The Road to Quantum Computers

Mario Berta (Department of Computing and QuEST Imperial)

marioberta.info – mathematical aspects of quantum information science
Understanding quantum systems (e.g., single atoms or electrons) is hard.

Richard Feynman
(The Nobel Foundation)

Understanding physics with computers ’81

“trying to find a computer simulation of physics seems to me to be an excellent program to follow out (...) nature is not classical, dammit, and if you want to make a simulation of nature, you would better make it quantum mechanical, and by golly it is a wonderful problem, because it does not look so easy”
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Information processing based on quantum physics:
Quantum Information Science
Quantum Technologies: Hardware

- **Build well-controlled quantum systems**: approaches range from cavity quantum electrodynamics, optical lattices, ion traps, superconductors, quantum dots, linear optics, nuclear magnetic resonance, etc.

Imperial Centre for Quantum Engineering, Science and Technology (QuEST)
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**Hardware based (direct) applications**

- Quantum sensing, quantum clocks, quantum annealing, analogue quantum simulations, etc.
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![Imperial Centre for Quantum Engineering, Science and Technology (QuEST)](image)

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- Fully programmable quantum computer requires: Quantum Software
### Main motivation

We can do things that we do not know how to do using only (future) classical technology.
Quantum Technologies: Software for Computation

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Quantum algorithm

for prime factorization breaks RSA public key cryptosystem – that is, virtually any encryption scheme in use today!

Shor's algorithm for prime factorization '94

(Wikimedia commons)
Quantum Technologies: Software for Communication

- **Quantum cryptography** has two aspects:
  - *Quantum-safe cryptography* studies how to protect from adversaries with access to quantum technologies.
  - *Quantum-based cryptography* leading to, e.g., unconditional secure key distribution based solely on the laws of physics.

- **Quantum communication** using quantum repeaters for networks leading to the *quantum internet*.
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Our work

Mathematical aspects of quantum cryptography & quantum communication.
Quantum Technologies: Time to act

- **Academic interest and funding:**
  UK national network of quantum technology hubs (UKNQT) + EU quantum manifesto flagship-scale initiative in quantum technology
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  Alibaba, Google, IBM, Intel, Microsoft, to name a few
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Thank you for your attention, Q&A time.