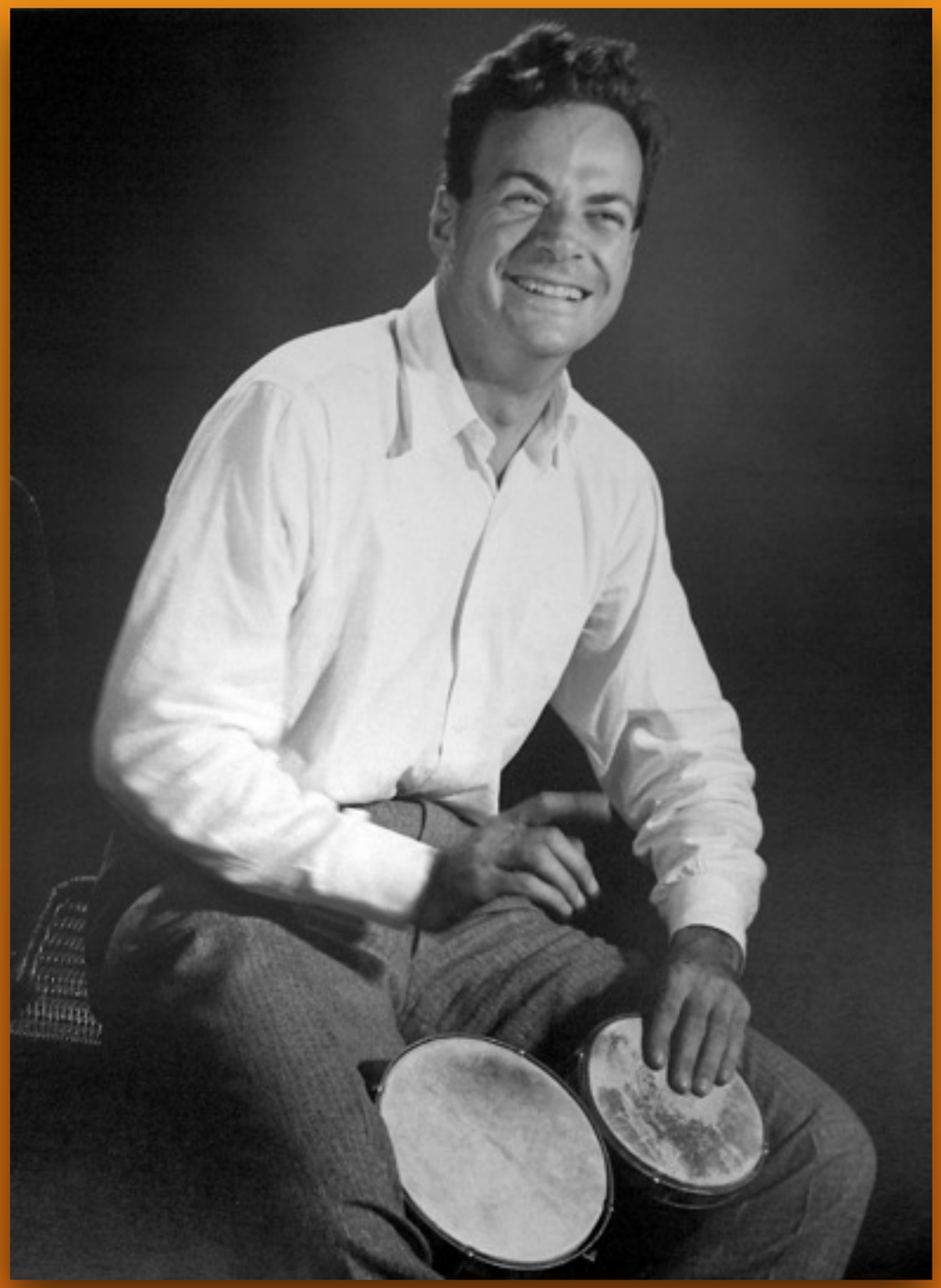


Computationally intensive

40 spin-1/2 particles = keep ~ 4 TB of coefficients

(One trillion complex numbers!)

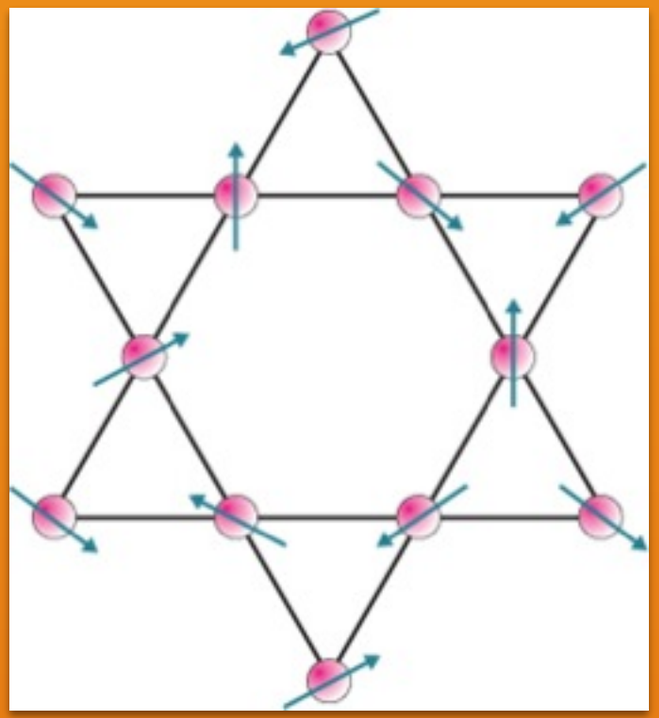
A 1982 suggestion by Feynman ignited the field of quantum computation.

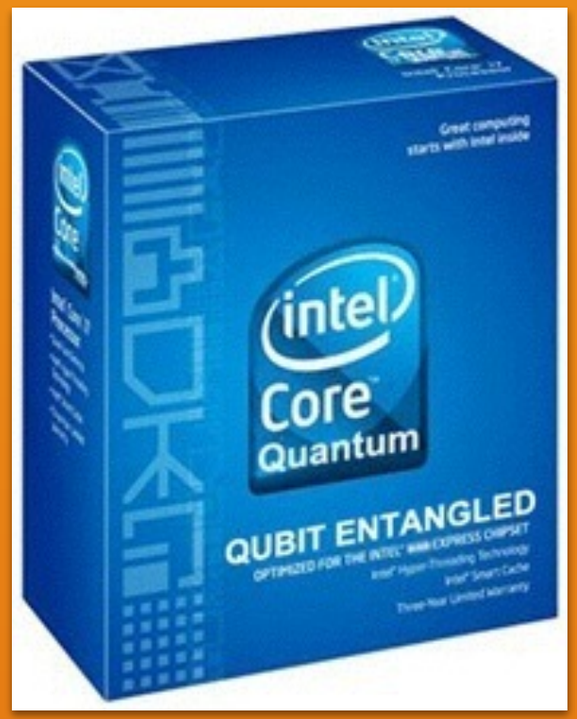


"…because nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical …"

Richard Feynman, "Simulating Physics With Computers", International Journal of Theoretical Physics, 1982

Simulating quantum systems (with other quantum systems) is faster.





Computationally simpler

40 spin-1/2 particles = 40 “quantum bits”

Simulating quantum systems
(with other quantum systems) is a difficult
engineering problem.

Robust Control

Environmental Isolation

Error Correction

Physical Implementation

How do we move forward?

How do we move forward?

Think different

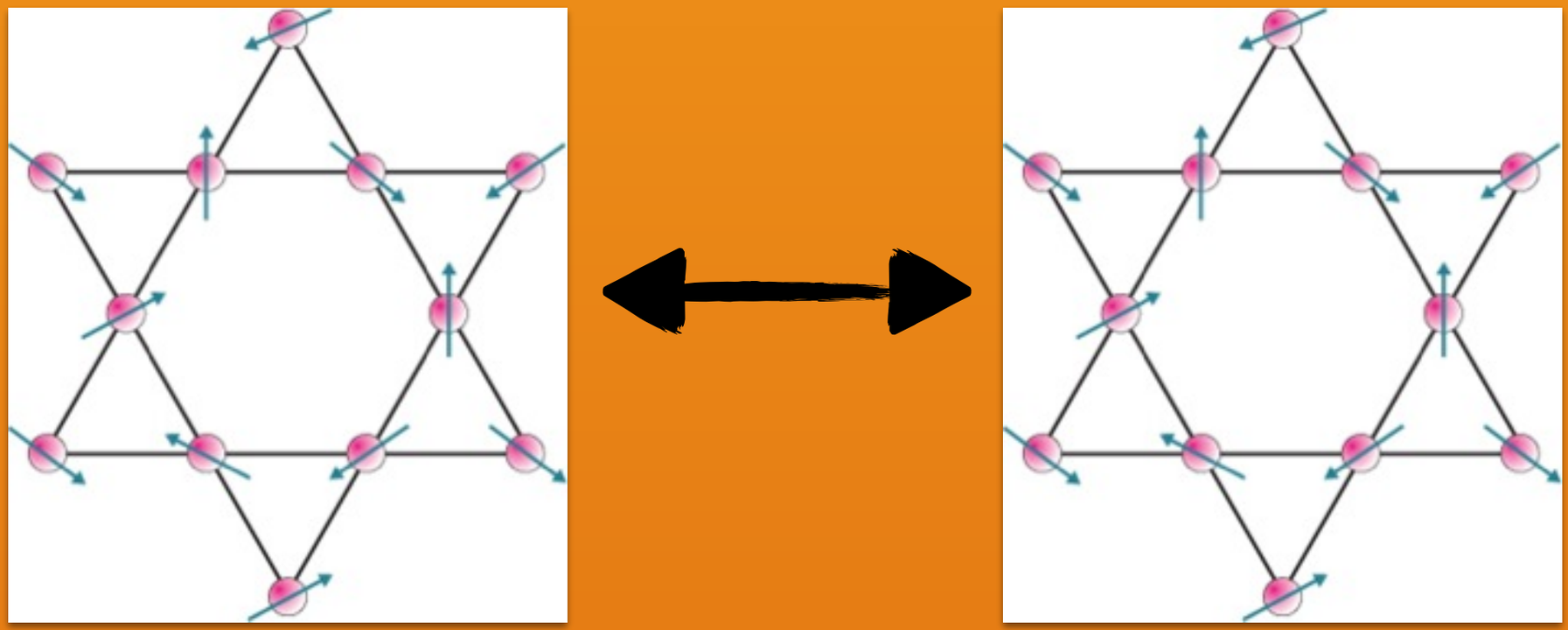
Perhaps special-purpose, highly optimized devices could be constructed.

Instead of full-scale computers, build simpler devices

No quantum macbook

Build Quantum Information Processors instead

Simulating quantum systems
(with other small quantum systems) is
tractable.



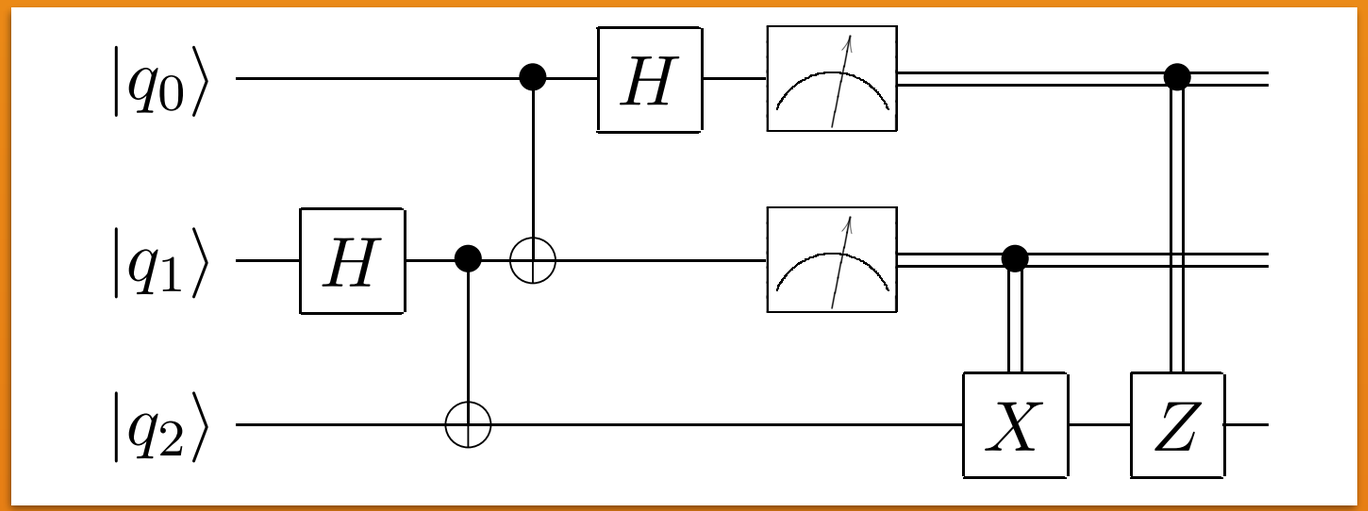
Simpler engineering

How do we do this simulation?

What physical systems will we use?

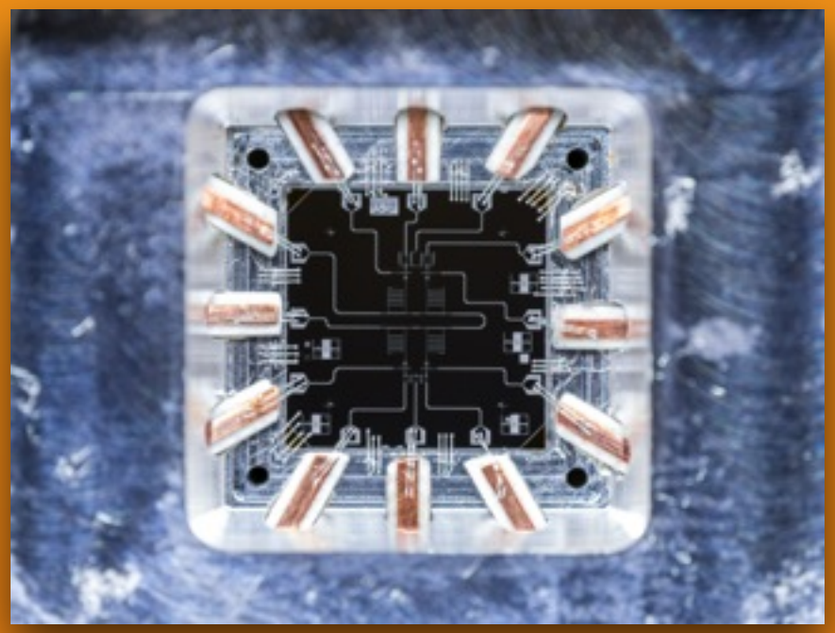
There are two main methods of simulation - digital and analog.

Digital = quantum gates/circuits

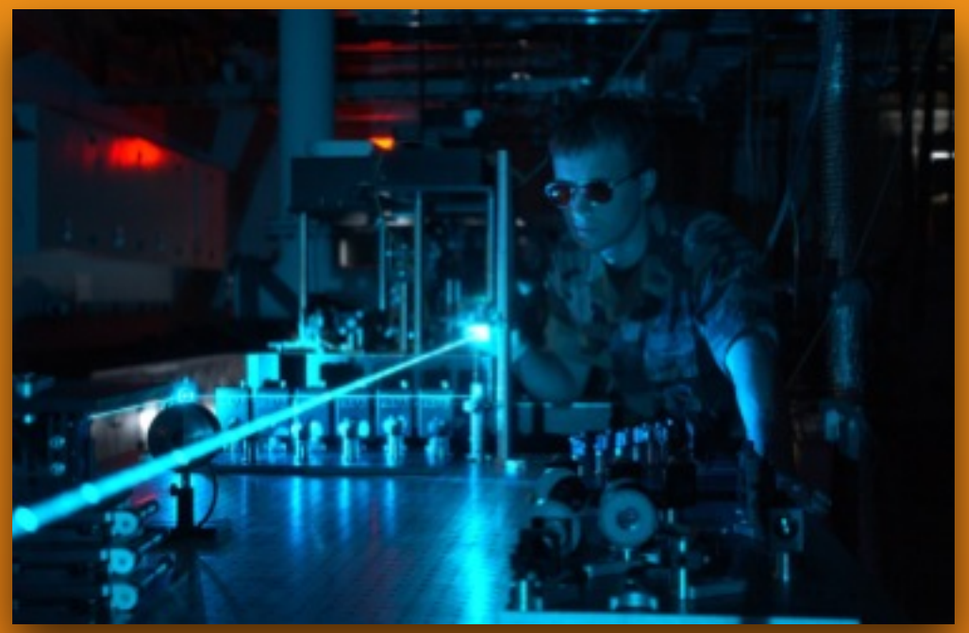


Analog = map Hamiltonian dynamics

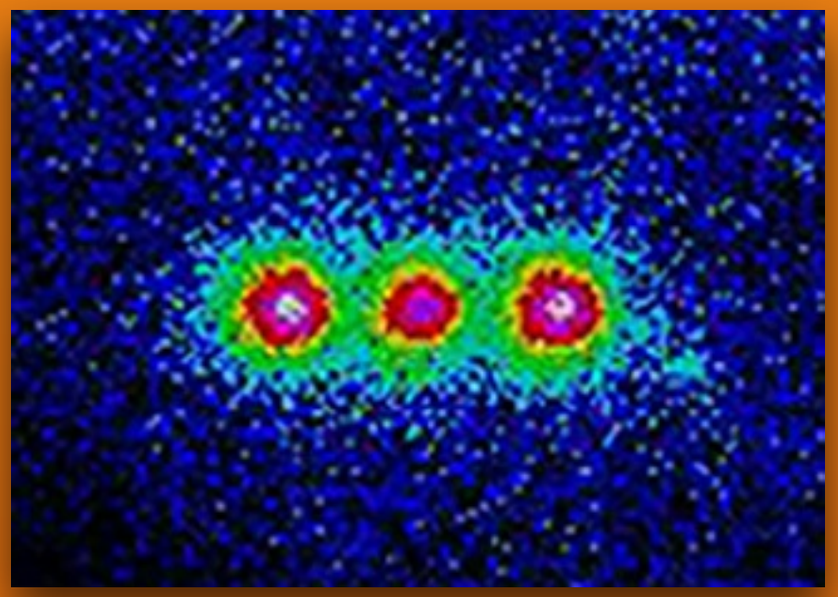
We are looking for useful and practical architectures on which to build QIPs.



Superconductors



Photonics



Ion Traps

QIPs could form the building blocks
of larger computer…sometime in the future!

Until then….

…we're studying the engineering requirements

Scalability Controllability Reliability

…we're examining what problems to investigate

Molecular Energy Levels

Materials Design

Condensed Matter Phenomena

QIPs (and the problems they help solve) may tell us something about Nature and enable large scale quantum computation.

Supplemental Material

Several algorithms suggested quantum computers could be more powerful than their classical counterparts.

Lov Grover, 1996

A fast quantum mechanical algorithm for database search

Peter Shor, 1994

Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer

It is just not feasible to build a full-scale, general purpose quantum computer.

Controllability

Reliability

Efficiency

Accuracy

We lack the ability to build robust, large quantum computers.

Pictures:

wind tunnel - http://www.eurocarnews.com/media/pictorials/2109/12387.jpg

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Cryptography: MAKSIM KABAKO/SHUTTERSTOCK

xiaomi Mi4 - http://arstechnica.com/gadgets/2014/08/xiaomi-mi4-review-chinas-iphone-killer-is-unoriginal-but-amazing/

Richard Feynman: http://www.geoffwilkins.net/images/feynman/feynman-bongos2.jpg

quantum circuit -http://www.media.mit.edu/quanta/qasm2circ/test2.pdf

Quantum Spin System: http://www.riken.jp/en/research/rikenresearch/highlights/6264

Apple watch - http://blog.dudepins.com/apple-watch-10-reasons-buy-iwatch/

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