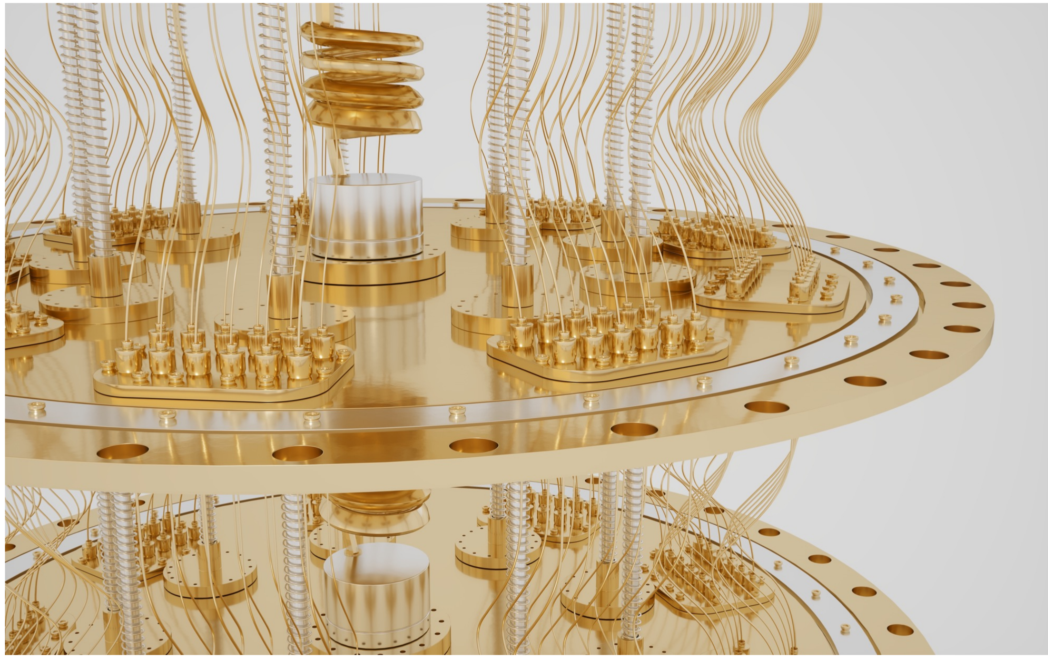
Quantum Algorithms Institute

QAI | QUANTUM ALGORITHMS INSTITUTE

Louise Turner, Chief Executive Officer



- About QAI
- About Quantum Computing
- Quantum Skills and Talent
- Things to Do

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About QAI

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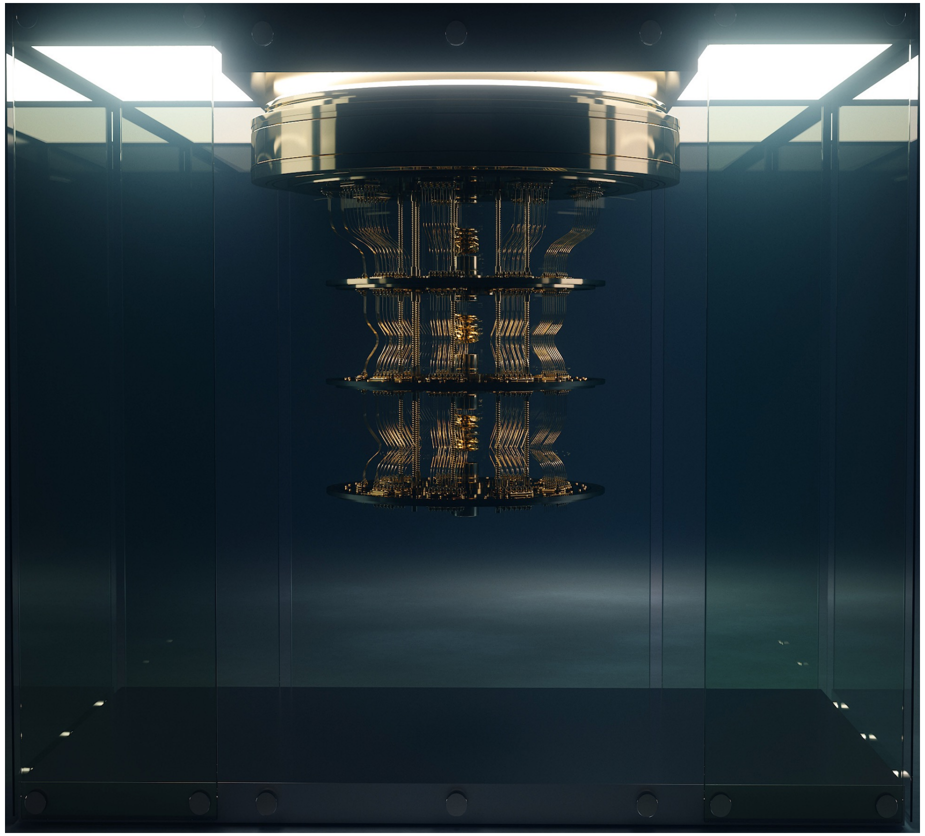
A Unique Partnership

Adding 1)quantum users & 2) quantum workforce

QAI's Focus



- Quantum to advance Canadian businesses
- Economic development
- Focus on
  - Quantum computing
  - Quantum networking
  - Post-quantum encryption
  - Application of quantum algorithms

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Three Streams of Business Activity

1. Playing with the Real World

2. Growing & Feeding Talent

3. Ecosystem Hum

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Playing with the Real World I

- Consult with quantum-curious companies
- Build quantum literacy
- Support applied quantum projects in BC companies
- Identify the right business problems to solve with quantum
- Match expertise from BC’s quantum community industry challenges
- Build expertise on use of quantum in the real world

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Playing with the Real World II

- Quantum expertise in universities
- QAI network of Academic Affiliates
- Internships and work opportunities for students and new grads

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Growing and Feeding Talent I

Education & training for two priority groups

1. Executive education for BC companies
    - Quantum literacy
    - Use quantum solutions in business
    - Develop a quantum-literate workforce
    - Build quantum-ready companies

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Growing and Feeding Talent II

Education & training for two priority groups

2. “Quantum Proximate” grads & post grads

- Math
- Stats
- Physics
- Chemistry
- Biochemistry
- Computer Science
- Engineering

Ecosystem Hum

QAI as…

- A physical hub for quantum activities, events and programs
- An online resource to access quantum materials and expertise
- A facilitator for quantum projects and applied research
- A location for BC's quantum community to gain access to quantum computers & hardware
- A sponsor and supporter of quantum events

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About Quantum Computing

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Computing with Qubits

Atomic Size

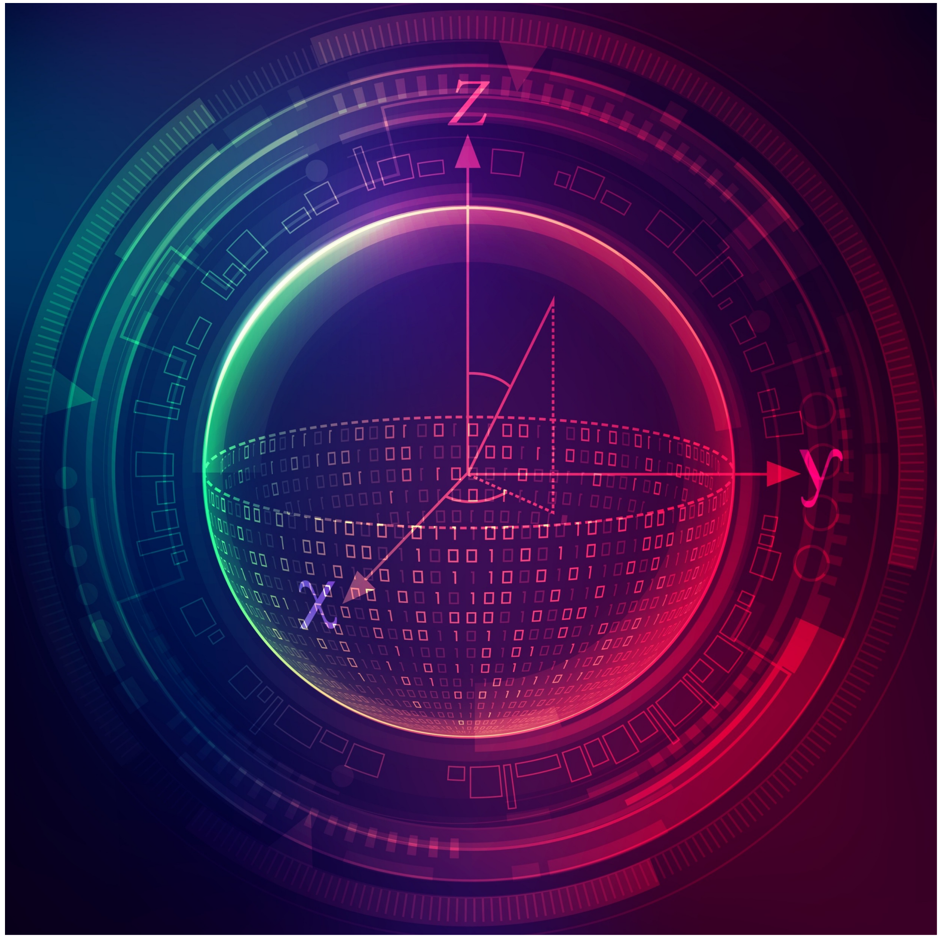
Non-Newtonian

Superposition

Interference

Entanglement

Affected by Measurement



Programming

Algorithms

Environmentally Sensitive

Vacuum Technology

Photonics

Cryogenics

Nanotechnology

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The Quantum Opportunity I

Four Types of Problem

1. Simulation
2. Optimization
3. Machine learning
4. Cryptography

Up to US$ 850 billion in value from 2021 to 2051

A top pharma company with a US$10bn R&D budget

- 30% increase in efficiency
- US$2.5 billion in savings p.a.
- 5% increase in annual operating profits

Q4Climate

Calculation on Google's Sycamore quantum computer

- 557,000 less energy than a classical supercomputer

Quantum Computing Timeline

Feynman

1981

1998

First two-qubit computer

1999

D-Wave

The Quantum Computing Company™

D-Wave Founded → World's First Quantum Computer

2011

2012

1QBit Founded

1QBit

2016

IBM

Cloud Quantum Computing → Falcon 27 Qubits → Eagle 127 Qubits → Osprey 433 Qubits

2019

Quantum Supremacy

1958

2020

2021

XANADU

2022

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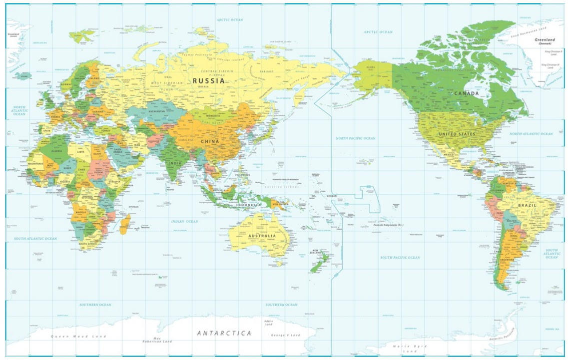
Acceleration of Investment

National quantum initiatives since 2016



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Public and private investments in quantum computing

US$ 35.5 billion
By 2022

Equity invested in quantum computing companies

US$1.3 billion
since 2018

2/3 of all quantum computing equity

2015: 42
2021: 195

World's quantum computing companies

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Quantum Computing Technologies

- Superconductors
- Trapped Ions
- Spin Systems
- Neutral Atoms
- Nitrogen Vacancy (NV) Centres
- T-Cells
- Photonic Simulators

- Error Correction
- Qubit Fidelity
- Reliability
- Scalability

- Quantum Software
- Classical to Quantum Conversion

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Quantum
Skills and Talent

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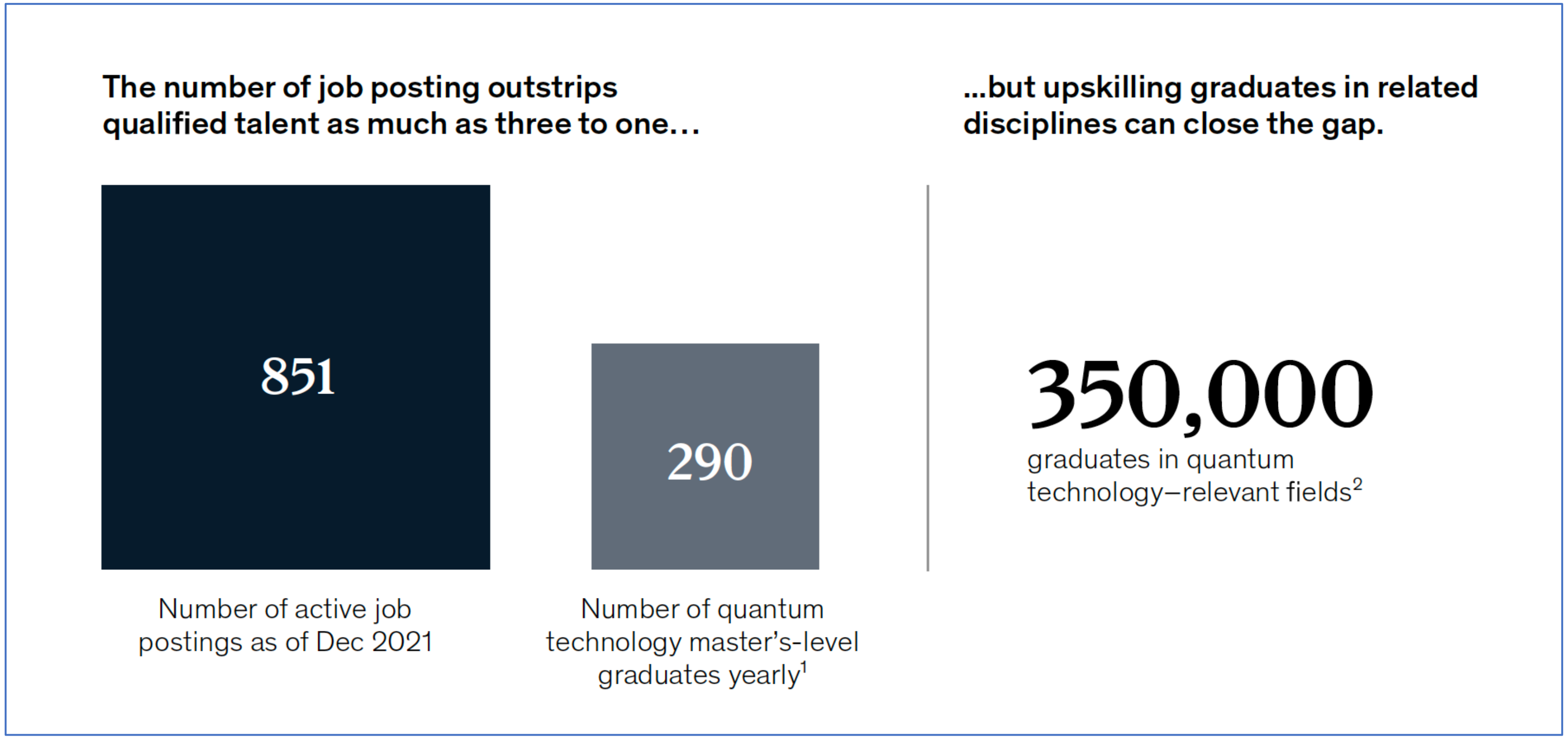
Quantum Talent Scarcity



McKinsey Data: 2021

Quantum tech relevant fields

- Math
- Stats
- Physics
- Chemistry
- Biochemistry
- Computer Science
- Engineering

Quantum research programs = 176

Quantum Masters programs = 29

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Rapid Re-Skilling

- Quantum Algorithms Institute
  - Survey of company needs
  - Professional development curriculum
  - Short courses & internships

- Pacific Institute for Mathematical Sciences
  - Math to Power Quantum
  - Short courses & internships

Longer Term STEM into Quantum

Let’s Talk Science is a national, charitable organization that motivates and empowers youth to fulfill their potential and prepare for their future careers and roles as citizens.

Let’s Talk Science supports learning and skill development using science, technology, engineering and mathematics (STEM).

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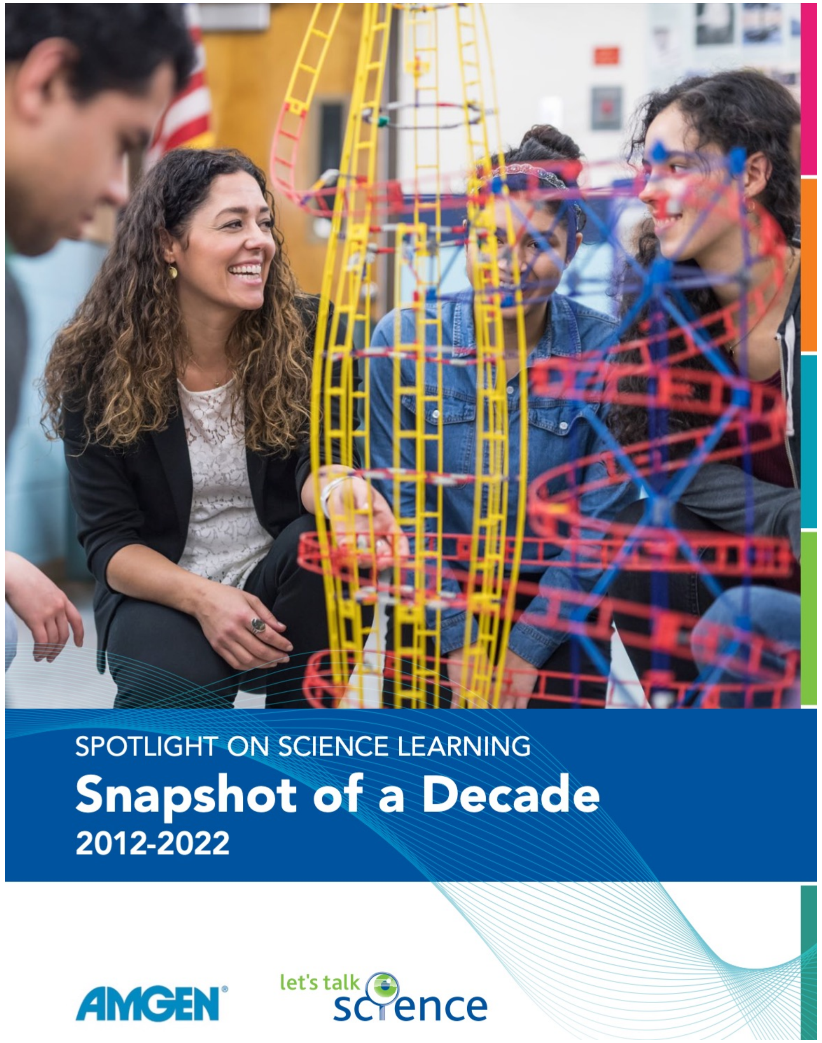
Ten Years of Research into STEM Learning



AMGEN

- Research in Partnership with AMGEN
- Consistent and practical approach to improving STEM education & outcomes

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2017 Review of Policy Recommendations

How We Teach

The strongest consensus relates to the importance of teacher education and professional development. The concern is not that teachers are poorly educated, but that too many of those who teach math and science are not specifically educated in those disciplines and in the best ways to teach them.

There is agreement that, to be successful, STEM education needs to be delivered by STEM specialists, even in the early years of education.

There is also agreement that STEM teachers need to be provided with professional learning and development opportunities, and that these opportunities must be sustained and activate collaborative learning communities among teachers within and among schools.

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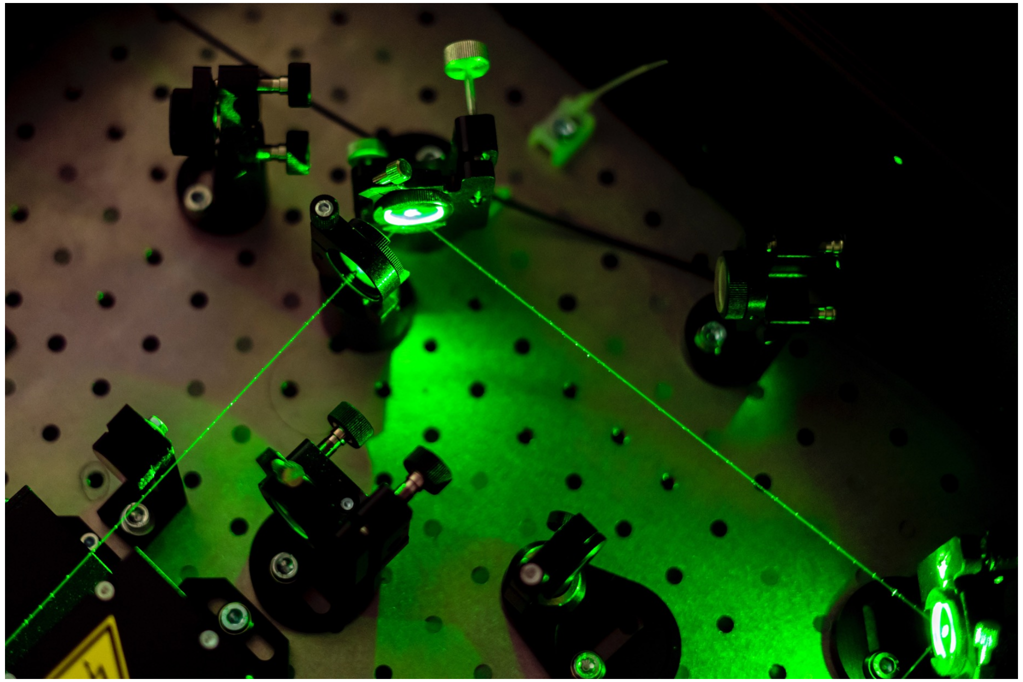
Hints and Tips from PRIMA Experts

- Teaching and Learning
  - Ideas & Experience
- Rapid Upskilling
- Longer term talent development



Things to Do

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Market Overview

- State of Quantum Computing: Building a Quantum Economy
- World Economic Forum Insight Report
  - September 2022

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QuantumAlgorithmZoo.org

Quantum Algorithm Zoo

This is a comprehensive catalog of quantum algorithms. If you notice any errors or omissions, please email me at stephen.jordan@microsoft.com. (Alternatively, you may submit a pull request to the repository on github.) Your help is appreciated and will be acknowledged.

Algebraic and Number Theoretic Algorithms

Algorithm: Factoring
Speedup: Superpolynomial
Description: Given an *n*-bit integer, find the prime factorization. The quantum algorithm of Peter Shor solves this in $\widetilde{O}(n^3)$ time [82,125]. The fastest known classical algorithm for integer factorization is the general number field sieve, which is believed to run in time $2^{\widetilde{O}(n^{1/3})}$. The best rigorously proven upper bound on the classical complexity of factoring is $O(2^{n/4+o(1)})$ via the Pollard-Strassen algorithm [252, 362]. Shor's factoring algorithm breaks RSA public-key encryption and the closely related quantum algorithms for discrete logarithms break the DSA and ECDSA digital signature schemes and the Diffie-Hellman key-exchange protocol. A quantum algorithm even faster than Shor's for the special case of factoring “semiprimes”, which are widely used in cryptography, is given in [271]. If small factors exist, Shor's algorithm can be beaten by a quantum algorithm using Grover search to speed up the elliptic curve factorization method [366]. Additional optimized versions of Shor's algorithm are given in [384, 386, 431]. There are proposed classical public-key cryptosystems not believed to be broken by quantum algorithms, *cf.* [248]. At the core of Shor's factoring algorithm is order finding, which can be reduced to the Abelian hidden subgroup problem, which is solved using the quantum Fourier transform. A number of other problems are known to reduce to integer factorization including the membership problem for matrix groups over fields of odd order [253], and certain diophantine problems relevant to the synthesis of quantum circuits [254].

Algorithm: Discrete-log
Speedup: Superpolynomial
Description: We are given three *n*-bit numbers *a*, *b*, and *N*, with the promise that $b = a^s \mod N$ for some *s*. The task is to find *s*. As shown by Shor [82], this can be achieved on a quantum

Navigation

Translations

This page has been translated into:
Japanese
Chinese

Other Surveys

For overviews of quantum algorithms I recommend:

Nielsen and Chuang
Childs
Preskill
Mosca
Childs and van Dam
van Dam and Sasaki
Bacon and van Dam
Montanaro
Hidary

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Pacific Institute for Mathematical Sciences

https://www.pims.math.ca

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- For future newsletters
- Applied research projects & opportunities
- Internship opportunities for undergrad and grad students
- Academic Affiliate programs
- Collaboration on quantum curriculum development & education

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Questions or Comments?

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