



Quantum Information Science

Dr. Gerald Gilbert

732.578.6366

ggilbert@mitre.org

MITRE Sponsored Research

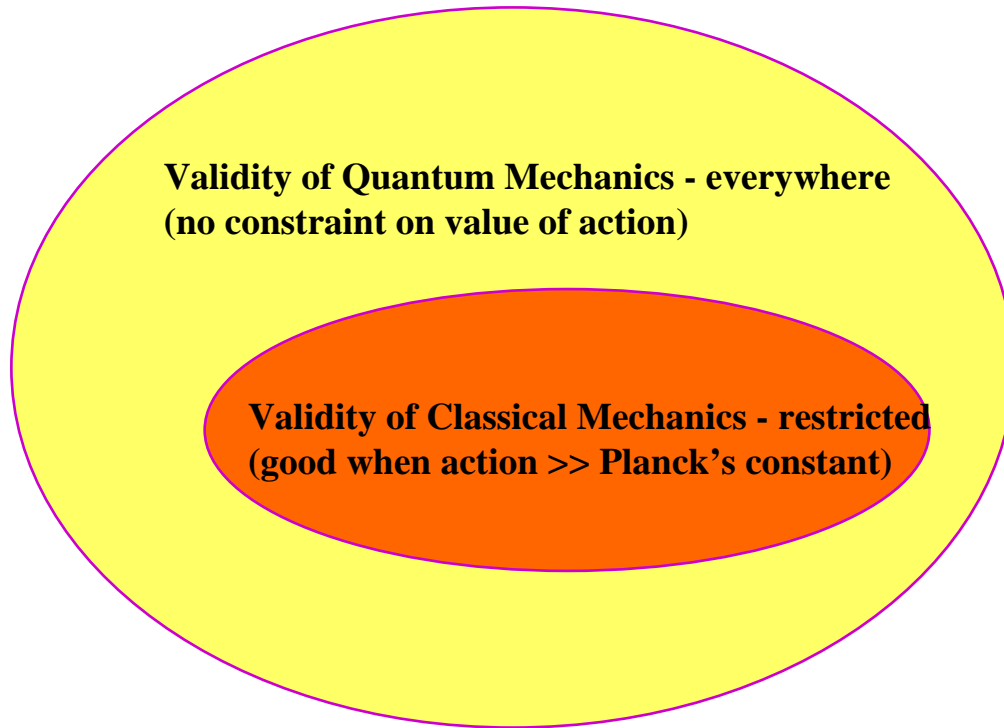
Problem

- Quantum computers can solve problems that are effectively *impossible* to solve with classical computers.

- What is the best design for a practical quantum computer?
 - fault tolerance, scalability, efficiency

- Can we discover new quantum computing algorithms, and new applications?

Background



This diagram (roughly) indicates the conditions for which one *must* use quantum mechanics (yellow), and those for which one *may* use classical mechanics (red).

Quantum Information Science exploits unique features of quantum mechanics to obtain results difficult or impossible to achieve with classical mechanical systems.

Objective


- Develop the **world's first efficient, scalable quantum computer design and prototype**
- Obtain **fundamental theoretical results**: maintain MITRE's position as a world leader in the field of quantum information science
- Contribute to solving problems of national importance in the areas of code-breaking, steganography analysis, real-time analysis of spread-spectrum communications, high-intensity computing, etc.

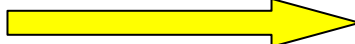
Activities



- **Perform theoretical and systems-engineering quantum computing analyses**
- **Develop quantum information processing components using the linear quantum optics or photonic cluster approach**
- **Design / demonstrate quantum memory device; prototype non-linear sign shift gate or cluster fusion operator**
- **Demonstrate quantum computing component(s)**

Highlight

CNOT: $U_{CN} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$  $\begin{matrix} |00\rangle \rightarrow |00\rangle \\ |01\rangle \rightarrow |01\rangle \\ |10\rangle \rightarrow |11\rangle \\ |11\rangle \rightarrow |10\rangle \end{matrix}$

Hadamard: $H = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$  $\begin{matrix} |0\rangle \rightarrow \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \\ |1\rangle \rightarrow \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle) \end{matrix}$

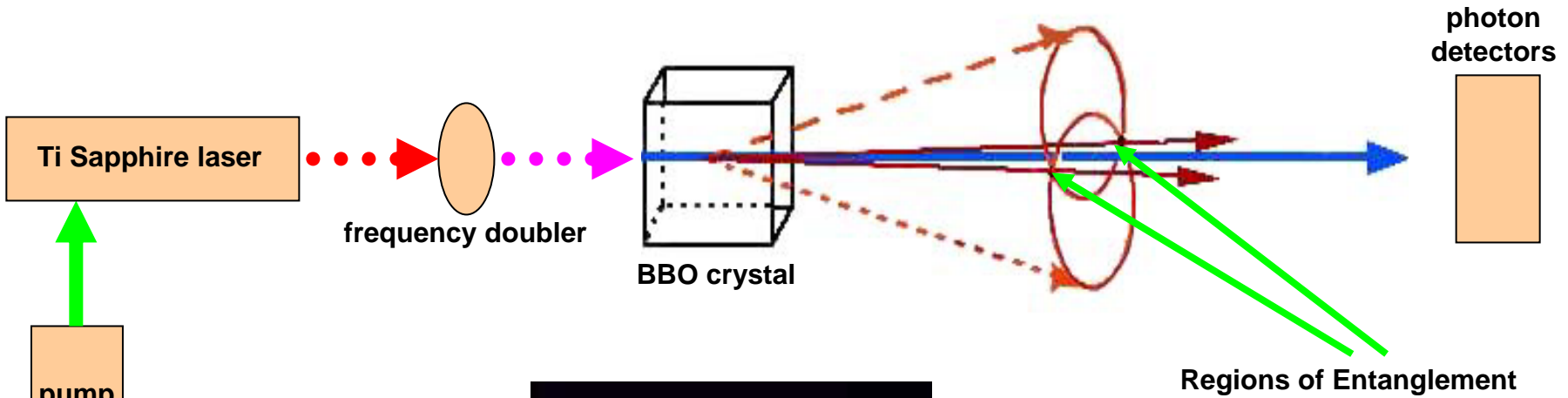
$$U_{CN} H |00\rangle = U_{CN} \frac{1}{\sqrt{2}} (|0\rangle + |1\rangle) |0\rangle$$

$$= \frac{1}{\sqrt{2}} (|00\rangle + |11\rangle)$$

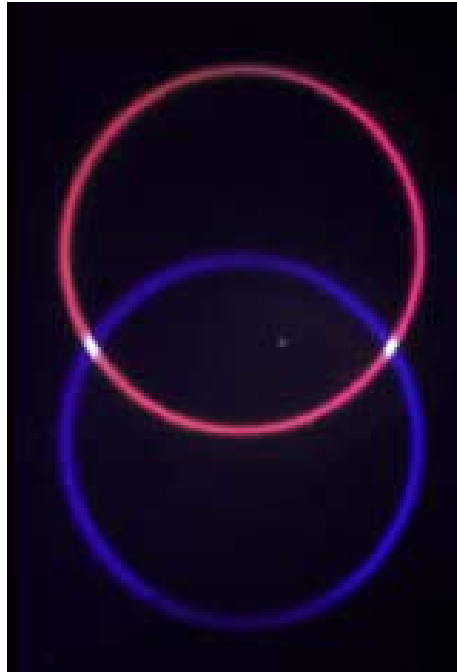
Hadamard followed by CNOT yields an entangled state

Such states provide computational capabilities that are not possible in classical computers.

Highlight/Demonstration



pump
laser



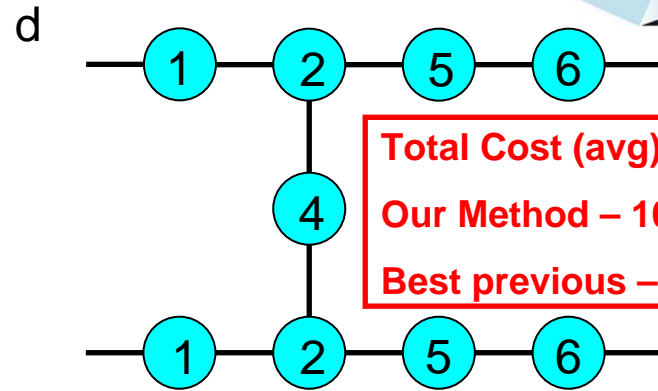
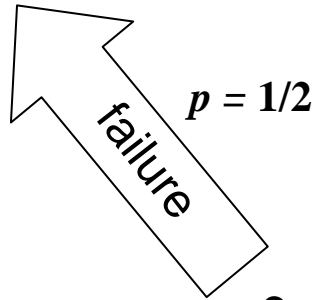
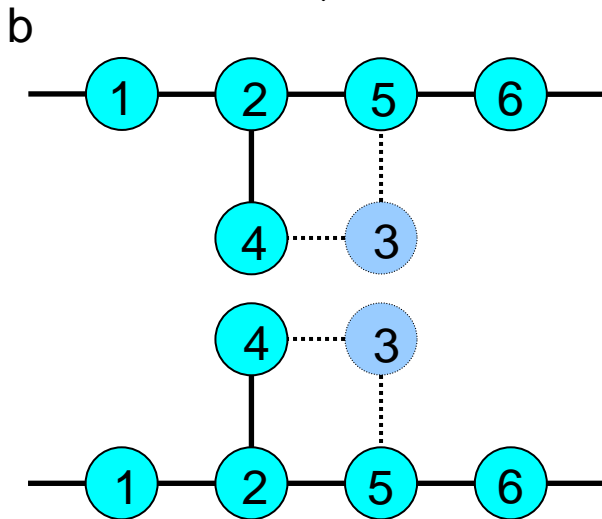
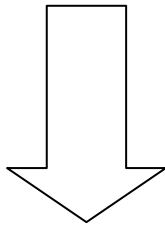
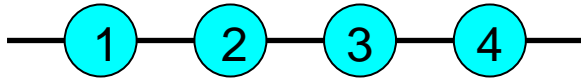
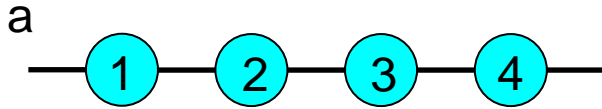
front-end view (actual data generated at MITRE)

Impacts

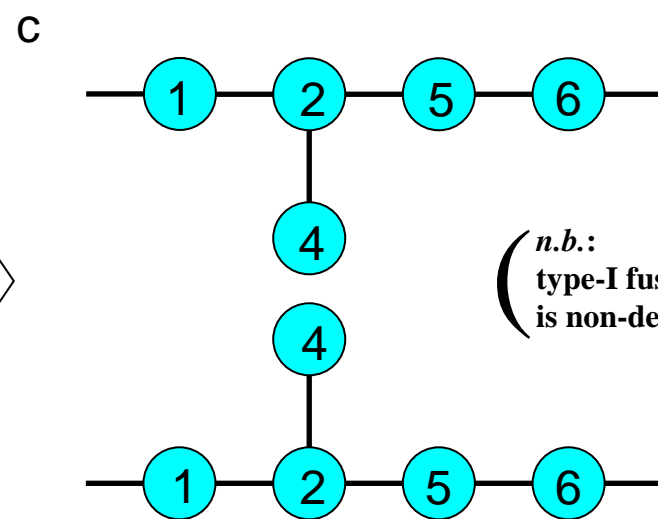
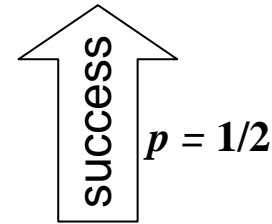


- **This work places MITRE at the very frontier of research worldwide: we are now recognized as a leading player in this high-visibility research area.**
- **Continue to develop a unique resource to assist government to manage development and deployment of this new technology**
- **Will make basic advances in technology that will be crucial in addressing problems of national importance**

Future Plans



Total Cost (avg):
Our Method – 10 bonds
Best previous – 34 bonds



(*n.b.:*
 type-I fusion
 is non-deterministic)