Quantum Computing

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MITRE Sponsored Research

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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?**

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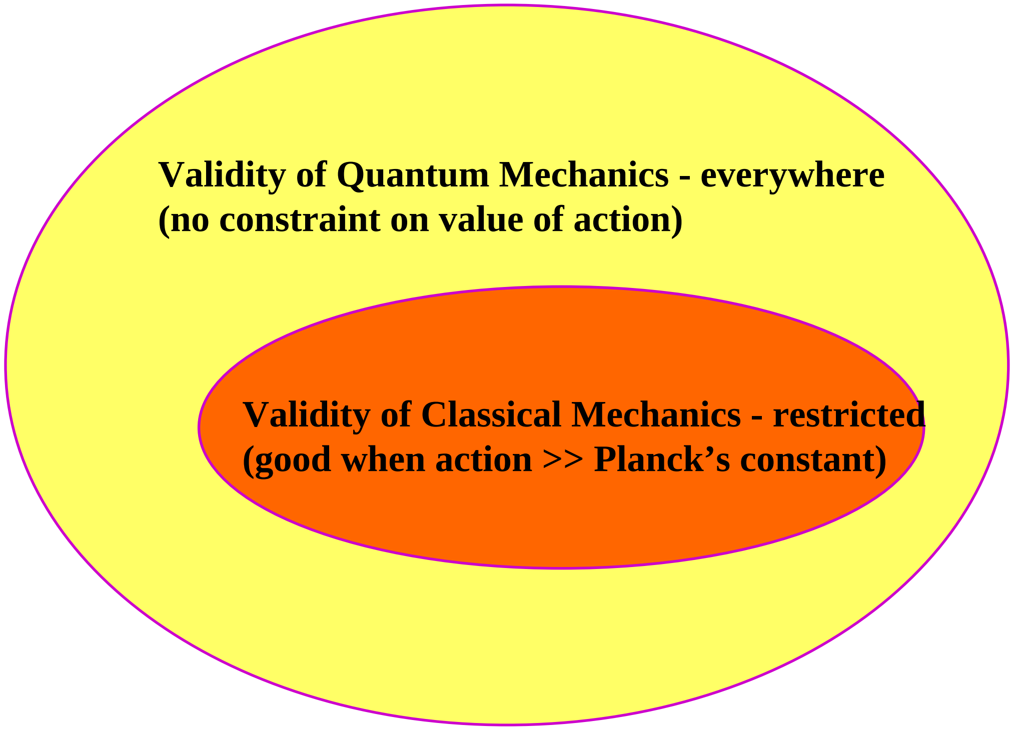
Background



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.

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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)

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Objective

- Develop the ***world's first efficient, scalable quantum computer design***; prototype selected components of the design
- 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.

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Highlight

CNOT: $U_{CN} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$ ⇒

$$|00\rangle \rightarrow |00\rangle$$
$$|01\rangle \rightarrow |01\rangle$$
$$|10\rangle \rightarrow |11\rangle$$
$$|11\rangle \rightarrow |10\rangle$$

Hadamard: $H = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$ ⇒

$$|0\rangle \rightarrow \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right)$$
$$|1\rangle \rightarrow \frac{1}{\sqrt{2}}\left(|0\rangle - |1\rangle\right)$$

$$U_{CN} H|00\rangle = U_{CN} \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right)|0\rangle$$
$$= \frac{1}{\sqrt{2}}\left(|00\rangle + |11\rangle\right)$$

Hadamard followed by CNOT yields an <u>entangled</u> state

Such states provide computational capabilities that are ***<u>not possible</u>*** in classical computers.

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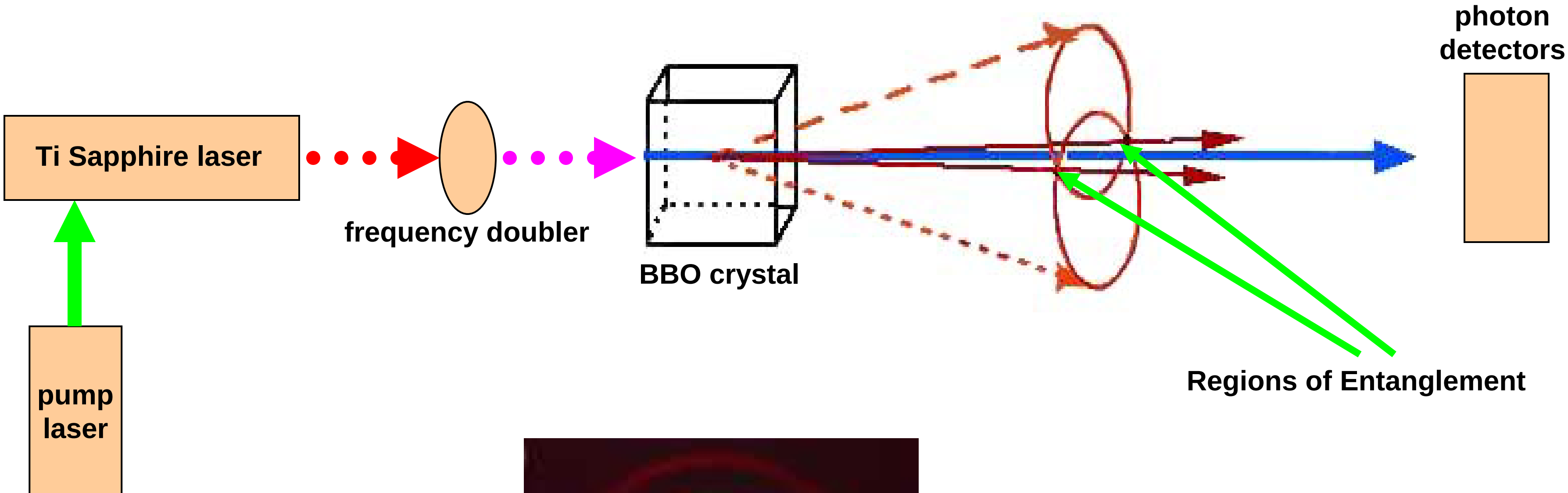
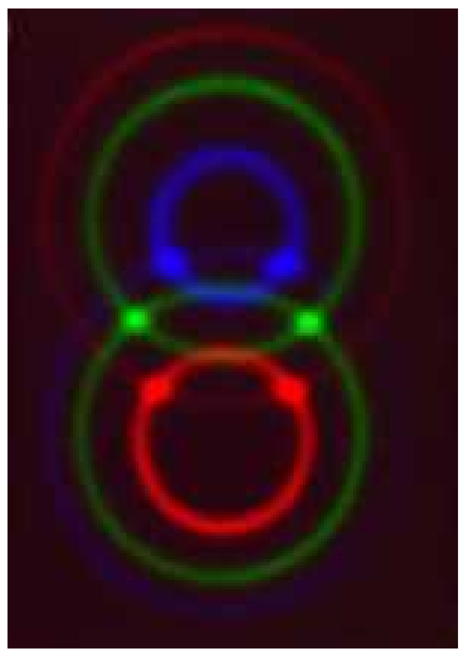
Demonstration





front-end view (actual experimental photograph)

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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

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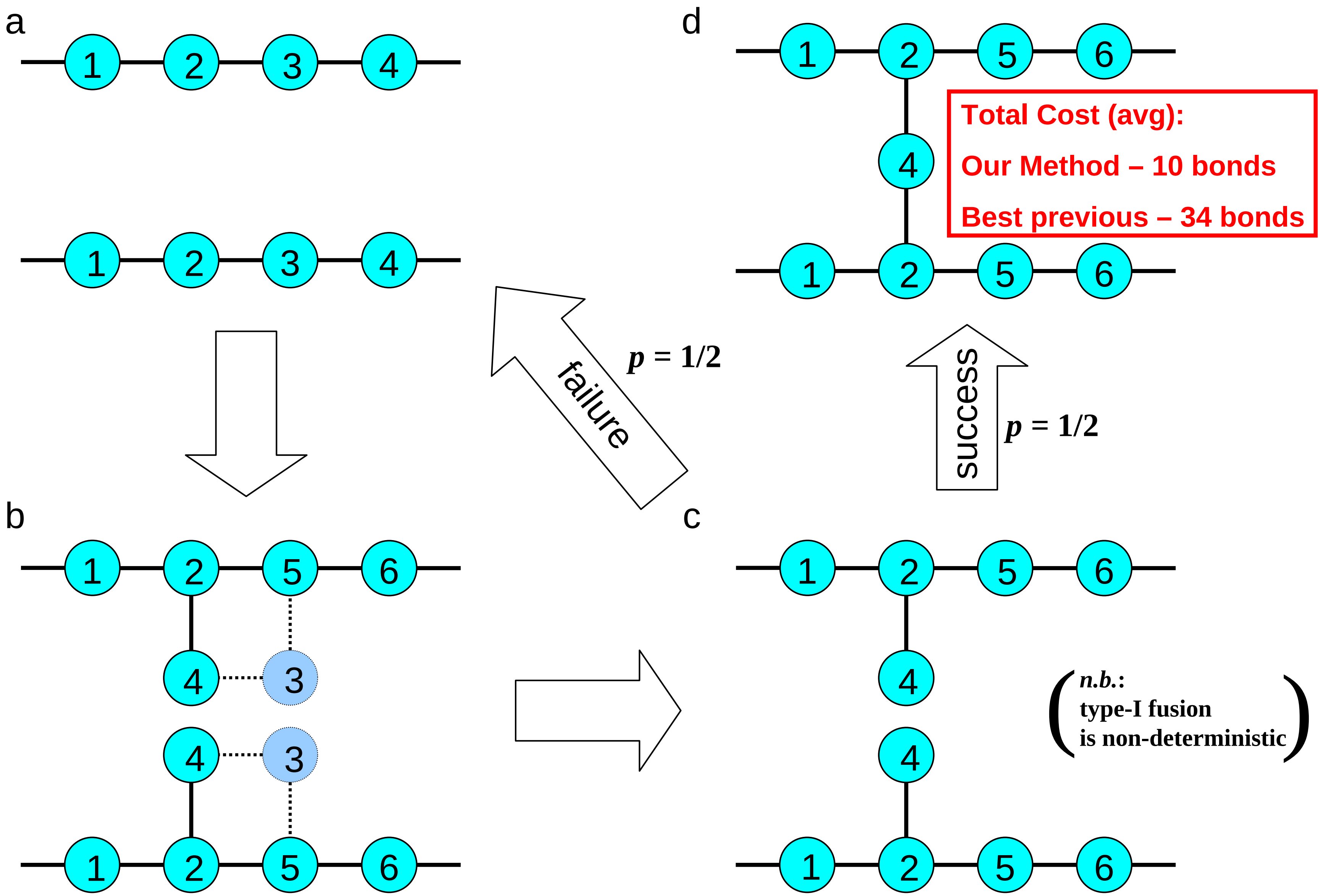
Future Plans



PHOTONIC CLUSTER BUILDING PROCESS

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