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Dissertation Awards Presentation

Christian Reimer

Acknowledgements

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EDUCATE. INSPIRE. CONNECT. SINCE 1951
LINDAU
NOBEL LAUREATE
MEETINGS

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Vanier
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How do I know if a research project is worth pursuing?

Are you excited about the project?

Is the impact of a successful project significant?

Are the individual steps to the final goal worth doing?

Are you willing to dedicate a significant part of your life to this problem?

These are very difficult questions to answer…

Focus on critical thinking, self-guided learning and independence

Become the expert in the field, and believe in your judgment

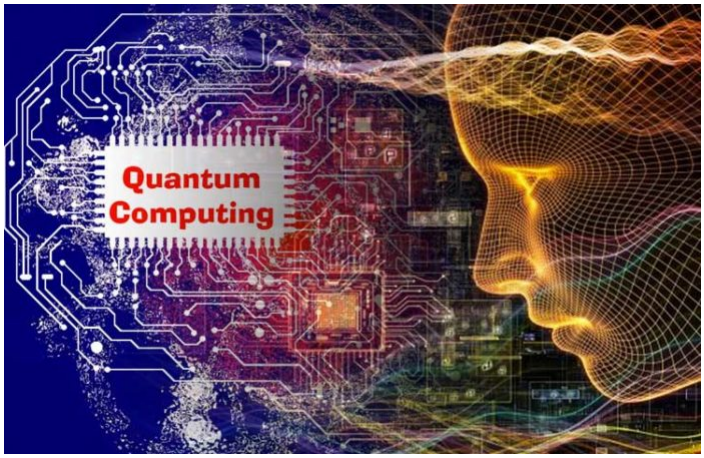
”Guided independence” vs. close scientific supervision

Find trusted mentors and collaborators (outside your group)

Choose a team based on personality, vision and enthusiasm

How do I know if a research project is worth pursuing?

The field I chose to work in: On-chip photonics and optical quantum computing

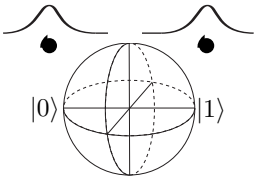


Why is a quantum computer so different?

Classical bit

0 1

Quantum bit

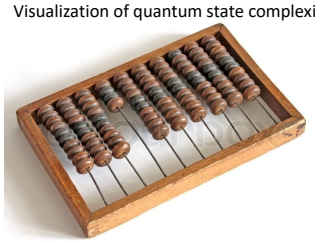


$$|\psi\rangle = a\,|0\rangle + b\,|1\rangle$$

How powerful can a quantum computer be?

Computation power scales with the quantum state size, which scales with 2^N

Visualization of quantum state complexity:



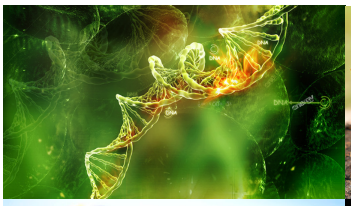
3 qubits

30 qubits

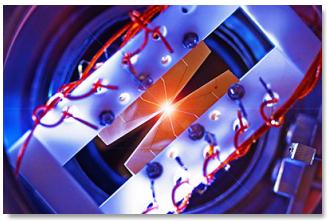
300 qubits

What could we do with a quantum computer?

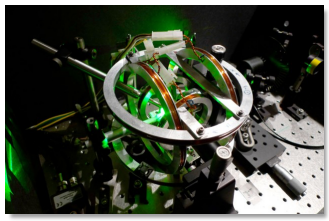
…
Simulate biology
…
Design fertilizers
…
Custom medication
…
Secure encryption
…
Forecast finance
…
Predict disasters
…



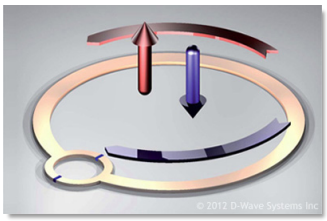
A quantum computer needs a quantum platform



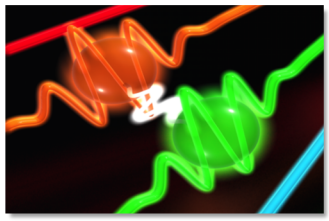
Ultra cold atoms and ions



Electron spins



Superconducting systems



Photons

How far are we with building a quantum computer?

Superconducting Quantum Computer

- Require 0.014 K temperature (Space is 2.7 K)
- Best systems currently around 50 qubits
- 14 qubit computer open to public at “IBM Q”

Trapped Atoms Quantum Computer

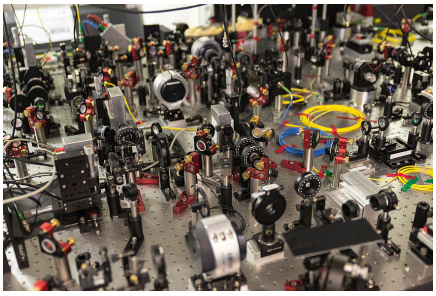
- Require ultra-high vacuum and low temp.
- Around 50 atoms in quantum simulators

Optical Quantum Computer

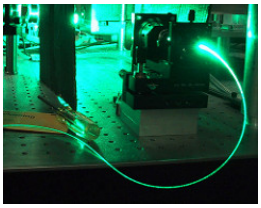
- Only quantum system working at room temp.
- Around 10 photons
- Thousands of entangled modes

Making optics more compact with fibers and chips

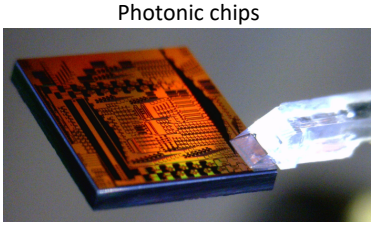
Typical free-space optical setup



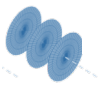
Optical fibers



Photonic chips

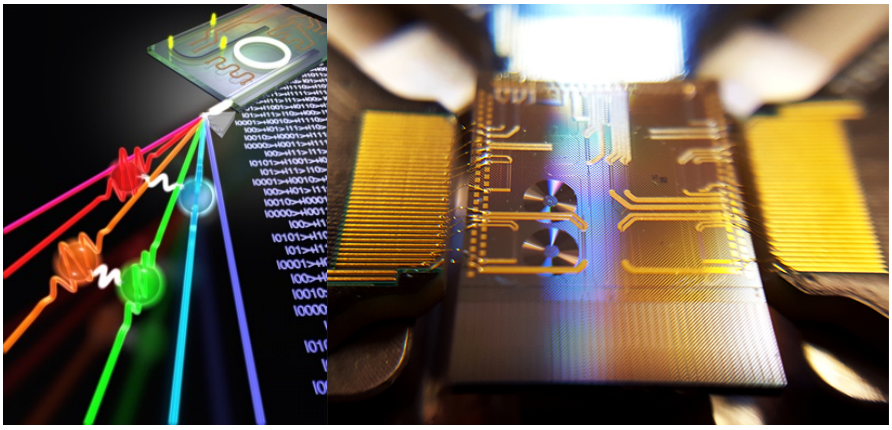


Time and frequency are good quantum resources for chips

	Position/Path	Polarization	OAM	Time / Frequency
$\|0\rangle$				
$\|1\rangle$				
Chip compatible:	✓	■	✗	✓
High-dimensional:	✓	✗	✓	✓
Multi-photon:	■	✓	✓	✓
Complexity scaling:	✗	✓	✗	✓

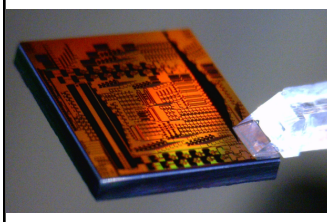
The main idea of my PhD studies…

Generate an optical frequency comb on a photonic chip
and entangle the frequency modes to form large quantum states



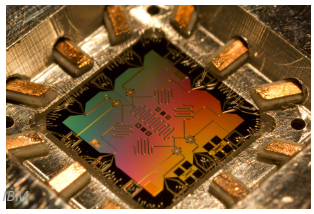
Successful proof-of-concept realizations

Quantum Sources



Chip entanglement source
- Multi-photon entanglement (Science 2016)
- High-D entanglement (Nature 2017)

Quantum computing



Quantum computer on a chip
- QuDit quantum computer (Nature Physics 2018)

Quantum internet

Quantum key distribution
- 24 and 40 km transmission (Science 2016, Nature 2017)