UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Quantum Computing & Materials

WORKING WITH DEFENCE

About UTS

The University of Technology Sydney (UTS) is one of Australia's leading universities, delivering research solutions and new technologies to the Defence and Aerospace industries. Our researchers work closely with Australia's Defence Science and Technology Group (DSTG), Australian Defence Force, Office of National Intelligence, U.S. Department of Defense, international Primes and local small-to-medium enterprises. We're proud to host the NSW Defence Innovation Network and co-host the NSW Space Research Network.

Quantum Computing

Our Centre for Quantum Software and Information (QSI) is a world-leading institution for quantum information and software research with 12 core members, four honorary members, seven post-docs, and over 35 postgraduate students. We publish top-tier research papers, with over 390 research outputs between 2015 to 2020; attracting more than 19 Australian Research Council grants (worth over AU$13M and giving 20 Quantum Information Processing (QIP) talks (third behind Caltech and MIT). QSI partners include U.S. Department of Defense Multidisciplinary University Research Initiative (MURI), Google, HRL Laboratories, Boeing, Zapata, Rigetti, Japanese Moonshot program, Lockheed Martin, U.S. Office of Naval Research, the E.U. Quantum Internet Alliance, Australian Defence Science and Technology Group (DSTG), and many more. Our hardware team focuses on developing tools and techniques critical for superconducting circuit-based quantum information science in our state-of-the-art Millikelvin Quantum Science lab.

Quantum Materials

We have expertise in modelling and spectroscopy of composite and nano/micro-structured materials including the design and numerical modelling (finite-difference time-domain, finite element method, semi-analytical) as well as coherent optical spectroscopy (linear and nonlinear optical response). We undertake synthesis of quantum materials such as diamond and hexagonal boron nitride (hBN) using chemical vapour deposition. We also specialise in site-specific engineering of single photon emitters and spin defects in these materials using electron and ion beam nanofabrication techniques. We have been working on the incorporation of the emitters/defects in photonic nanostructures such as optical resonators/cavities and waveguides, which we fabricate using electron beam lithography and reactive ion etching techniques.

Capabilities

- **Quantum algorithms and complexity**
  Enriching the quantum algorithm toolbox and bridging computational complexity theory techniques.
- **Quantum programming theory**
  Advancing formal methods and automatic tools for verification of quantum programs and cryptographic protocols.
- **Fault tolerant architecture design**
  Developing architectures to achieve large-scale fault tolerant quantum computation.
- **Quantum control and characterisation**
  Advancing techniques for precise control and measurement of quantum systems to facilitate scalable and reliable quantum computing.
- **Quantum hardware**
  Designing state-of-the-art hardware fabrication and experimental control techniques critical to the realisation of practical at-scale quantum technologies.
- **Quantum key distribution**
  We employ single photon emitters as light sources in quantum key distribution, and spin defects (such as boron vacancies in hBN and nitrogen-vacancy centres in diamond) for quantum sensing.

Some of our Defence projects

DARPA Quantum Benchmarking program

We have partnered with the US Defense Advanced Research Projects Agency (DARPA) to qualitatively assess the performance of quantum computing algorithms and applications at scale. We are working to develop new benchmarks that measure progress towards specific computational challenges and estimate the hardware-specific resources required to achieve performance. We are collaborating with global companies such as HRL Laboratories, Boeing and General Motors, and quantum technology companies including Zapata Computing, Rigetti Computing, and IonQ, with the goal of creating the de-facto standard framework in quantum performance analytics. Developing quantum yardsticks will guide progress towards building large, fault-tolerant quantum computers with revolutionary potential. Our researchers are developing the BenchQ software suite for this purpose with the University of Southern California, University of Texas at Dallas, Aalto University in Finland, and Zapata Computing.

Quantum Control Based on Real-Time Environment Analysis by Spectator Qubits

This AUSMURI project under the Next Generation Technologies Fund, led by Defence Science and Technology Group (DSTG), offers near-term work on quantum error correction and quantum software related to quantum control. In the first phase, researchers have successfully demonstrated that the spectator qubit paradigm is viable. By using the novel spectator paradigm to create greater control over qubits, the project is a step towards revolutionising the way we process and store information and may create knowledge that one day enables error-tolerant quantum computers.

Precision tomography of a three-qubit donor quantum processor in silicon

This UTS-UNSW consortium created under AUSMURI has established a viable route for scalable quantum information processing using donor nuclear and electron spins, proving the feasibility of near error-free quantum computing by building silicon-based devices compatible with current semiconductor manufacturing technology. The performance of quantum processors was verified using gate set tomography, a method developed at Sandia National Laboratories in the US and applied by QSI tomography expert A/Prof Christopher Ferrie in this study.

Defence acquisition optimisation using quantum algorithms

This NSW Defence Innovation Network research project draws upon our world-leading research in quantum optimisation algorithms to determine the viability of quantum algorithms run on both near-term faulty and long-term fault-tolerant quantum computers. The goal is to provide a speed up over classical algorithms for the quadratic knapsack problem (QKP) with applications to defence acquisition. Defence capability planning can be encoded as a QKP problem. Efficient quantum algorithms for this problem could provide a rapid and accurate method to select the programs to maximise defence capability within the fixed budget. The developed algorithm will have potential applications to several defence optimisation problems, such as the distribution of sensors and radars and communication problems.

Quantum sensing using spin defects in wide bandgap materials

With funding from U.S. defence agencies and the ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS), we have been working on the sensing of electron and magnetic fields, temperature and strain using spin defects in wide bandgap materials.

Quantum Key Distribution (QKD)

With funding from NSW Defence Innovation Network and the ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS), we have developed a prototype for building-to-building QKD and underwater QKD using single photon emitters in hBN.

Contact us

For more information on our Defence and Space capabilities visit: **uts.edu.au/defence-space**

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