EN2912C: Future Directions in Computing
Lecture 15: Introduction to Quantum Computing

Prof. Sherief Reda
Division of Engineering
Brown University
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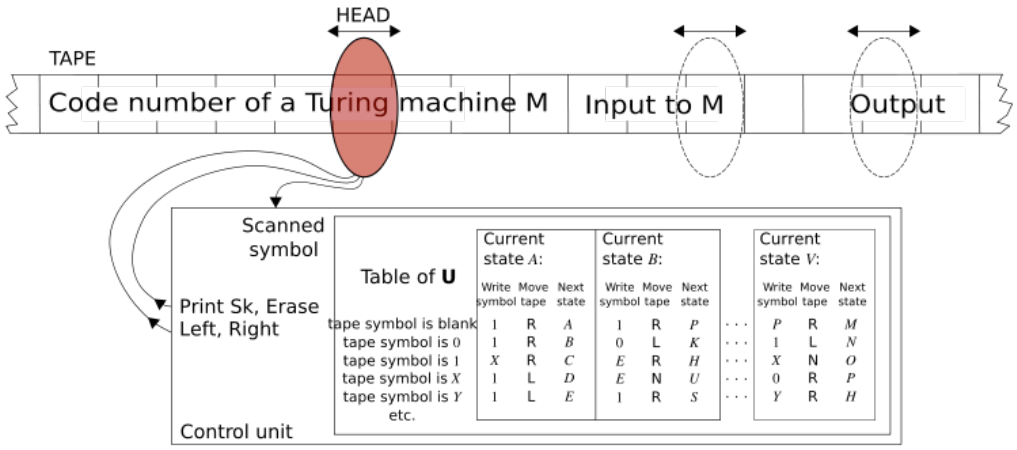
Topics discussed in quantum computing

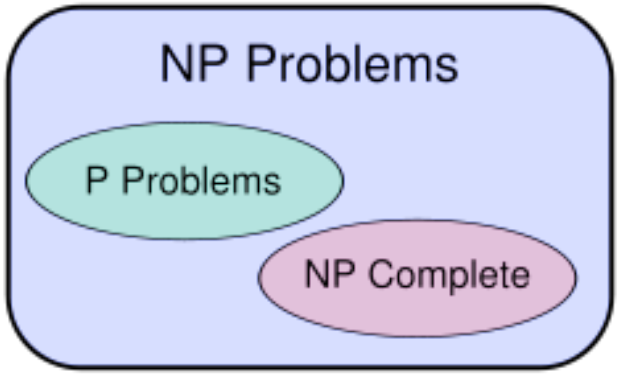
1. Introduction / Linear algebra refresher
2. Quantum models of computing
3. Superdense coding and teleportation / Deutsch Algorithm
4. Grover's search algorithm / Shor's integer factorization algorithm
5. Quantum error correction
6. Quantum circuit implementation technologies
7. Quantum computer architecture

Complexity of computation

- Polynomial and superpolynomial problems
- The Church-Turing thesis
- Turing machines
- Probabilistic Turing machines
- Quantum Turing machines

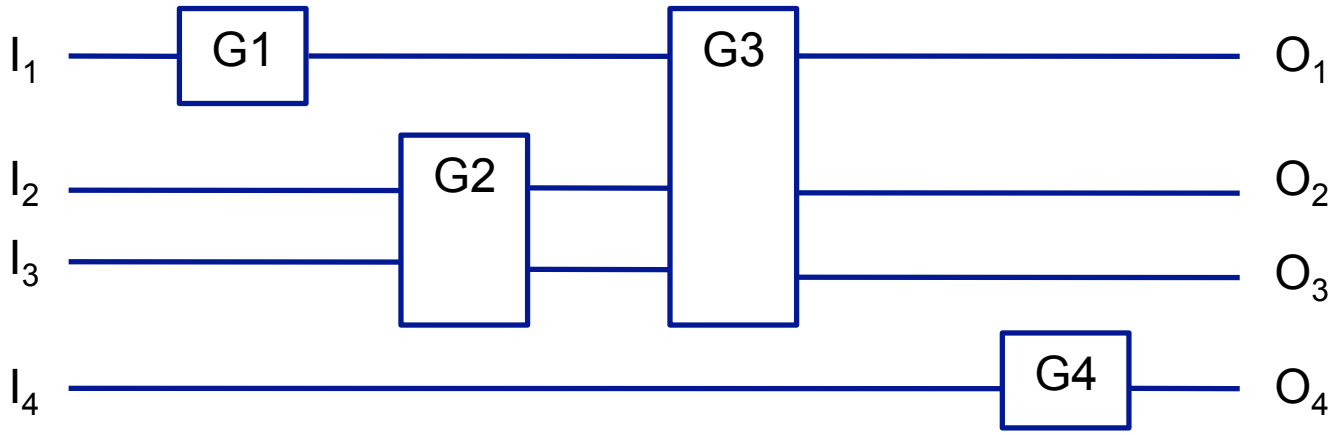


Turing machine



P and NP problems

Circuit model of computation



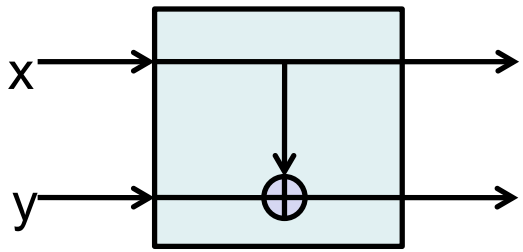
- Reversibility
- Universal building blocks
- Size, depth and width

Linear algebra of circuit model

States are represented as a vectors $\begin{pmatrix} p_0 \\ p_1 \end{pmatrix}$

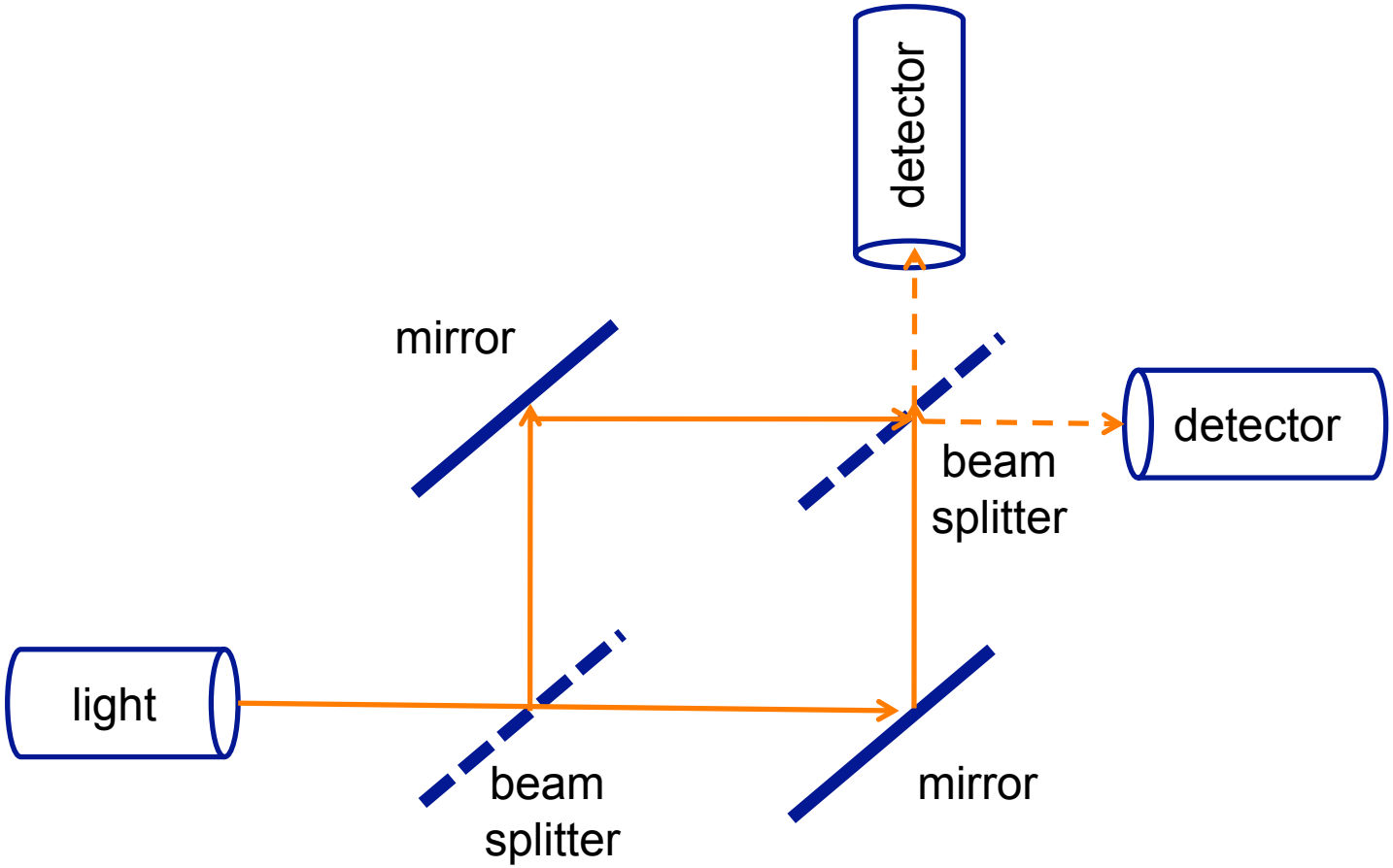
Gates are represented as operators, e.g., NOT $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$

CNOT gate



$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

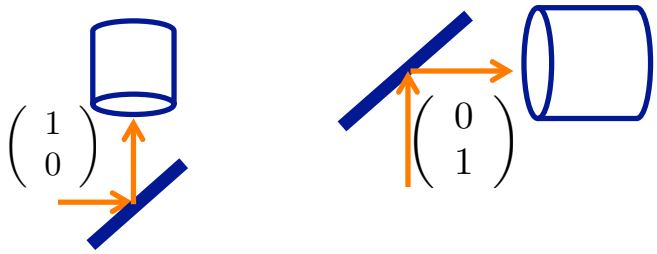
Quantum physics and computing



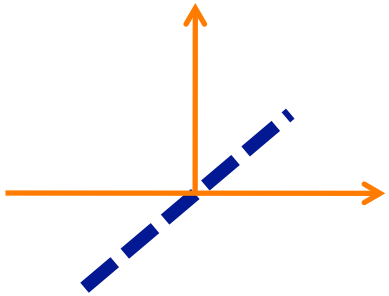
- Which detector detects the light photons?
- Classical physical is unable to explain results of the experiment
- See the experiment at http://www.quiprocone.org/Protected/DD_lectures.htm

Quantum physics and computing

Pure states

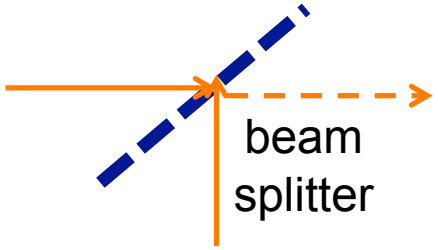


Impact of first beam splitter



$$\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & i \\ i & 1 \end{pmatrix}\begin{pmatrix} 1 \\ 0 \end{pmatrix} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ i \end{pmatrix} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 0 \end{pmatrix} + \frac{i}{\sqrt{2}}\begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

Impact of second beam splitter



$$\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & i \\ i & 1 \end{pmatrix}\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ i \end{pmatrix} = \begin{pmatrix} 0 \\ i \end{pmatrix}$$