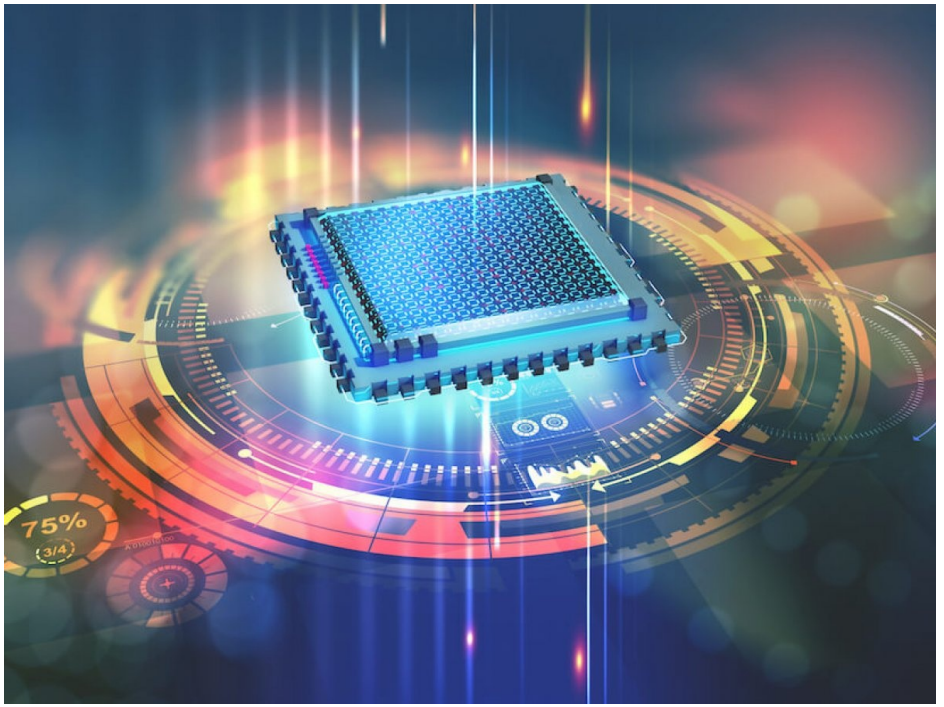
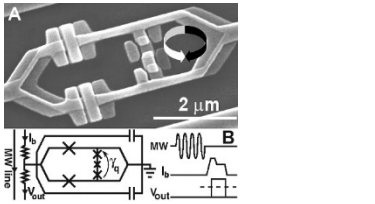
# Introduction to Quantum Computing



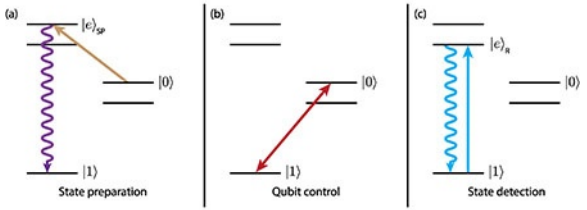
# Why are we here?

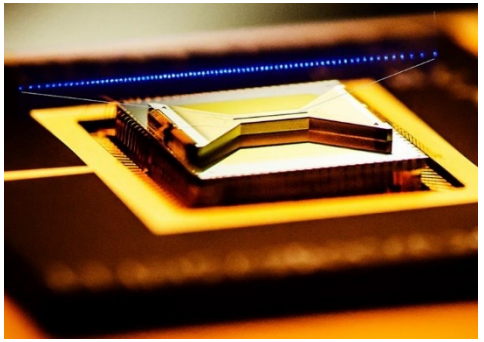
- The world obeys Quantum Theory
- Computers that fully harness quantum effects could outperform classical ones
- Building quantum computers is very hard, but not ridiculously, impossibly hard
- We are at a special moment: beginning to build nontrivial quantum computers
- **This course**: you will learn what a quantum computer is, why we think it will be useful (quantum algorithms), and why we think it can be built (quantum error correction)

# Quantum computers exist...




Superconducting qubits
Yale, Google, IBM, Rigetti



Ion traps
ionQ/UMD, NIST Boulder, Honeywell

# …and there is much work on them

- Different technologies
- Significant industrial effort in both hardware and software: Amazon, Google, IBM, Microsoft, Rigetti, PsiQuantum,  ionQ, Intel,  Lockheed-Martin, ColdQuanta, Zapata, QC Ware, Xanadu…
- Our goal:  What are these things (going to be) good for?

# Course structure

- Two modules, in sequence, and lab:
  - First module: Ivan Lanese (me)
  - Second module: Ugo Dal Lago
  - Lab: Filippo Orazi (course tutor)
    - Will use Qiskit (a quantum programming language)

# What we will cover?

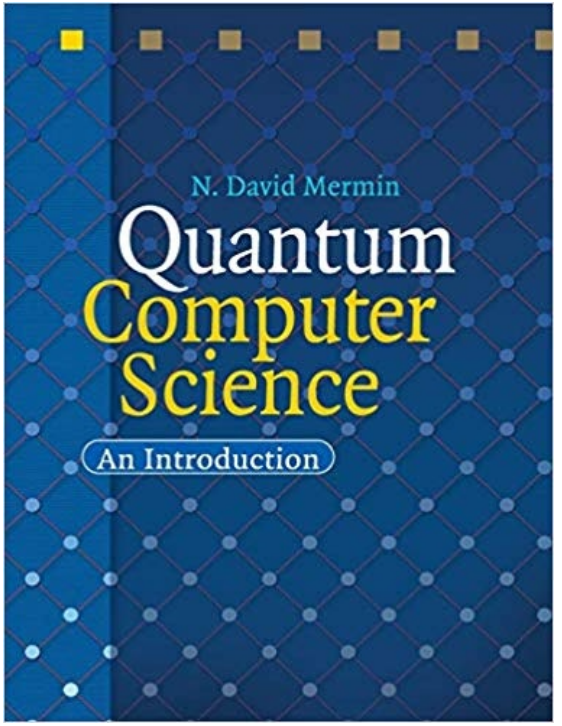
- First module:
  - Introduction to quantum computing
  - Quantum circuits
  - Simple circuits (Deutsch’s problem, Bernstein-Vazirani, Simon’s, …)
- Second module:
  - Main algorithms (Grover, Shor, …)
  - Hints on error correction and quantum cryptography

# Mathematics on demand

- Quantum computing relies on quite strong mathematical basis
  - Complex linear algebra
  - Qubits values are unitary vectors in a 2 dimensional complex space…
- I will introduce it only when needed
  - Drawback: sometimes properties and notation will appear out of the blue, and you will not have a full understanding of the mathematical context
  - Advantage: we can start speaking about computing and programs quite soon, instead of spending the first month on mathematical background

# Teaching material

- All available on the virtuale website
- Slides, exercises
- Reference book
  (also available for download
  from UNIBO library)



# Exam

- Two options:
  - Oral exam
  - Project or in-depth study (topic to be agreed with professors)

# Suggestions and hopes

- Quantum computing is not easy:
  - Strong mathematical basis
  - Counterintuitive phenomena
  - Please don’t lag behind, otherwise understanding will be difficult
- I appreciate interactions
  - Ask when there are doubts
  - I will propose you exercises and quiz, and I want to see your solutions and proposals