THE UNIVERSITY of EDINBURGH
informatics

Introduction to Quantum Computing

Lecture 1: Introduction and Logistics

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- Discussions and Questions on **Piazza Forum**

Structure of the course

- Lectures
  - Weeks 1 to 10
  - Tuesday 10:00 – 10:50 @ Teviot Lecture Theatre, Doorway 5, Medical School, Teviot
  - Wednesday 11:10 – 12:00 @ LG.11, 40 George Square
  - Thursday 11:10 – 12:00 @ LG.11 40, George Square
- Tutorial (start week 2)
  - Tutorial 0 on week 2
  - 8 tutorials in total: weeks 3 to 10
  - AT 2.07, 4 groups
  - Thursday 13:10 - 14:00; Thursday 14:10 – 15:00
  - Friday 14:10 – 15:00; Friday 15:10 – 16:00
- Q&A after any lecture

Assessment

- Coursework 25%
  - One assignment released week 6 – 23rd October
  - Due Friday 8th November 12:00 (week 8)

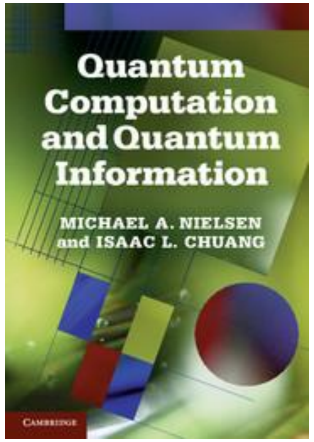
- Exam 75%
  - December
  - Revision session on week 10.

- Course has changed since last year! (20 credits from 10)
  - Not all material is covered in past papers
  - Coursework would be different (more based on programming)

Syllabus

- Intro to quantum mechanics and quantum circuits (6 lectures, Raul)
- Quantum algorithms: basic and FT (8 lectures, Raul)
- Quantum Programming: Pennylane (5 Lectures, Chris)
- Near-term quantum algorithms & quantum ML (3 lectures, Petros)
- Measurement-based quantum computation (3 lectures, Petros)
- Quantum error correction (3 lectures, Joschka)

Resources



- Quantum Computation and Quantum Information"
  by Michael A. Nielsen & Isaac L. Chuang

- Quantum Computing Lecture Notes
  by Ronald de Wolf
  https://arxiv.org/abs/1907.09415

- Introduction to Quantum Computation
  Sevag Gharibian
  Lectures notes link

- Lecture Notes: https://opencourse.inf.ed.ac.uk/iqc/schedule
  Extra material/details given at the schedule
  Recordings from the Learn page of the course

Quantum Informatics

Store, process and communicate information exploiting the laws of quantum mechanics

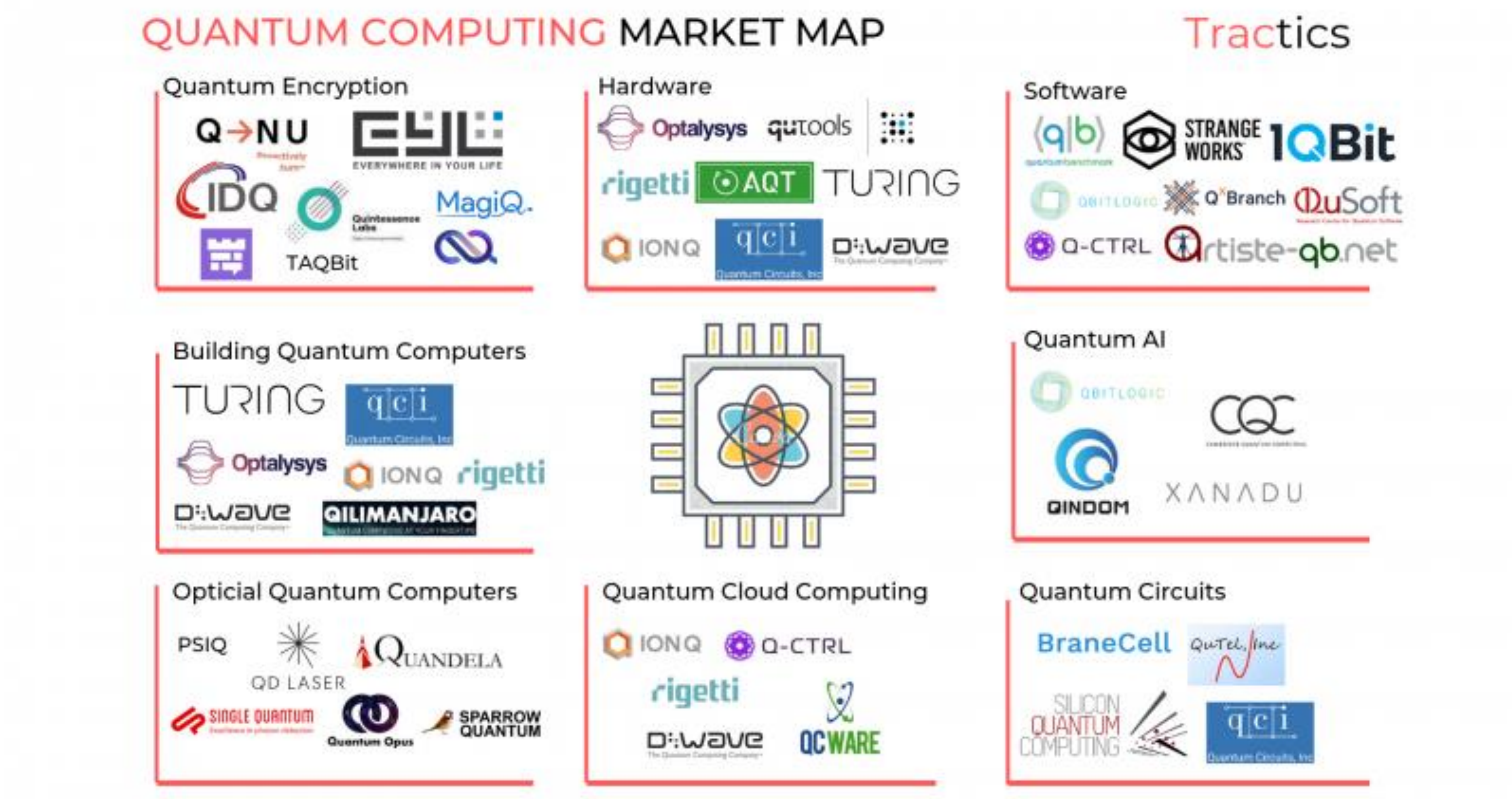
Computation

Cyber Security

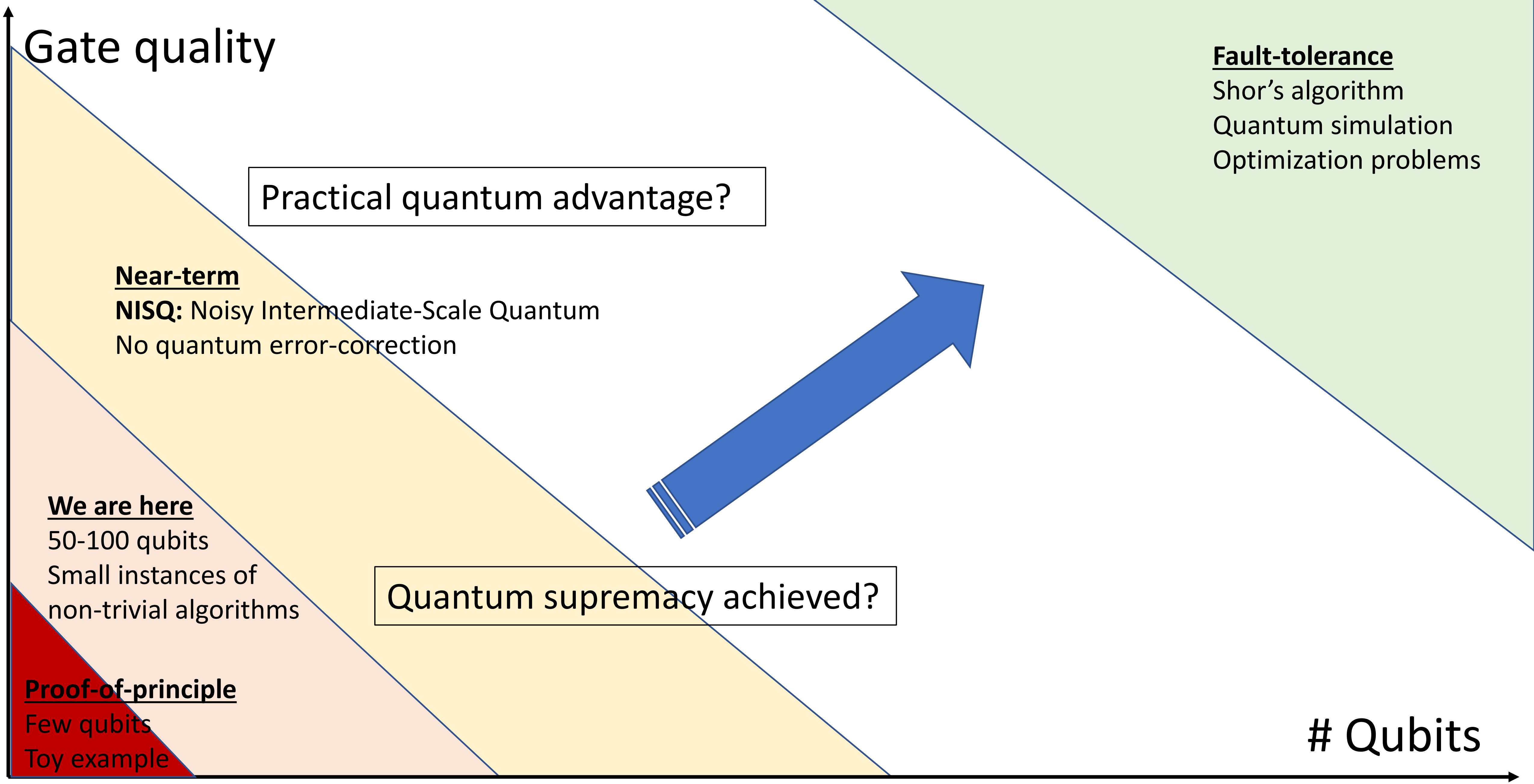
Quantum Cyber Security
INFR11187 during S2
Petros Wallden (CO) and Mina Doosti

Quantum Computing Ecosystem

The future of quantum computing is on the making right now!

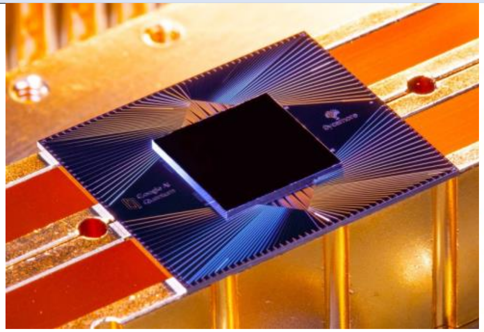


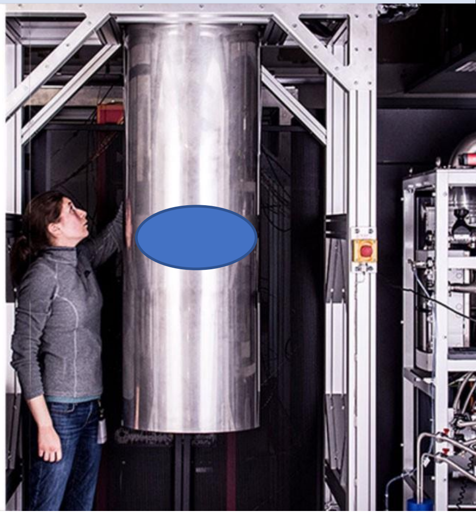
The prospects of quantum computation



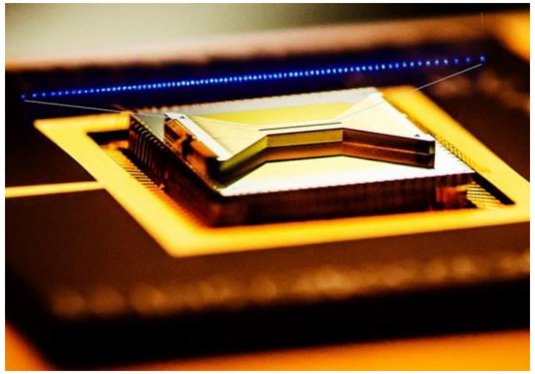
Hardware architectures

- Superconducting circuits

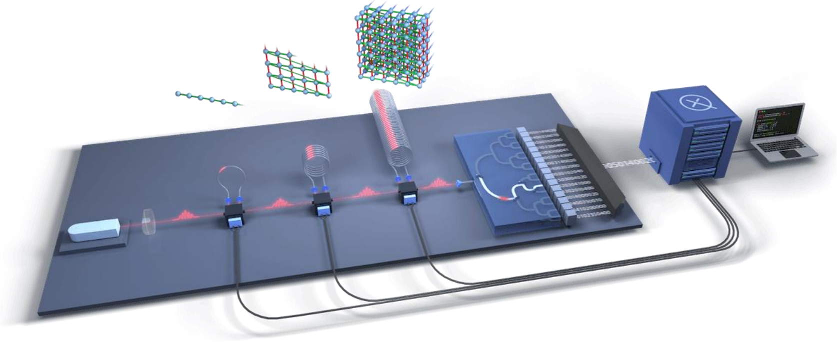




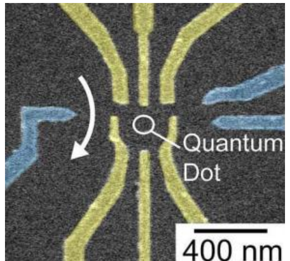
- Ion Traps



- Photonics

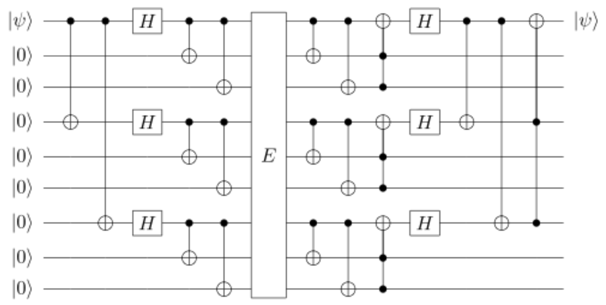


- Quantum dots

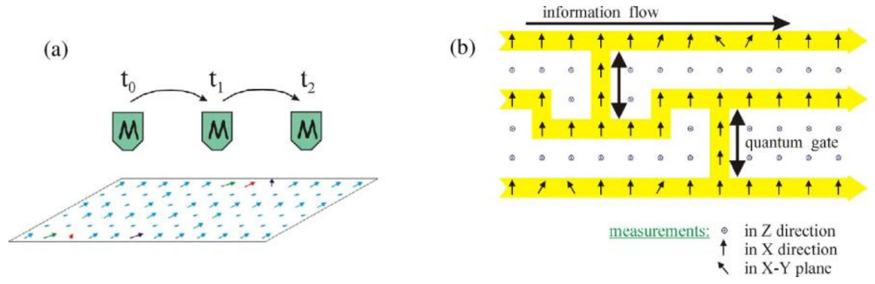


Models of Quantum Computation

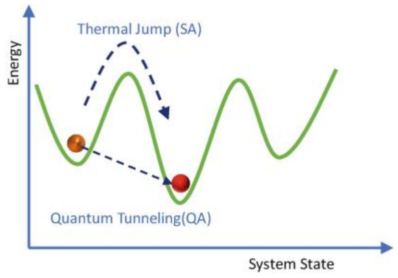
- Quantum Circuits



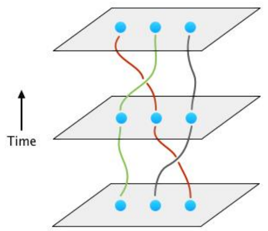
- Measurement-based Quantum Computation



- Adiabatic Quantum Computation
  Quantum annealers



- Topological Quantum Computation

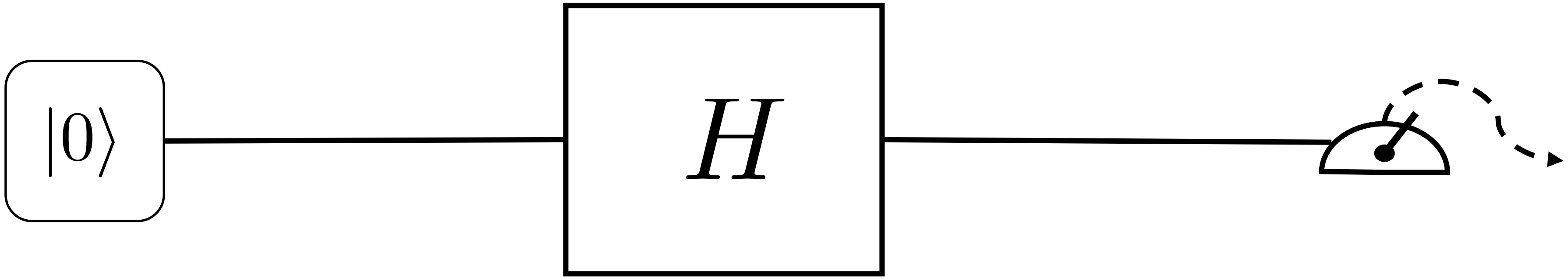


The ideal life of a qubit in a nutshell

State preparation — Source of quantum states

Operation — Circuit/Gates

Measurement



Quantum random number generator circuit

Myths and Realities

On the Power of Quantum Computation

Myth 1

Quantum Computers are much faster in performing operations than Classical Computers

Myths and Realities

On the Power of Quantum Computation

Myth 1

Quantum Computers are much faster in performing operations than Classical Computers

Reality

Quantum computers are **not** faster. Speed-up is obtained because quantum theory allows algorithms/operations impossible for classical computers.

Myths and Realities

On the Power of Quantum Computation

Myth 2

Quantum Computers simultaneously perform all branches of a (probabilistic) computation and can use all that information

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On the Power of Quantum Computation

Myth 2

Quantum Computers simultaneously perform all branches of a (probabilistic) computation and can use all that information

Reality

QC span the space of possibilities in a peculiar way (behave as complex probabilities). However, at the end of the computation the result is obtained by a **single read-out/measurement** and "unrealised" paths do not contribute.

Myths and Realities

On the Power of Quantum Computation

Myth 3

Quantum Computers give equally impressive computational speed-up to all problems

Myths and Realities

On the Power of Quantum Computation

Myth 3

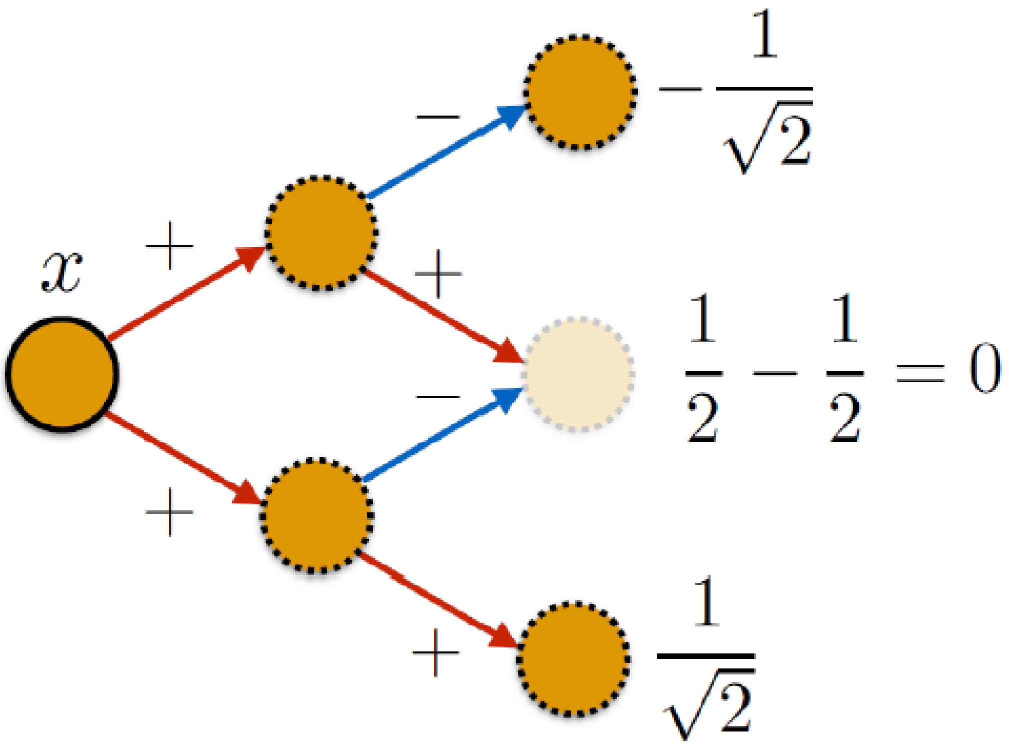
Quantum Computers give equally impressive computational speed-up to all problems

Reality

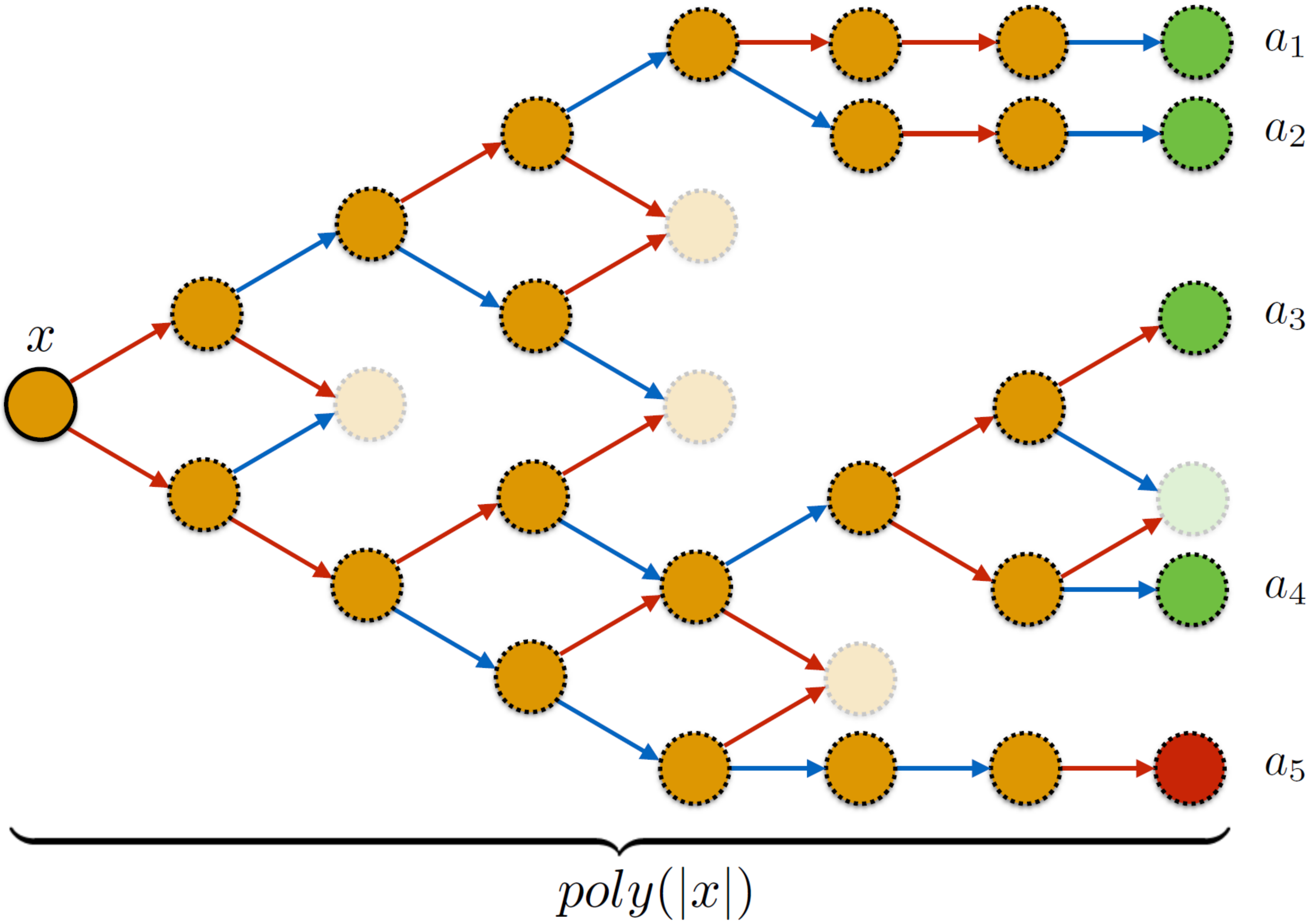
Quantum computers can give from exponential speed-up (factoring) to much smaller quadratic speed-up (search). The exact optimal quantum algorithm depends on the problem and is crucial for quantum cryptanalysis.

How it works?

- Quantum computers behave as probabilistic computers but with complex-valued "probabilities"
- Probability is the mod square of the sum of the complex amplitudes



How it works?



How it works?

- For **speed-up**: need an algorithm that many terms cancel each other
- Non-trivial: need **suitable algorithm design** for each task
- $|\sum_i a_i|^2 = \sum_i |a_i|^2 + \sum_{i \neq j} a_i^* a_j$

  First term: classical probabilities

  Second term: Amplify or cancel probability (interference)
- **Classical systems:** random amplitudes $\rightarrow$ interference $\approx$ zero