Networked Quantum Information Technologies(NQIT)

PI and Director Ian Walmsley

Co-director User engagement Evert Geurtsen

Co-director Systems integration Dominic O'Brien

UK National Quantum Technologies Programme

- A five-year £270M programme announced by the UK government in the 2013 Autumn statement.
- Programme started October 2014.
- To exploit the potential of quantum science and develop a portfolio of emerging technologies with the potential to benefit the UK.
- Industry, government and academia working together to create opportunities for UK wealth creation.

Department for Business Innovation & Skills
EPSRC Pioneering research and skills
Innovate UK Technology Strategy Board
Knowledge Transfer Network
[dstl]
NPL National Physical Laboratory
CESG

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UK National Quantum Technologies Hub Network

- £120 million investment in four hubs to explore the properties of quantum mechanics and how they can be harnessed for use in technology
- Hubs
  - Sensors and Metrology (Birmingham)
  - Quantum enhanced imaging (Glasgow)
  - Communications (York)
  - Computing (Oxford)

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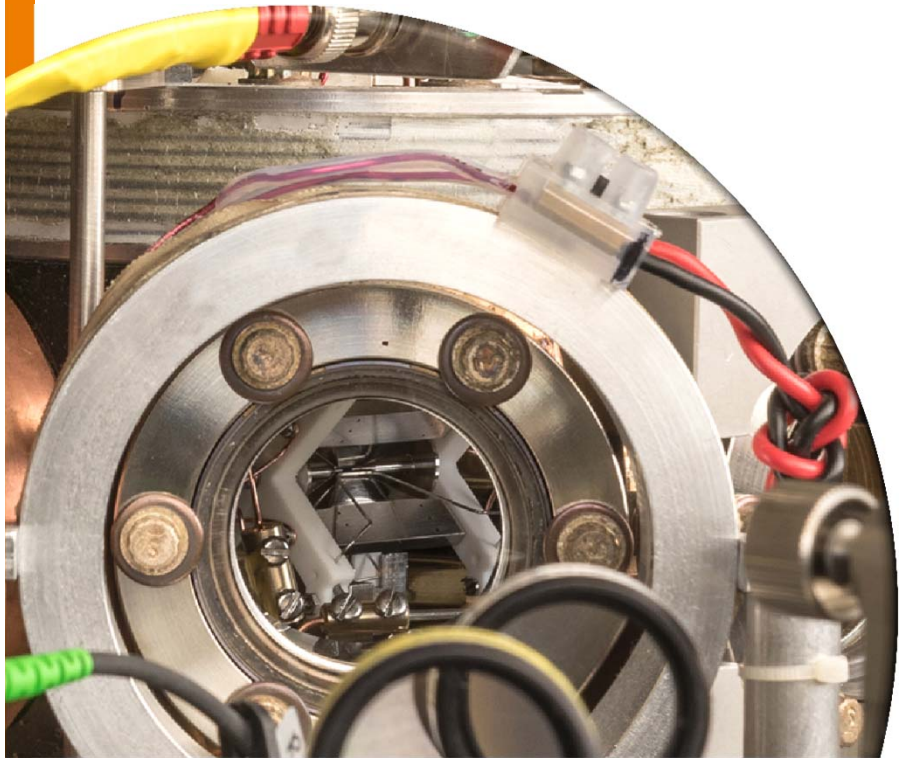
Quantum Technologies



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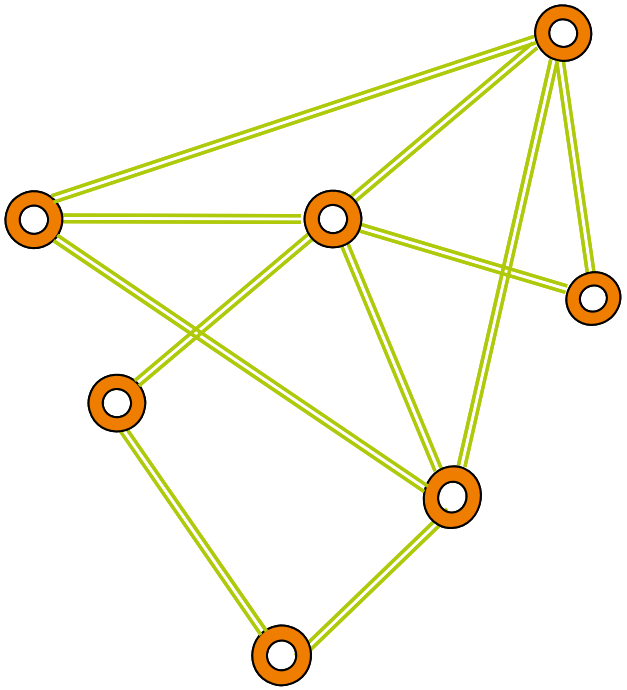
NQIT Approach: Quantum Networks

Networks consist of ***nodes*** and ***channels***



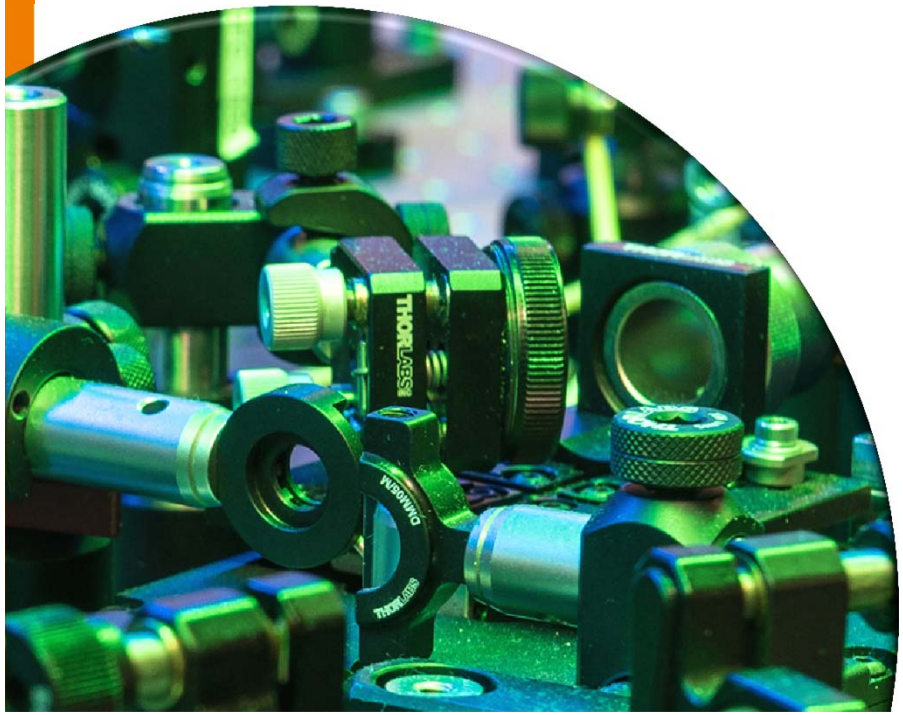
- ***Nodes*** have processing capability
- ***Channels*** have communication capability
- ***Pathways*** are reconfigurable
- ***Elements*** are replaceable

Quantum networks deliver

- Sensor arrays
- Universal communications
- Computation & simulation

Photonic links between matter-based nodes; a ***light-matter hybrid network*** is a strong candidate for long-distance networks

NQIT Research & Technology



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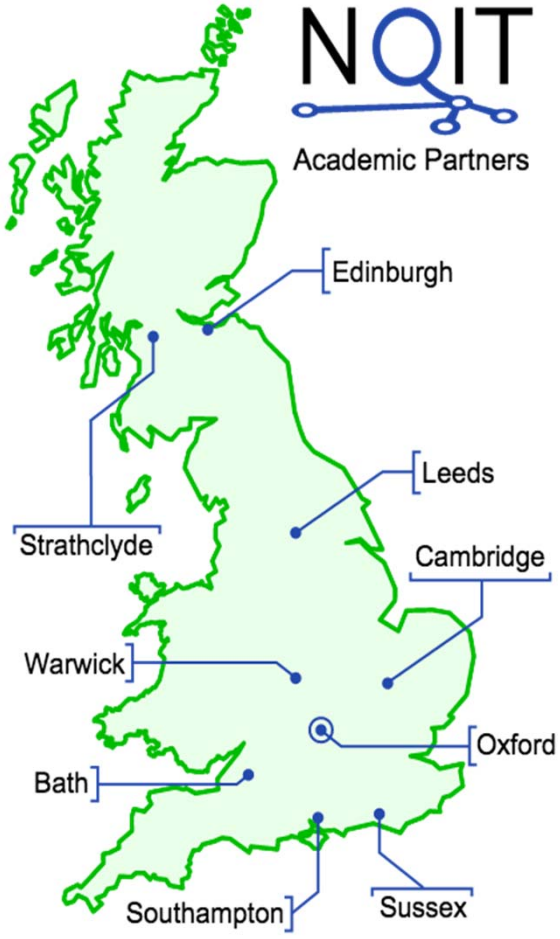
EPSRC



THE UNIVERSITY of EDINBURGH

UNIVERSITY OF LEEDS

University of Strathclyde Glasgow

UNIVERSITY OF CAMBRIDGE

WARWICK

UNIVERSITY OF OXFORD

UNIVERSITY OF BATH

US UNIVERSITY OF SUSSEX

UNIVERSITY OF Southampton

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elementsix
a De Beers Group Company

covesion

CATAPULT
Satellite Applications

ASPEN
INCORPORATING
ADMIRAL

OXFORD INSTRUMENTS
The Business of Science®

OXFORD CAPITAL

CQT
Centre for Quantum Technologies
National University of Singapore

TOSHIBA
Leading Innovation

Google

NPL
National Physical Laboratory

Raytheon

Fraunhofer
UK

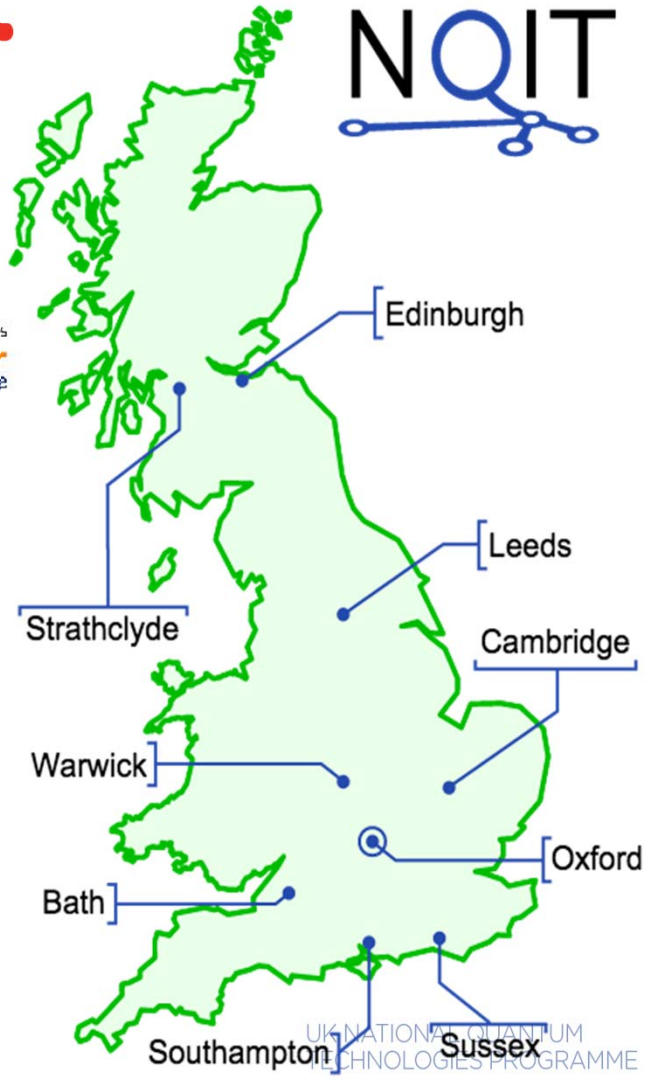
ROHDE&SCHWARZ

M SQUARED

ETSI
World Class Standards

LOCKHEED MARTIN

And many more…



A COMPUTER USING IONS

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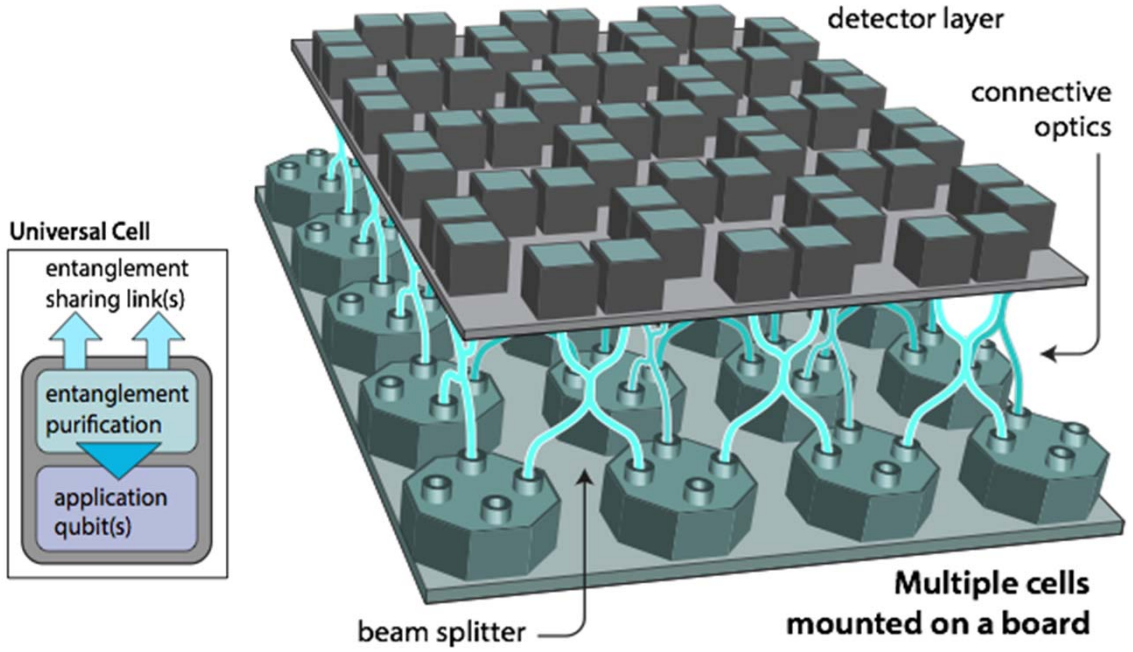
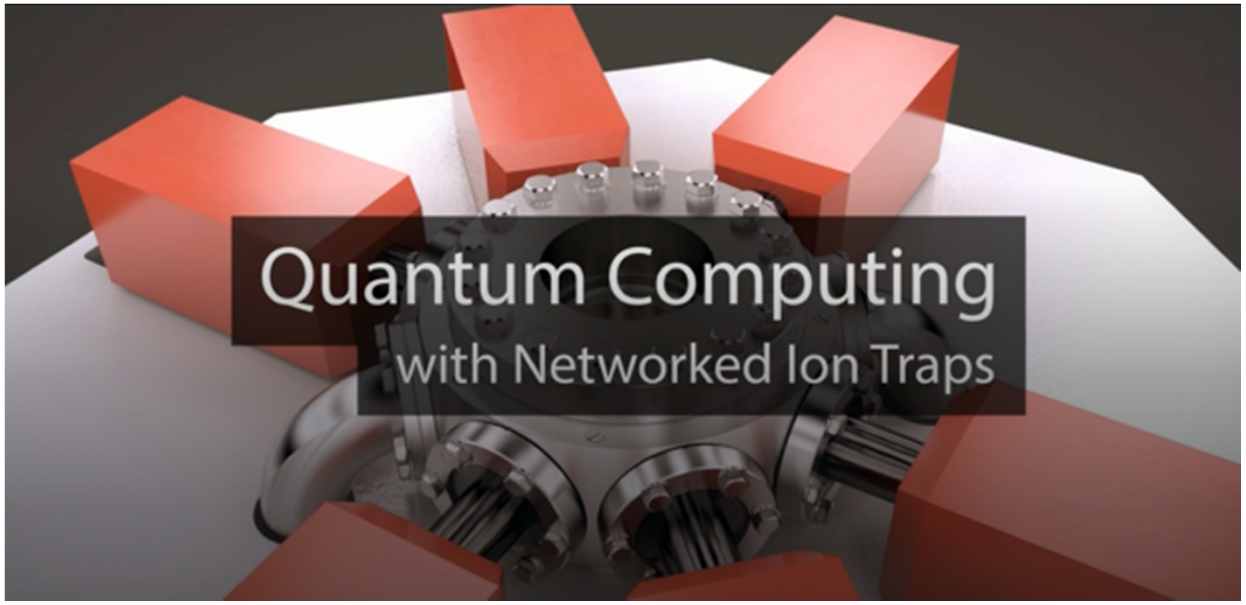
Q20:20 Engine

Optically linked array of 20 cells…



How do we scale the system?



See : https://youtu.be/b7EJKhigjU8

HOW TO ENGINEER THE SYSTEM

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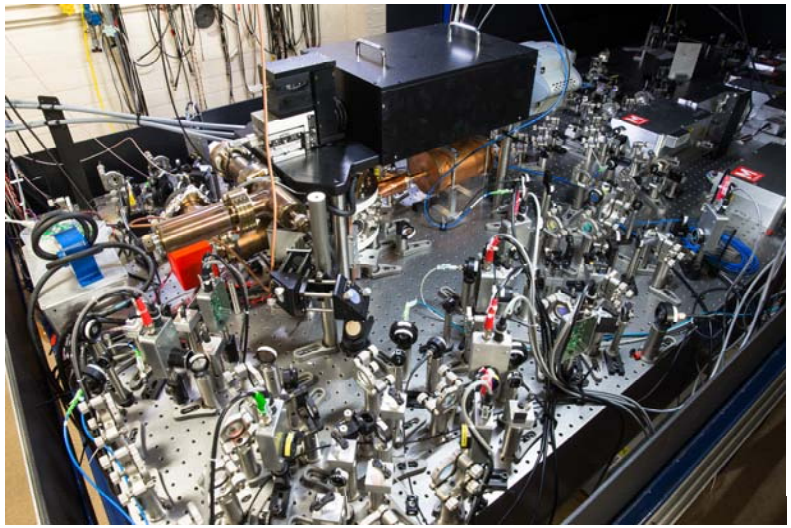
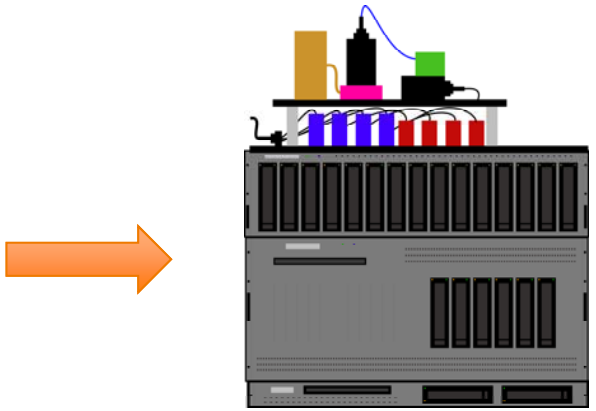
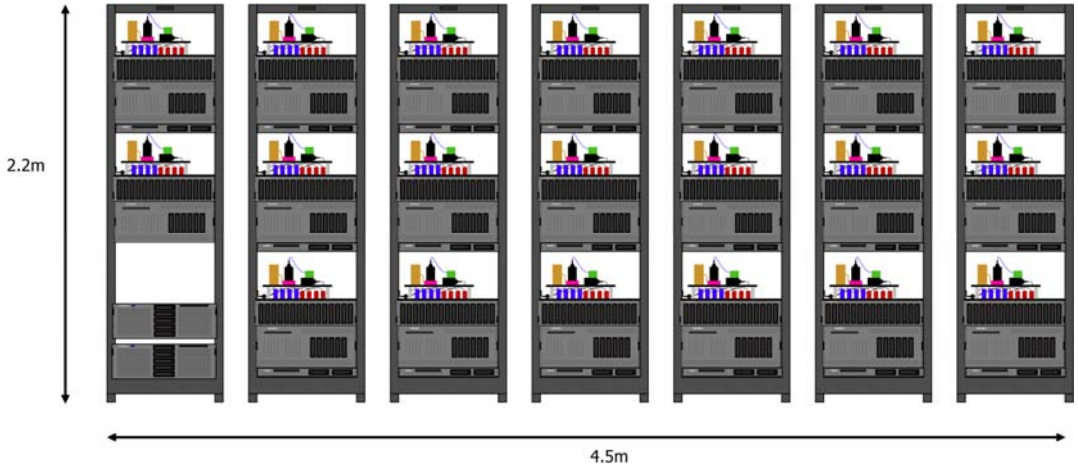
Q2020: the challenge







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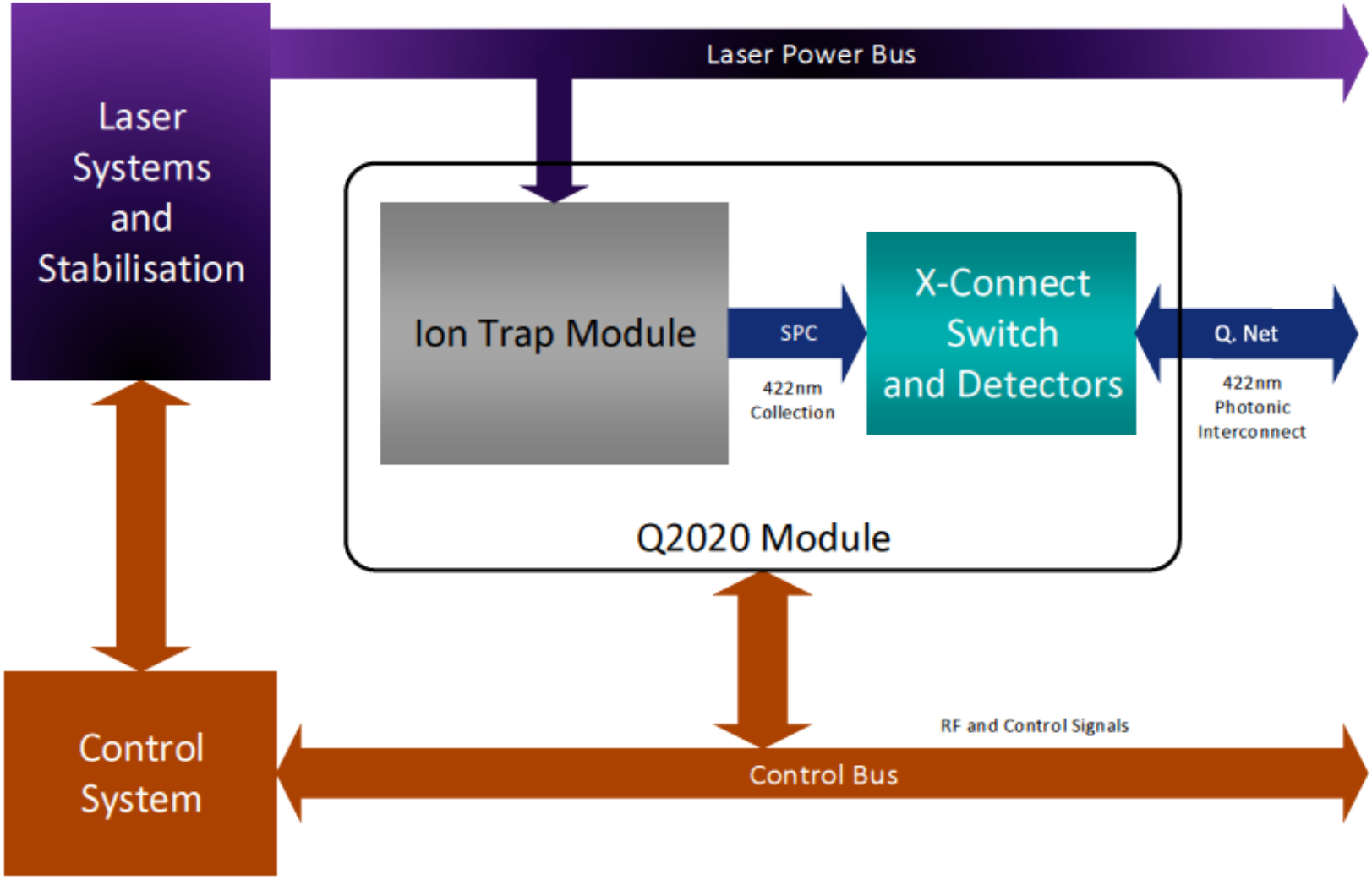
Q20:20 module overview



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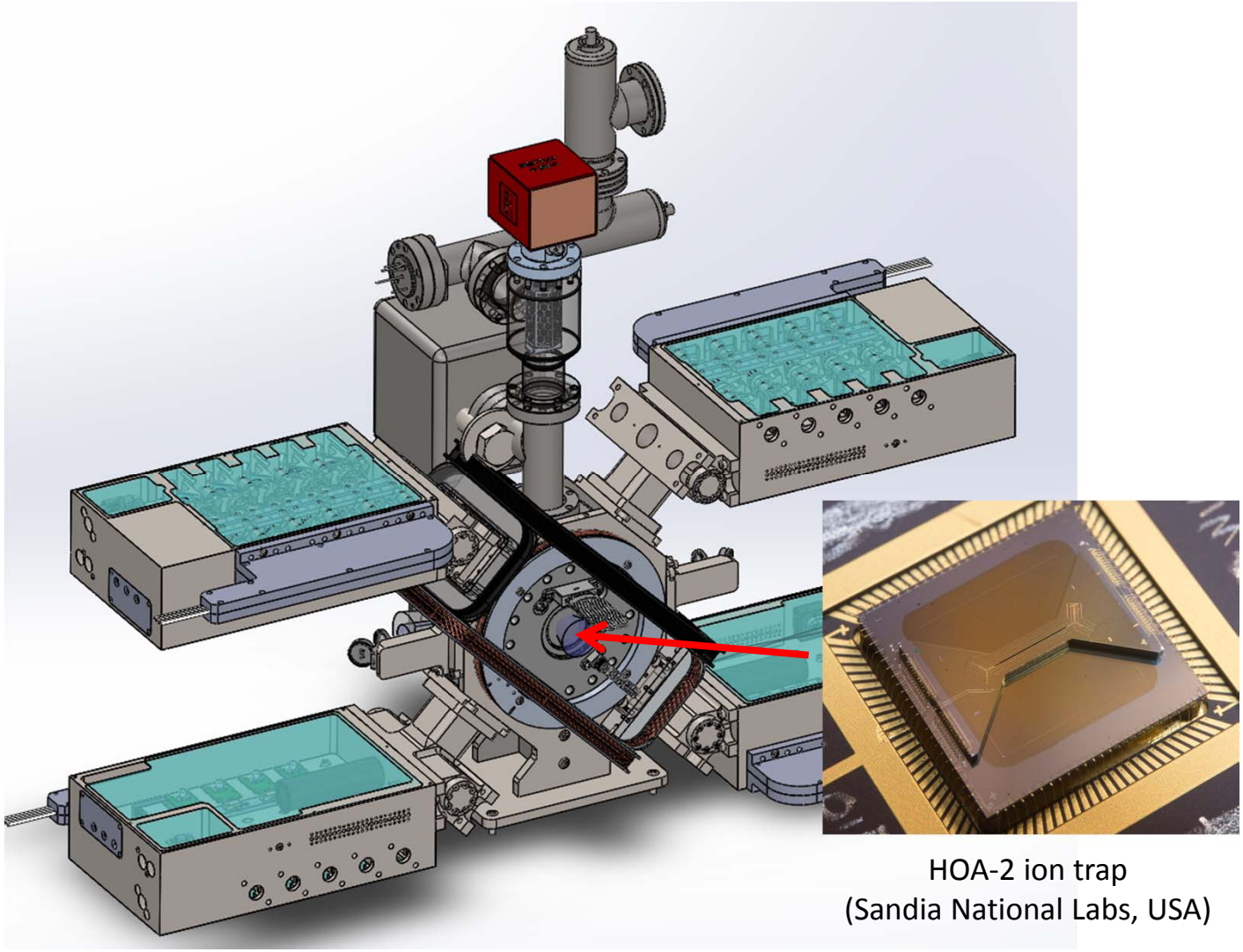
Systems integration: engineered nodes



HOA-2 ion trap
(Sandia National Labs, USA)

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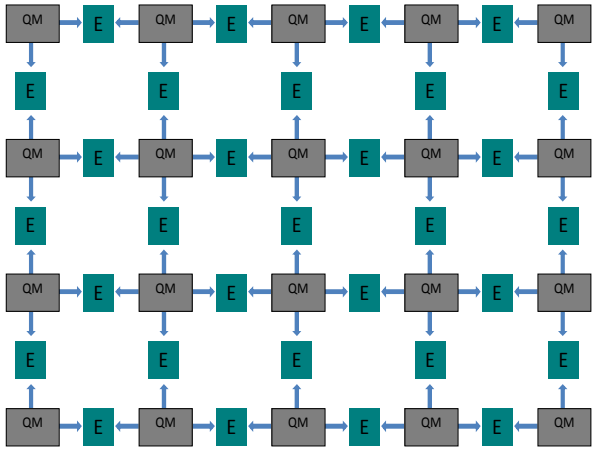
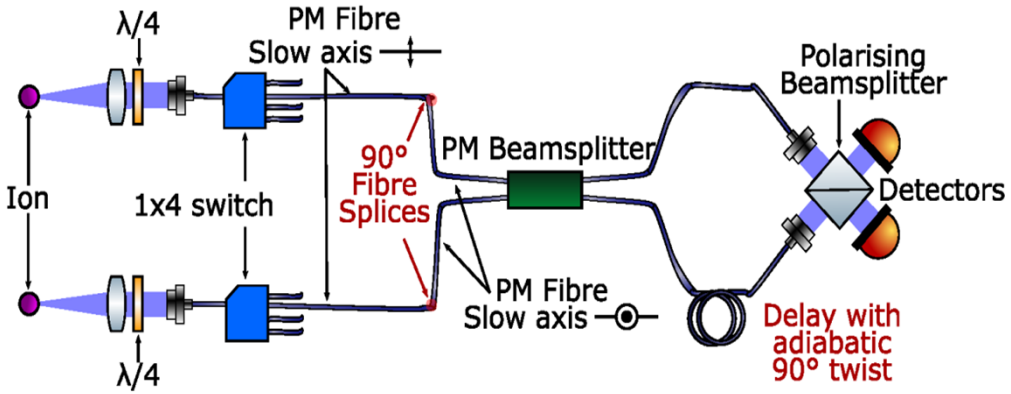
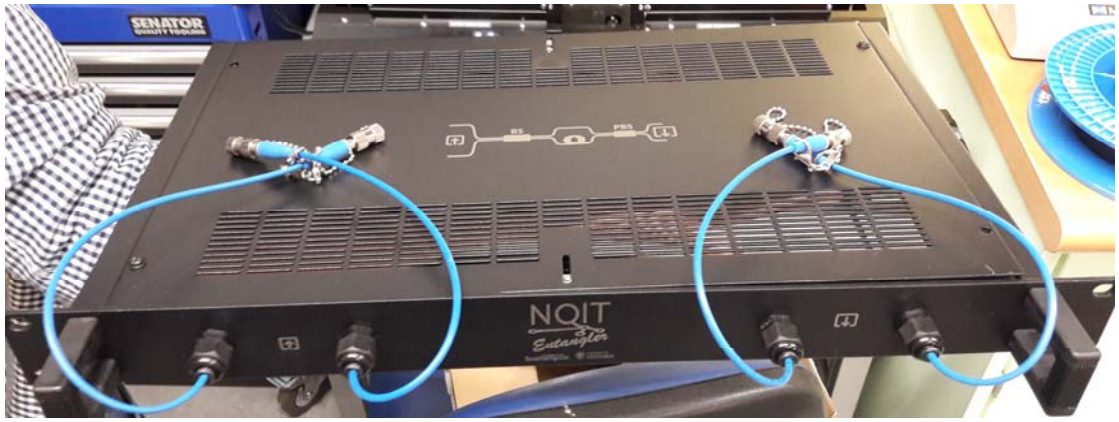
Systems integration: entanglers



Architecture



Detail

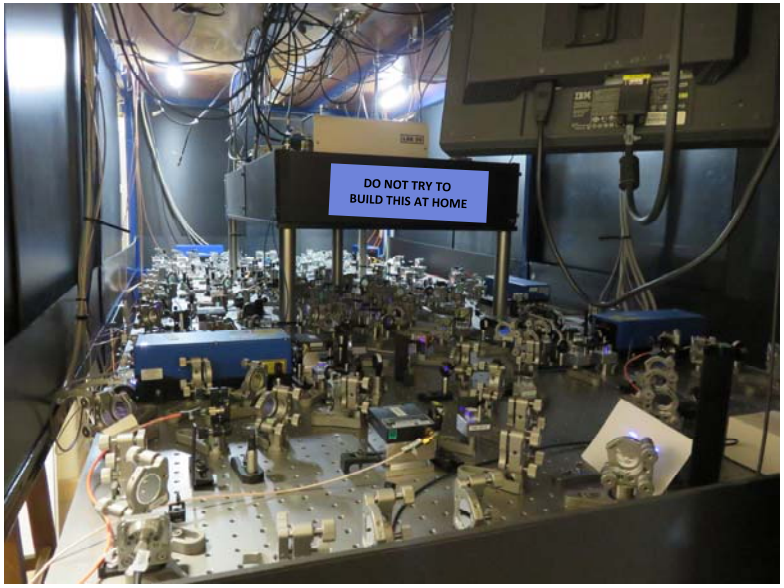


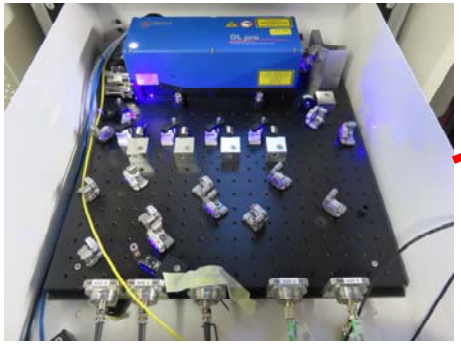
Implementation

WP1: “engineered” laser systems

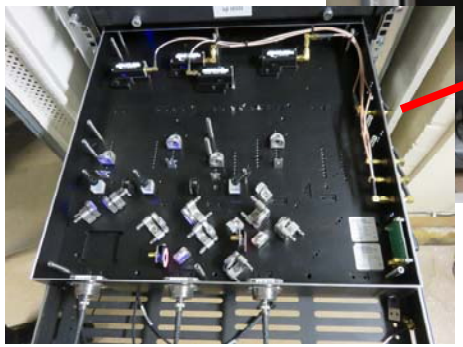
OLD: “traditional” optical table laser setup (Ca^+)

NEW: rackmount laser system (Sr^+)





laser subsystem



AOM subsystem

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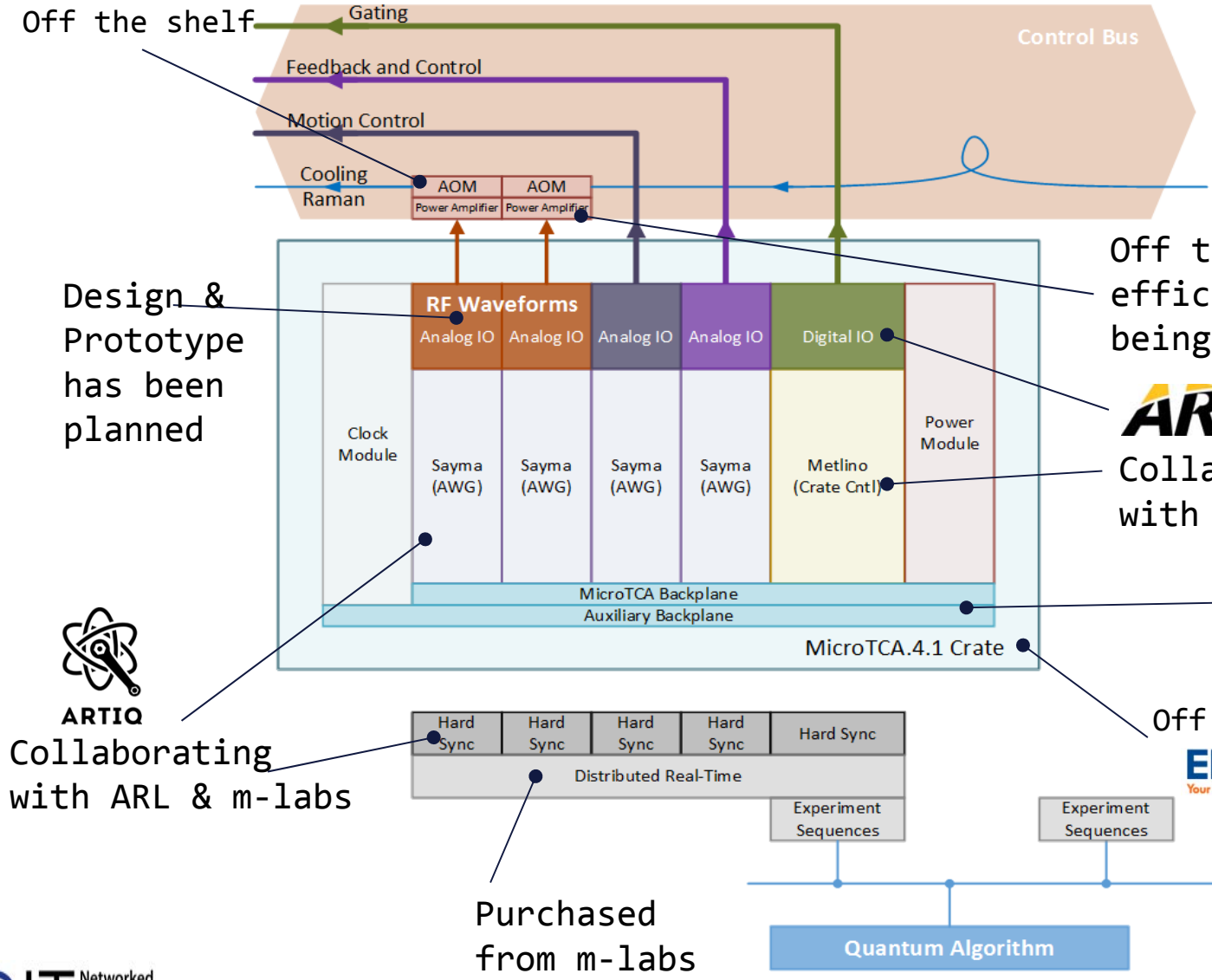
Systems integration: control



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ALTERNATIVE NODES (QUBITS)

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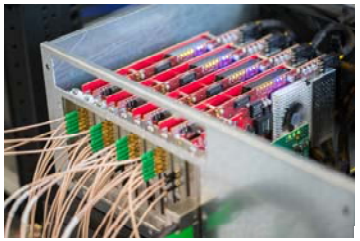
Superconducting Qubits

- New coaxial circuit architecture demonstrated
- 1- and 2-qubit circuits measured
- Coherence times ~ 10 µs
- Single qubit gate fidelities ~99.5%
- Two-qubit gates under development
- New spin-out - Oxford Quantum Circuits Limited

Experimental facilities



High-speed addressing electronics

Rahamim et al., APL 110, 222602 (2017)
International patent application WO2017021714A1 (2017)

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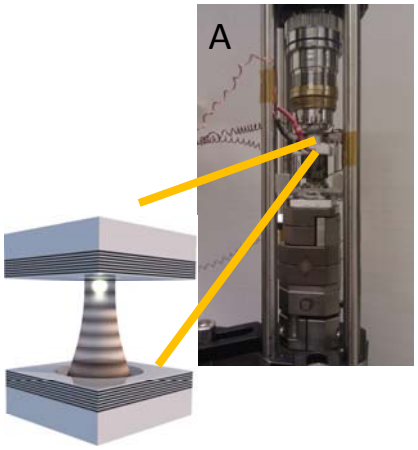
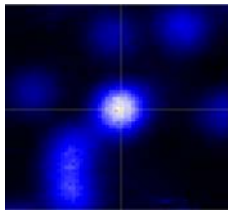
Diamond colour centres (NV- and SiV-)

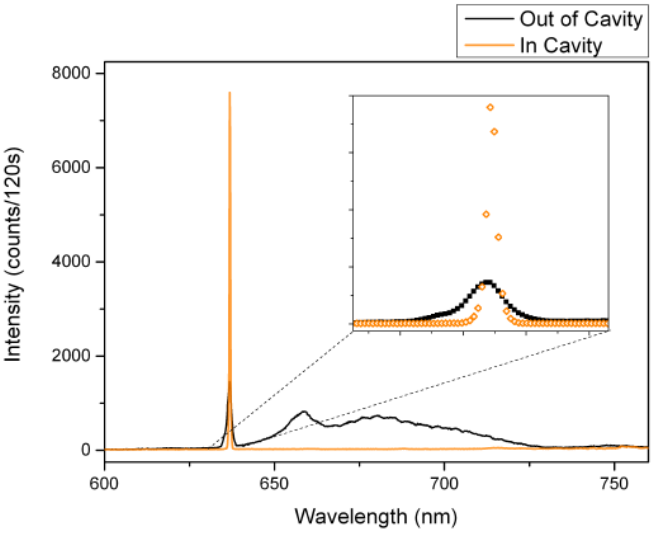
- nm precision fabrication of open cavities
- Low T coupling to single NV emission from nanodiamond



Cryogenic cavity coupling apparatus



Implanted NV-defects



Effect of cavity coupling on NV emission

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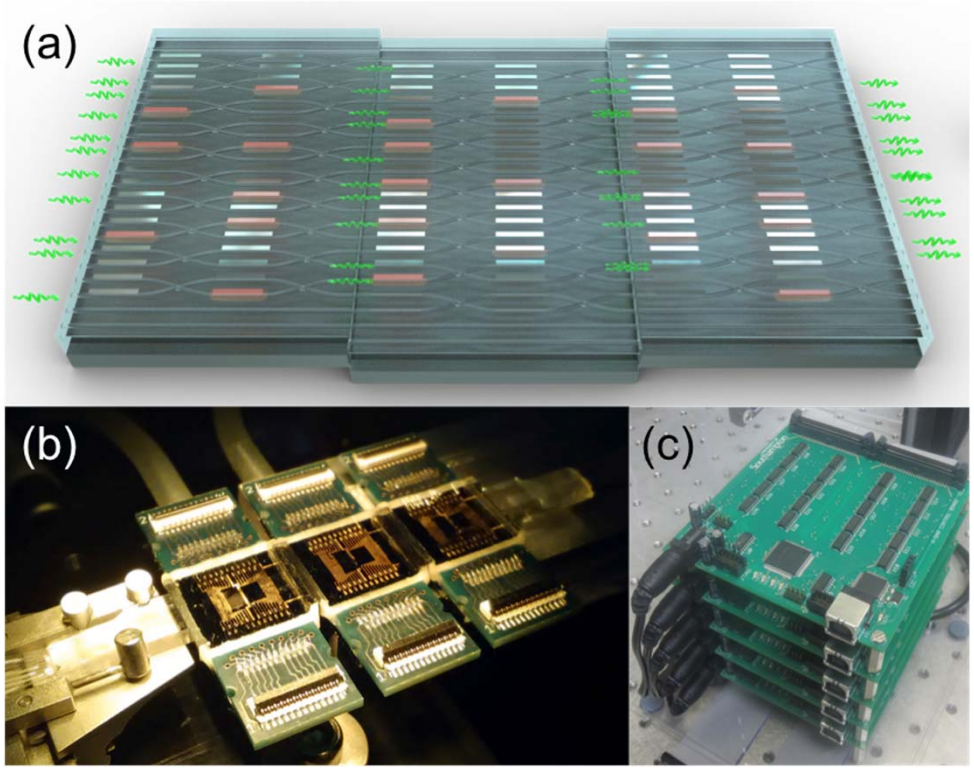
Photonics

- Modular waveguide chips for quantum photonics



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APPLICATIONS

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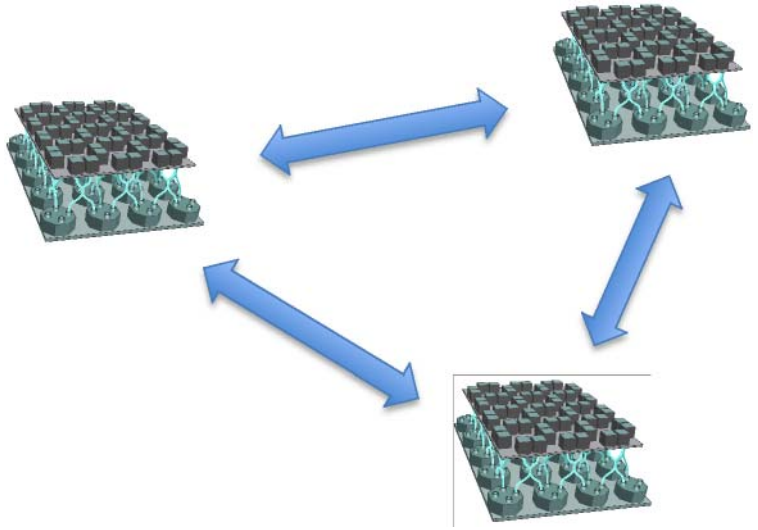
Secure communications and verification

- A prototype quantum internet.
- Cryptographic protocols on networks:
  - Distribution of a secure key.
  - Generation of trusted randomness.
- Secure multi--party computation.
- Design device--independent protocols.
  - Quantum entanglement between nodes enables security even when honest users do not trust their quantum devices.
- Protocols and security proofs tailored to the NQIT hardware.



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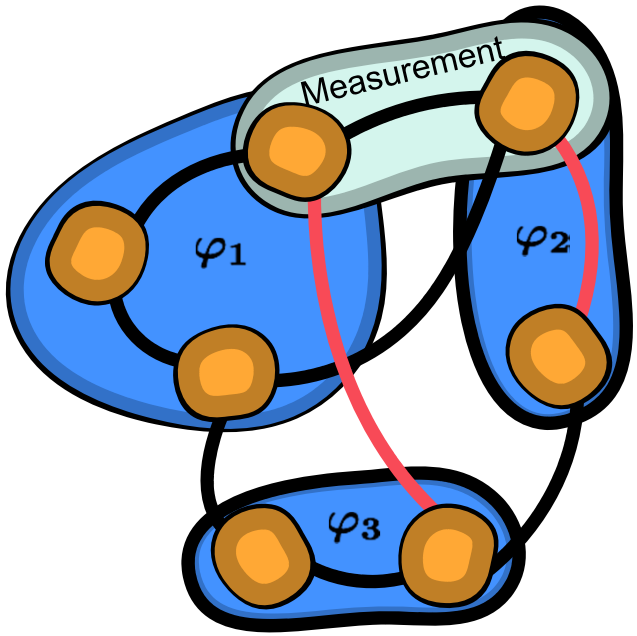
UNIVERSITY OF OXFORD DEPARTMENT OF COMPUTER SCIENCE

THE UNIVERSITY OF EDINBURGH UK NAT… TECHN… …AMME

Networked Quantum Sensors

- Exploit quantum correlations to enable enhanced precision
- Understanding the role of inter and intra-mode correlations in networked sensors.
- With limited or restricted measurements (e.g., inaccessible nodes).
- In the presence of adversarial intervention or inadvertent noise.
- What are the security and information transfer rates through the network, e.g., with damaged links (shown in red)?



Simultaneous estimation of multiple parameters: $\varphi_1, \varphi_2, \ldots$

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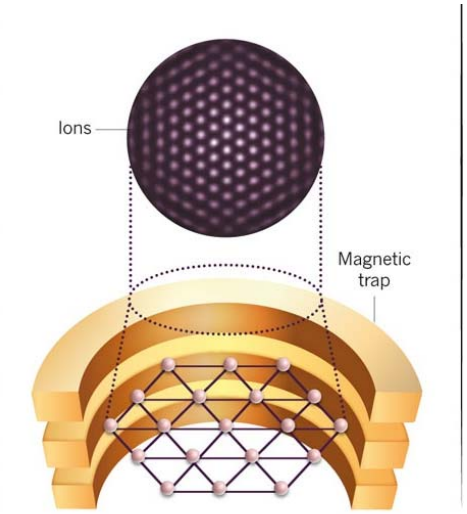
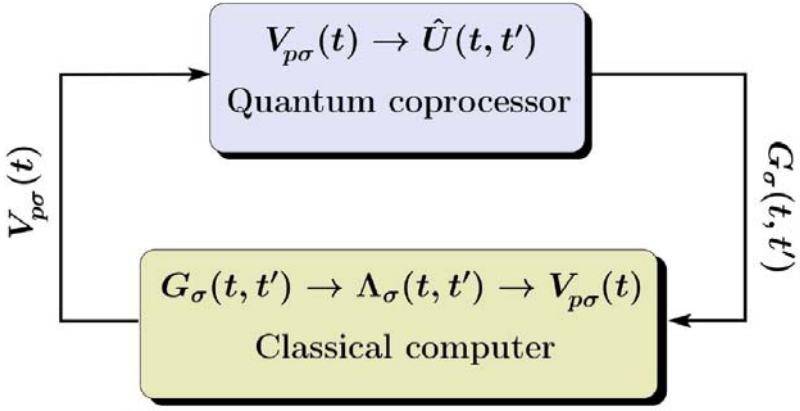
Quantum Enabled Discovery

- Materials systems well-suited to modelling using quantum systems
  - Superconductors





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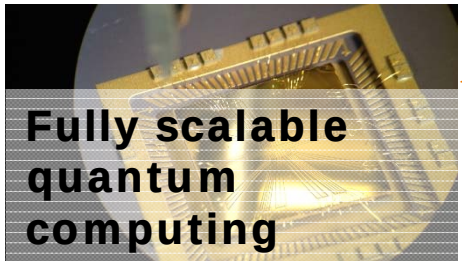
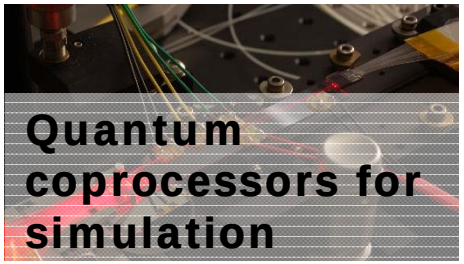
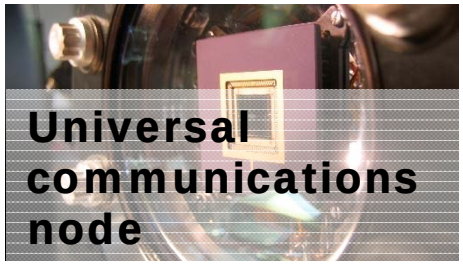
Quantum/classical emulation and interfacing
The Quantum Computing Stack

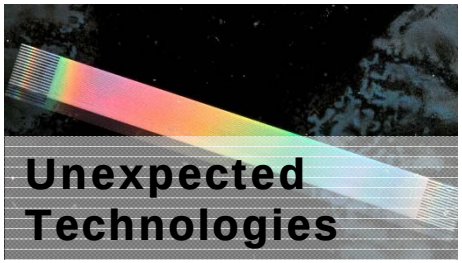
- provide a platform for development and testing of quantum algorithms and protocols
- Quantum network compiler
  - providing front-end tools for NQIT hardware with a sound theoretical basis
- Software Quantum Emulator
  - Tools for algorithm testing focused on NQIT hardware

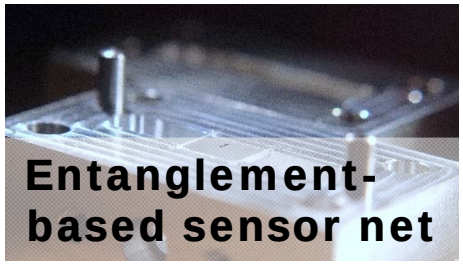
The path to quantum computing

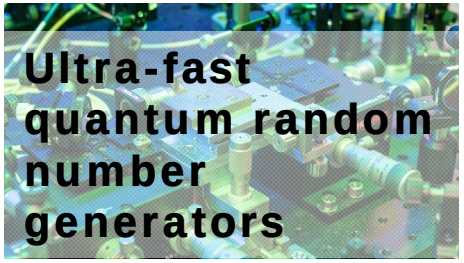


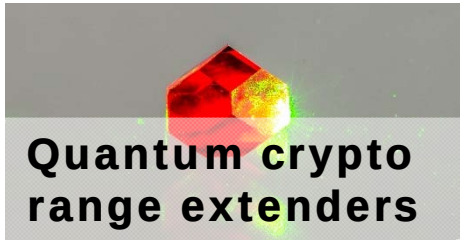


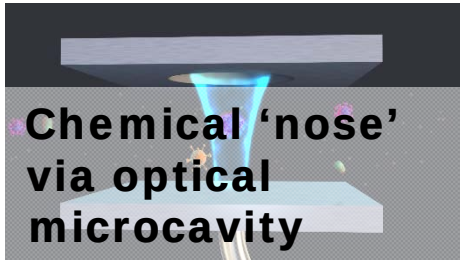












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