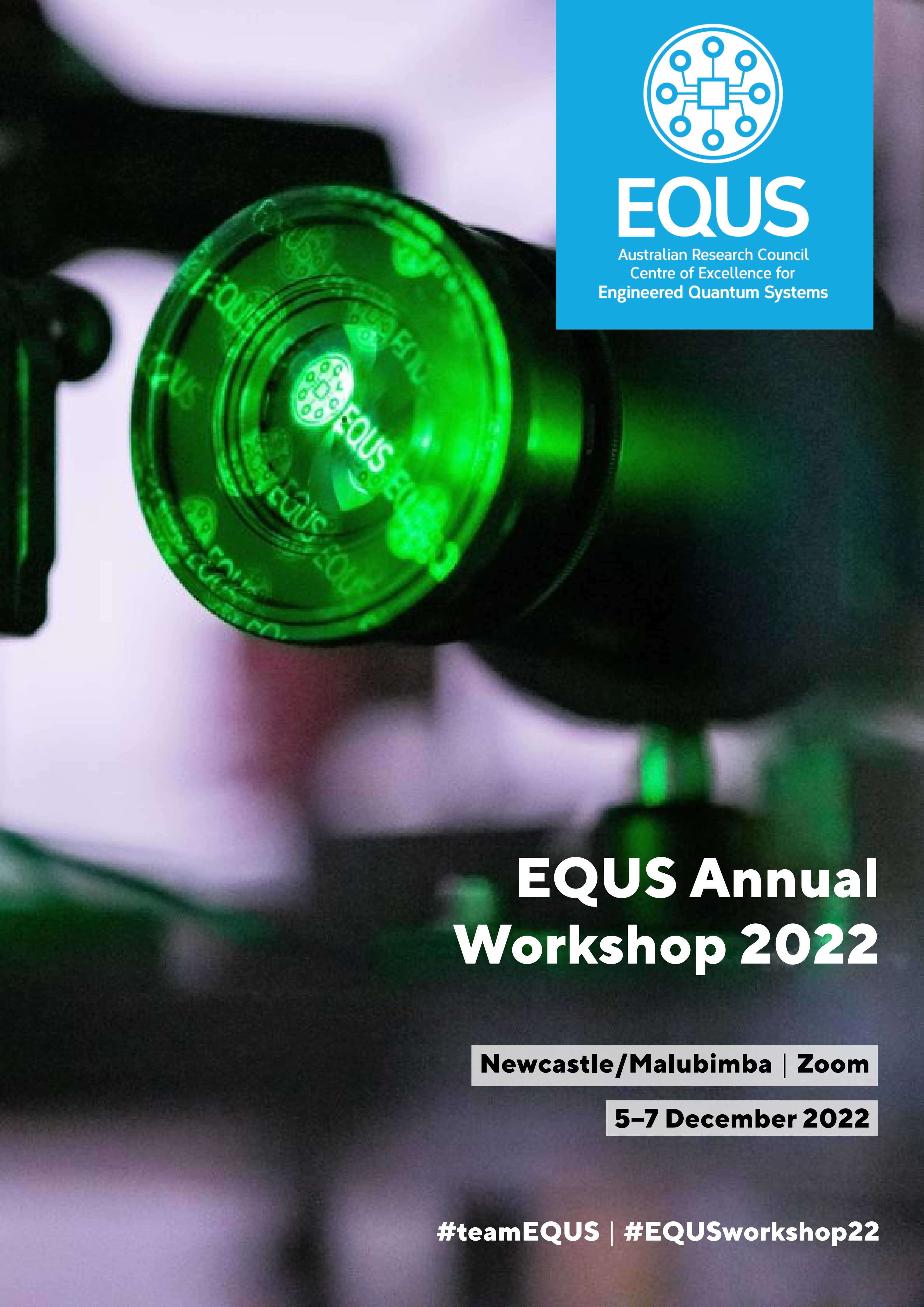

EQUS

Australian Research Council
Centre of Excellence for
Engineered Quantum Systems

EQUS Annual Workshop 2022

Newcastle/Malubimba | Zoom

5–7 December 2022

#teamEQUS | #EQUSworkshop22

EQUS acknowledges the Traditional Custodians and Cultures of the lands and seas on which we live and work. We pay our respects to all First Nation Peoples, Elders and Ancestors. We acknowledge that sovereignty was never ceded and stand in solidarity towards a shared future.

When we acknowledge Country, one of things we're doing is honouring and respecting the long tradition of knowledge-making in First Nations cultures, including in the STEM disciplines of science, technology, engineering and maths.

In particular, we acknowledge the Awabakal and Worimi Peoples as the Traditional Custodians of the land and waters situated within the Newcastle local government area, including wetlands, rivers, creeks and coastal environments, and recognise their continued connection to the surrounding land and waters.

It always was and always will be Aboriginal land.

Overview

Timetable

(All times are AEDT)	Tea/coffee	Start	End	Dinner/social
Day 0: Sunday 4 December				6:00 pm
Day 1: Monday 5 December	8:00 am	9:00 am	6:30 pm	7:30 pm
Day 2: Tuesday 6 December	8:00 am	9:00 am	4:15 pm	7:30 pm
Day 3: Wednesday 7 December	8:00 am	9:00 am	2:00 pm	
SAC meeting		1:15 pm	3:00 pm	

Bus departure times

Newcastle airport to Rydges Newcastle: 3:55 pm Sunday 4 December
Rydges Newcastle to Newcastle airport: 2:00 pm Wednesday 7 December

Sydney Nano Hub (Physics Rd) to Rydges Newcastle: 6:30 am Monday 5 December
Rydges Newcastle to Sydney Nano Hub (Physics Rd): 2:00 pm Wednesday 7 December

Venue details

Conference & accommodation

Rydges Newcastle
Wharf Rd & Merewether St
Newcastle/Malubimba NSW 2300

Sunday drinks & canapés: Terrace Bar
Welcome to Country: Harbour Terrace
Tuesday dinner & awards: Ballroom
Scientific Advisory Committee meeting: Harbour Boardroom

Monday dinner & trivia

The Lucky Hotel
237 Hunter St
Newcastle/Malubimba

Day 1

Monday 5 December

8:00 am–9:00 am	Tea & coffee
9:00 am–9:15 am	**Welcome to Country: Cheryl Suey Smith-Yaramun**
9:15 am–9:30 am	**Director's welcome: Thomas Volz**
9:30 am–10:30 am	**Keynote presentation: Alexia Auffèves**
10:30 am–11:00 am	Morning tea
	Session 1
11:00 am–11:20 am	Robert Wolf
11:20 am–11:40 am	Aidan Strathearn
11:40 am–12:00 pm	Callum Sambridge
12:00 pm–12:20 pm	Abdallah El Kass
12:20 pm–1:00 pm	**Pitch competition**
1:00 pm–2:00 pm	Lunch
2:00 pm–3:00 pm	**Keynote presentation: Lisa Annese**
3:00 pm–3:15 pm	**Portfolio update: Public Engagement**
3:15 pm–3:30 pm	**Portfolio update: Mentoring & Career Development**
	Session 2
3:30 pm–3:50 pm	Jeremy Bourhill
3:50 pm–4:10 pm	Gerard Milburn
4:10 pm–4:30 pm	Soroush Khademi
4:30 pm–6:30 pm	**Poster session & afternoon tea**
6:30 pm–7:30 pm	Free time
7:30 pm–9:30 pm	**Dinner & trivia**

Day 2

Tuesday 6 December

8:00 am–9:00 am	Tea & coffee
	Session 3
9:00 am–9:20 am	Daniel Burgarth
9:20 am–9:40 am	Carolyn Wood
9:40 am–10:00 am	Will Campbell
10:00 am–10:30 am	**Portfolio update: Translational Research Program**
10:30 am–11:00 am	Morning tea
11:00 am–12:00 pm	**Keynote presentation: Yvonne Gao**
	Session 4
12:00 pm–12:20 pm	Elizabeth Marcellina
12:20 pm–12:40 pm	Giacomo Pantaleoni
12:40 pm–1:00 pm	Sarath Raman Nair
1:00 pm–2:00 pm	Lunch
	Session 5
2:00 pm–2:20 pm	Elisabeth Wagner
2:20 pm–2:40 pm	Pradeep Nandakumar
2:40 pm–3:00 pm	Lewis Williamson
3:00 pm–3:30 pm	**Portfolio update: Translational Research Program**
3:30 pm–4:15 pm	**Three-minute thesis competition**
4:15 pm–4:30 pm	Afternoon tea
4:30 pm–7:30 pm	Free time
7:30 pm–10:30 pm	**Dinner & awards**

Day 3

Wednesday 7 December

8:00 am–9:00 am	Tea & coffee
9:00 am–10:00 am	**Keynote presentation: Jess Wade**
	Session 6
10:00 am–10:20 am	Daniel Peace
10:20 am–10:40 am	Samuel Smith
10:40 am–11:00 am	Andrew White
11:00 am–11:30 am	Morning tea
11:30 am–11:45 am	**Portfolio update: EQUIP (Equity in Quantum Physics)**
11:45 am–12:00 pm	**Portfolio update: Quantum for Educators**
	Session 7
12:00 pm–12:20 pm	Charles Woffinden
12:20 pm–12:40 pm	Fabio Costa
12:40 pm–1:00 pm	Xanthe Croot
1:00 pm–1:15 pm	**Director's farewell: Andrew White**
1:15 pm–2:00 pm	Snack box collection
1:15 pm–3:00 pm	Scientific Advisory Committee meeting

Keynote speakers

Alexia Auffèves

Research Director, CNRS International Research Lab MajuLab

Quantum technologies need a quantum energy initiative

Day 1: Monday 5 Demember, 9:30 am–10:30 am

Quantum technologies are currently the object of high expectations from governments and private companies, as they hold the promise to shape safer and faster ways to extract, exchange and treat information. However, despite its major potential impact for industry and society, the question of their energetic footprint and efficiencies has remained in a blind spot of current deployment strategies. In this keynote, I will present the recently launched quantum energy initiative (QEI, https://quantum-energy-initiative.org/). The QEI aims at developing a holistic understanding of these questions by structuring a transverse, interdisciplinary and international research line connecting quantum thermodynamics, quantum information science, quantum physics and engineering. Our goal is to create the conditions for energy efficient, sustainable quantum technologies, and possibly bring out a quantum advantage of energetic nature.

Professor Alexia Auffèves is a research director at the CNRS International Research Lab MajuLab (Singapore) and an EQUS Partner Investigator. After an experimental PhD under the supervision of Professor S. Haroche, she was recruited at CNRS in 2005 in Grenoble, where she developed a research line around the theory of quantum optics and quantum thermodynamics. She promotes the physics-philosophy interface within the Grenoble centre for quantum science and technologies, which she ran between 2017 and 2022. In 2022, she launched the Quantum Energy Initiative, an interdisciplinary and international research community to understand the energetic footprint of emerging quantum technologies.

Lisa Annese

CEO, Diversity Council Australia

Diversity 101: Engaging your workforce & activating your organisation

Day 1: Monday 5 Demember, 2:00 pm–3:00 pm

The business benefits for diversity and inclusion in the workplace are well documented by research organisations, government and leading practice employers. Organisations that commit to and implement effective diversity and inclusion policies and strategies are more likely to retain a satisfied workforce resulting in greater profitability, innovation and organisational performance. But how to sift through what seems like a sea of resources, advice and tools? And what will be most effective for your organisation? This knowledge program is designed to enable your team to better understand workplace diversity and inclusion, and to develop an effective diversity and inclusion strategy.

Lisa Annese has been the Chief Executive Officer of Diversity Council Australia since 2 June 2014. In this role, she leads debate on diversity and inclusion in the public arena, and oversees the development of thought leadership research pieces for Australian workplaces. In 2018, Lisa was named one of the AFR's 100 Women of Influence. She was elected to the Board of Amnesty International Australia in 2019 and appointed to the Board of Women for Election is 2021. Lisa is a member of Chief Executive Women and Executive Producer of DCA's podcast, The Art of Inclusion.

Lisa has had a long career in the diversity and inclusion space, across the corporate, government and not-for-profit sector. Some of her career highlights include: advocating for policy action to eliminate workplace harassment and gendered violence and closing the gender pay gap, presenting DCA's leading research internationally; developing the first ever citation recognising Employers of Choice in Gender Equality and the first ever census of 'Australian Women in Leadership' while at the Workplace Gender Equality Agency, and co-authoring "Chief Executives Unplugged: CEO's Get Real About Women in the Workplace".

Yvonne Gao

Assistant Professor, National University of Singapore

Quantum information processing with bosonic modes: a story of cats, cavities and coherence

Day 2: Tuesday 6 Demember, 11:00 am–12:00 pm

Circuit quantum electrodynamics provides a versatile platform capable of creating, manipulating and measuring quantum states, making it an attractive candidate for robust quantum information processing. In the framework of circuit quantum electrodynamics, information may be stored and processed as continuous-variable quantum states in superconducting microwave cavities. Such stored multiphoton states are promising candidates for long-lived quantum memories and for logical qubits that can be protected against environmental noise.

Here, we exploit the advantages offered by the circuit quantum electrodynamics hardware to create a robust quantum resource state based on a squeezed cat state in a single superconducting cavity. We demonstrate the controllability of the cavity state in the presence of weak nonlinearity and create a squeezed cat state through a deterministic protocol. Furthermore, we study the time dynamics of the squeezed cat state in the presence of intrinsic decoherence and show that the quantum features of the state are protected by squeezing, making such states attractive candidates for robust encoding of quantum information.

Dr Yvonne Gao is a Principal Investigator in the Centre for Quantum Technologies and a Presidential Young Professor in the Department of Physics, National University of Singapore. Her team works on building robust quantum hardware using superconducting microwave circuits. Their devices provide useful avenues to develop novel techniques for quantum information processing and to explore interesting effects in quantum physics. For her contributions in quantum hardware development, Yvonne has been awarded the Singapore Young Scientist Award, the Singapore National Research Foundation Fellowship and MIT Tech Review's Innovators Under 35 (Asia-Pacific) award.

Jess Wade

Research Fellow, Imperial College London

Chiral materials and creating a more inclusive academic community

Day 3: Wednesday 7 Demember, 9:00 am–10:00 am

Quantum science can help people change the world. Whether it is the climate crisis, ongoing pandemic or pressures on our healthcare services, at a time of unparalleled challenges and uncertainty, technologies enabled by quantum science can provide solutions. Despite that, too many people opt out of physics at a young age, and too many are pushed out as a result of systemic inequities reproduced and reinforced by the culture of academia. There are various reasons for this, including a shortage of skills-specialist teachers, unconscious (and very conscious) bias, societal stereotypes, and misconceptions about what physics is and what physicists do. I believe that outreach and advocacy can change that, but only if we focus on quality and not quantity. I will talk about how who we talk about matters and the importance of using evidence when designing outreach programmes and equity initiatives.

To take full advantage of the opportunities enabled by quantum science and realise a new age of sustainable, efficient technologies, it is essential we identify new materials platforms for preparing, controlling, storing and reading-out quantum states. Chiral molecular materials (that is, organic semiconductors that exist as left- and right-handed non-superimposable mirror-image pairs) offer unparalleled opportunity to control electron and photon spin, owing to a combination of their unique optical, electrical and magnetic properties. I will discuss ongoing efforts in our lab to understand and exploit the quantum properties of chiral molecular materials.

Dr Jess Wade is an Imperial College Research Fellow working in the Department of Materials at Imperial College London. Her research considers new materials for optoelectronic devices, with a focus on chiral organic semiconductors and how to optimise these chiral systems such that they can absorb/emit circularly polarised light as well as transport spin-polarised electrons. For her PhD Jess concentrated on new materials for photovoltaics and the development of advanced characterisation techniques to better understand their molecular packing. Outside of the lab, Jess is involved with several science communication and outreach initiatives. She is committed to improving diversity in science, both online and offline.

Abstracts

Session 1

Day 1: Monday 5 December, 11:00 am–12:00 pm

Robert Wolf
Advances in Penning-trap ion imaging and control for quantum sensing and simulation
The University of Sydney

Coherently manipulated crystals of ions in a Penning trap are promising candidates for near-term quantum simulation of complex many-body phenomena and for the search for dark matter using quantum sensing [1, 2]. At the University of Sydney, we have recently developed a Penning trap to perform such experiments with crystals that contain hundreds of beryllium ions. In this contribution, we introduce this system and two major technical innovations that support these applications. First, we have implemented a high-bandwidth time-correlated single-photon-counting camera which allows efficient single-site detection of individual ions in a large, two-dimensional ion crystal—a prerequisite for investigating spatial correlations in many-body quantum systems. The large amount of image data is analysed by an object-detection algorithm using an artificial neural network. Second, we describe a laser-beam delivery system based on compact piezo-actuated optical mirrors which enable efficient beam-position tuning inside the room-temperature bore of a superconducting magnet. This system enables *in situ* maximisation of the ratio of coherent spin-spin interaction strength to spontaneous emission in laser-mediated interactions. We demonstrate long-range entanglement with a variable coupling strength and near-ground-state cooling using electromagnetically induced transparency in this system.

[1] M. G arttner *et al.* Measuring out-of-time-order correlations and multiple quantum spectra in a trapped-ion quantum magnet. *Nat. Phys.* 13:781–786 (2017).
[2] K. A. Gilmore *et al.* Quantum-enhanced sensing of displacements and electric fields with two-dimensional trapped-ion crystals. *Science* 373:673–678 (2021).

Aiden Strathearn

Effects of wavefront curvature in optical atomic-beam clocks

The University of Queensland

We rely on atomic clocks to provide a reproducible basis for our understanding of time and frequency. The accuracy of these devices is outstanding, and state-of-the-art systems achieve systematic uncertainties of the order of 10^{-18}. A careful understanding of the sources of uncertainties and shifts in the laser frequency is vital to the development of future clocks. In optical atomic clocks, lasers are often modelled as plane waves, but in reality the wavefronts are curved, leading to deviations in the behaviour of the clock signal predicted using plane-wave models [1]. Here we develop an analytic theory for atoms interacting with Gaussian lasers with curved wavefronts, allowing us to elucidate the effects of wavefront curvature on the operation of Ramsey–Bordé interferometric atomic-beam clocks. We simulate a previous ^{40}Ca beam clock experiment [1] and find that a realistic model for the laser that includes wavefront curvature is essential to reproduce the observed signal sensitivity to the optical parameters. In particular, our model confirms the nonintuitive observation that the contrast of the Ramsey fringes is optimised when the laser is focused away from atomic beam. We also find that the combination of the optical Guoy phase and atomic time-of-flight shifts induced by curved wavefronts leads to frequency shifts of a few hundred hertz away from the recoil-shifted clock transition frequency. Finally, we use our model to explore how the optical setup may be optimised to give stable and predictable frequency corrections to the clock transition as well as high contrast Ramsey fringes.

[1] J. Olson *et al.* Ramsey–Bordé matter-wave interferometry for laser frequency stabilization at 10^{-16} frequency instability and below. *Phys. Rev. Lett.* 123:073202 (2019).

Callum Sambridge

Heterodyne phase tracking at femtowatt optical power

The Australian National University

This talk presents a demonstration of phase-tracking behaviour in the weak-light regime (10 femtowatts and below). In addition, we present modelling, simulation and experimental work that demonstrates, for the first time, phase tracking at the sub-femtowatt level, more than 1,000 times smaller than what is used for the GRACE Follow-On Laser Ranging Interferometer or is planned for LISA. Previous work in the field of weak-light phase tracking demonstrates phase tracking with continually improving noise performance and minimum optical powers tracked. As well as improving on the previous results, this work addresses the gap in our understanding of how these systems behave in the weak-light regime. This technology is mission-enabling for missions such as microhertz-band space-based gravitational-wave detectors and may enable smaller and cheaper geodesy missions.

Abdallah El Kass

Quantum capacitance parametric amplifier

The University of Sydney

Fast and high-fidelity readout of radio-frequency signals at cryogenic temperatures is of paramount importance for the observation of quantum processes inside dilution fridges. We demonstrate a low-noise parametric amplifier that exploits the voltage-controllable quantum capacitance of the two-dimensional electron gas in a GaAs heterostructure. The quantum capacitance parametric amplifier (QCPA) prototype exhibits gains greater than 20 dB, a high dynamic range with 1-dB compression of −66 dBm, and a noise temperature of 1.3 K. Furthermore, it is operable in the presence of a magnetic field (measured up to 1.9 T) with no shielding, and its power consumption, being of the order of 5 μW, is affordable at a fridge's base temperature (20 mK), making the QCPA a viable option for the monolithic integrated on-chip readout of semiconductor qubits. The QCPA is further proven suitable for higher ambient temperatures (4 K) and is thus well placed to address other niche deep-cryogenic applications.

Session 2

Day 1: Monday 5 December, 3:30 pm–4:30 pm

Jeremy Bourhill
Clock Flagship and novel cavity designs
The University of Western Australia

Gerard Milburn
The physics of learning machines
The University of Queensland

A learning machine, like all machines, is an open system driven far from thermal equilibrium by access to a low-entropy source of free energy. We discuss the connection between machines that learn, with low probability of error, and the optimal use of thermodynamic resources for classical and quantum machines. Fixed-point and spiking perceptrons are discussed in the context of possible physical implementations. An example of a single-photon quantum kernel evaluation illustrates the important role for quantum coherence in data representation. Machine learning algorithms, implemented on conventional complementary metal–oxide–semiconductor (CMOS) devices, currently consume large amounts of energy. By focusing on the physical constraints of learning machines rather than on algorithms, we suggest that a more efficient means of implementing learning may be possible, based on quantum switches operating at very low power.

Soroush Khademi
Estimating mechanical states via quantum measurement
The University of Queensland

The rapid progress in the design, fabrication and measurement of cavity optomechanical systems has made them increasingly attractive for quantum science and technology. In these systems, the quantum state of the mechanical oscillator may be estimated by measuring the back-reflected laser beam and post-processing the measurement data. After revisiting the problem of causal estimation (when only the past data is used) in previous work [1], we have worked on how to obtain a 'smoothed' estimation where both past and future data are available. In this talk, I will show that, in sharp contrast to the former problem, applying the classical approach to the smoothing problem results in an output that violates the Heisenberg uncertainty principle; thus, a genuinely quantum formulation must be used. For the first time, we suggest a way to apply quantum smoothing theory to an optomechanical system which puts out a physical state for the mechanical oscillator.

[1] C. Meng *et al.* Measurement-based preparation of multimode mechanical states. *Sci. Adv.* 8:eabm7585 (2022).

Session 3

Day 2: Tuesday 6 December, 9:00 am–10:00 am

Daniel Burgarth
Taming the rotating-wave approximation
Macquarie University

The rotating-wave approximation (RWA) is one of the oldest and most successful approximations in quantum mechanics. It is often used for describing weak interactions between matter and electromagnetic radiation. Recent experimental advances in achieving strong light-matter couplings and high photon numbers often reach regimes where the RWA is not great. At the same time, quantum technology creates growing demand for high-fidelity quantum devices, where even errors of a single percent might render a technology useless for error-corrected, scalable quantum computation. In this talk, I will report error bounds for the RWA applied to the quantum Rabi model, leading to the Jaynes-Cummings interaction. This allows us to determine for a given setup whether the RWA is reasonable or not. A key message is that this depends not only on the frequency and coupling strength, but also on the initial state and in particular the number of photons.

Carolyn Wood
Mass-energy equivalence in atom-light interactions and fundamental tests with composite particles
The University of Queensland

Composite particles (such as atoms and molecules) are excellent tools for tests of joint quantum and general-relativistic effects, such as time dilation of quantum clocks, tests of gravity in the mesoscopic regime, and coupling of quantum particles to various environments. A two-level system coupled to a field is a simple but powerful model of a quantum system interacting with an external environment. As the internal state of the system can change in response to the field—for example, its internal energy increases at the expense of absorbing a particle from the field—the model is often called a 'particle detector'. Simple such models, with a point-like two-level system on a classical trajectory, are called Unruh-DeWitt detectors. Recent models incorporating quantum effects of the detector's centre of mass have produced interesting results; however, they cannot yet capture known relativistic effects required in typical applications of the model, such as in atom-light interactions.

We have addressed this problem by incorporating quantisation of the centre of mass and the internal mass-energy into the Unruh-DeWitt model. We show that internal energy changes due to emission or absorption are relevant even in the lowest-energy limit—corrections to transition rates due to the mass of the detector changing cannot be ignored unless the entirety of the centre-of-mass dynamics is also ignored. Our results imply that one cannot have a consistent model of a massive particle interacting with a relativistic quantum field without including relativistic mass-energy equivalence, at the least, in the dynamics of the particle. In this talk, I will discuss these recent results and others from our group, as well as some open problems arising from this research.

Will Campbell
Acoustic cavities and tests of fundamental physics
The University of Western Australia

Session 4

Day 2: Tuesday 6 December, 12:00 pm–1:00 pm

Elizabeth Marcellina
Hybrid quantum systems
The University of Sydney

One of the current challenges in realising functional quantum computers is scalability. Here we discuss a possible scheme to achieve it, which is to integrate different qubit systems and build hybrid quantum computers. I will discuss some of the latest candidate protocols for hybrid quantum computers.

Giacomo Pantaleoni
The Zak transform: a framework for quantum computation with the Gottesman–Kitaev–Preskill code
The University of Sydney

The Gottesman–Kitaev–Preskill (GKP) code encodes a qubit into a bosonic mode using periodic wavefunctions. This periodicity makes the GKP code a natural setting for the Zak transform, which is tailor-made to provide a simple description for periodic functions. In this talk, I will review the formalism of the Zak transform and show how it describes GKP states and error correction. With the aid of this framework, I construct a new bosonic subsystem decomposition—the modular variable subsystem decomposition—by dividing the Hilbert space of a mode, expressed in the Zak basis, into that of a virtual qubit and a virtual gauge mode. Tracing over the gauge mode gives a logical-qubit state, and preceding the trace with a particular logical-gauge interaction gives a different logical state—that associated with GKP error correction.

Sarath Raman Nair
Diamond spin ensembles for quantum technology
Macquarie University

An ensemble of nitrogen-vacancy (NV) spins in diamond is an excellent room-temperature quantum technology platform, particularly for quantum sensing. In this talk, we will present the progress of three main research projects with diamond NV spins in the Quantum Materials and Applications (QMAPP) group at Macquarie University. First, we will present a quantum control experiment to enhance the room-temperature coherence time of an ensemble of NV spins by acting on its environment. Then, we will present the progress of developing a room-temperature diamond NV MASER suitable for quantum sensing. Finally, we will talk about the study of coupling NV spins to grape dimer cavities, an effort to explore novel cavity designs for NV MASER systems.

Session 5

Day 2: Tuesday 6 December, 2:00 pm–3:00 pm

Elisabeth Wagner
Theory and applications of non-unitary quantum cellular automata
Macquarie University

This talk presents a way to measure the information flow in an important class of quantum systems—quantum cellular automata—that are invariant in time and space and are defined only by local dynamics [1]. For unitary quantum cellular automata, a net flow of quantum information has been quantified by an index theory [2]. The associated measure is translationally invariant and invariant under finite-depth local circuits; however, it is not defined when the system is coupled to an environment, such as for non-unitary time evolution of open quantum systems. For non-unitary quantum cellular automata, we propose a new measure of quantum information flow we call a current, which is not rigid but may be computed locally using the matrix-product operator representation of the quantum channel [3].

[1] T. Farrelly. A review of quantum cellular automata. *Quantum* 4:368 (2020).
[2] D. Gross, V. Nesme, H. Vogts & R. F. Werner. Index theory of one-dimensional quantum walks and cellular automata. *Commun. Math. Phys.* 310:419 (2012).
[3] E. Wagner, R. Nigmatullin, A. Gilchrist & G. K. Brennen. Information flow in non-unitary quantum cellular automata . *arXiv* 2204.09922 (2022).

Pradeep Nandakumar
In situ control of macroscopic photonic wavefunctions in superconducting waveguide quantum electrodynamics
The University of Queensland

Waveguide quantum electrodynamics is a nascent field of quantum optics that describes the interaction between quantum emitters and photons in a one-dimensional infinite radiation channel. Recently, several novel regimes of light-matter interaction have been identified by embedding qubits in waveguides that support photonic bandgaps [1]. When the energy of the qubits lies close to the band edge, qubit-photon bound states are predicted to emerge. The photonic part of this bound-state wavefunction is exponentially localised around the qubit position and extends to the ends of the waveguide. In this talk, I will present experimental results that demonstrate the *in situ* frequency-tunable characteristics of these bound states, such as the localisation length, the interaction strength between multiple bound states and the chirality of photonic wavefunctions without changing the special organisation of the qubits [2].

[1] N. M. Sundaresan *et al.* Interacting qubit-photon bound states with superconducting circuits. *Phys. Rev. X* 9:011021 (2019).
[2] N. P. Kumar *et al.* Bound states in microwave QED: crossover from waveguide to cavity regime. *arXiv* 2208.00558 (2022).

Lewis Williamson

Engines at the quantum scale: utilising coherence, correlations and quantum control

The University of Queensland

In 1959, Scovil and Schulz-DuBois showed that a three-level atom can function as an engine [1]. Since then, there has been growing interest in engines that operate at the quantum scale, including recent experimental demonstrations of single-particle engines [2–5]. Despite its long history, there are many unanswered questions in the field of quantum engines. In particular, can quantum features such as coherence and entanglement be utilised in engine operation? Furthermore, most studies have focused on the single-particle or non-interacting regime, with less known about the many-body regime.

In this talk, I will summarise our work on quantum engines, with a focus on many-body quantum systems routinely realised in experiments. First, I will show how coherence in an interacting bosonic system allows for nonclassical work extraction, generalising a recent single-particle protocol to the many-body regime [6,7]. Then, I will give a brief overview of two other directions of our research: I will discuss a proposal to realise a thermochemical engine in a Bose–Einstein condensate, which could aid in cooling or enlarging condensates; and I will discuss early results on the diabatic operation of a quantum spin chain engine, which builds on recent work demonstrating entanglement-enhanced adiabatic performance [8]. Our work demonstrates the exciting potential of many-body quantum effects in engine operation, and paves the way for their realisation in the laboratory.

[1] H. E. D. Scovil & E. O. Schulz-DuBois. Three-level masers as heat engines. *Phys. Rev. Lett.* 2:262–263 (1959).
[2] J. Roßnagel *et al.* A single-atom heat engine. *Science* 352:325–329 (2016).
[3] N. Cottet et al. Observing a quantum Maxwell demon at work. *Proc. Natl Acad. Sci. USA* 114:7561–7564 (2017).
[4] D. von Lindenfels *et al.* Spin heat engine coupled to a harmonic-oscillator flywheel. *Phys. Rev. Lett.* 123:080602 (2019).
[5] J. P. S. Peterson *et al.* Experimental characterization of a spin quantum heat engine. *Phys. Rev. Lett.* 123:240601 (2019).
[6] P. Kammerlander & J. Anders. Coherence and measurement in quantum thermodynamics. *Sci. Rep.* 6:22174 (2016).
[7] J. Klatzow *et al.* Experimental demonstration of quantum effects in the operation of microscopic heat engines. *Phys. Rev. Lett.* 122:110601 (2019).
[8] L. Williamson & M. Davis (in preparation).

Session 6

Day 3: Wednesday 7 December, 10:00 am–11:00 am

Daniel Peace

Towards high-dimensional integrated quantum photonics

The University of Queensland

High-dimensional quantum information processing has the potential to reduce circuit complexity and experimental resources while improving computational efficiency. A common approach for encoding information with photons in free-space optics is using the orbital angular momentum or 'shape' degree of freedom. In integrated photonics, the analogous encoding uses the transverse modes of a multimode waveguide. Constructing a photonic circuit that supports such encoding requires replacing the individual components that comprise the larger circuit (beam splitters, waveguide crossers and bends) and are traditionally single-mode with those that support many modes with low loss and crosstalk. Designing such components is often non-trivial and thus presents an interesting application for the use of photonic inverse design methods. These methods may also be applied to other key components, such as mode converters and multiplexers, to reduce device footprint and improve performance compared to conventional design approaches.

Samuel Smith

A local pre-decoder to reduce the bandwidth and latency of quantum error correction

The University of Sydney

Andrew White

Making better photons by getting rid of experimentalists

The University of Queensland

Session 7

Day 3: Wednesday 7 December, 12:00 pm–1:00 pm

Charles Woffinden

Measuring rotation in a Bose–Einstein condensate with phonon interferometry

The University of Queensland

Inertial sensors are critical in navigation systems but are typically reliant on satellite navigation (satnav). New classes of inertial sensors that exploit quantum effects promise to give enhanced absolute measurements of motion in satnav-denied environments such as in space or underwater. Here we discuss the use of a ring-shaped Bose–Einstein condensate as a rotation sensor by creating low-energy phonon standing-wave excitations and then observing the precession of the nodes of the excitation in response to rotation. Our sensor has a measured sensitivity of 0.3 rad s^{-1} and a shot noise limit of 0.04 rad s^{-1}. We present the output of simulations which indicate the dominant damping mechanisms that limit higher sensitivity and propose potential improvements.

Fabio Costa

A De finetti theorem for quantum causal processes

The University of Queensland

Xanthe Croot

Protected qubits in superconducting circuits

The University of Sydney

Portfolio updates

Public Engagement

Day 1: Monday 5 December, 3:00 pm–3:15 pm

Ben McAllister & Kristen Harley

Mentoring and Career Development

Day 1: Monday 5 December, 3:15 pm–3:30 pm

Gavin Brennen & Katrina Tune

Translational Research Program

Day 2: Tuesday 6 December, 10:00 am–10:30 am

Tom Stace & Lyle Roberts

Day 2: Tuesday 6 December, 3:00 pm–3:30 pm

Clare Birch (Blackbird Ventures) & panellists

EQUIP (Equity in Quantum Physics)

Day 3: Wednesday 7 December, 11:30 am–11:45 am

Katrina Tune & Tim Newman

Quantum for Educators

Day 3: Wednesday 7 December, 11:45 am–12:00 pm

Katrina Tune & Lachlan Rogers

Competitions

Pitch competition

Day 1: Monday 5 December, 12:00 pm–1:00 pm

Entrants

Benjamin Carey (UQ)
Kyle Clunies-Ross (UQ)
Prasanna Pakkiam (UQ)
Tim Hirsch (UQ)

Three-minute thesis competition

Day 2: Tuesday 6 December, 3:30 pm–4:15 pm

Entrants

Adesh Kushwaha (USYD)
Ben Field (USYD)
Christophe Valahu (USYD)
Gargi Tyagi (USYD)
Lirandë Pira (UTS)
Mark Webster (USYD)

Poster competition

Day 1: Monday 5 December, 4:30 pm–6:30 pm

Entrants

Aaron Quiskamp (UWA)
Abhijeet Alase (USYD)
Adesh Kushwaha (USYD)
Ali Fawaz (MQ)
Andrew Wade (ANU)
Anirban Dey (MQ)
Arjun Rao (USYD)
Benjamin Carey (UQ)
Cassandra Bowie (UQ)
Catriona Thomson (UWA)
Charles Woffinden (UQ)
Chun-Ching Chiu (UQ)
Cindy Zhao (UWA)
Dan George (MQ)
Dat Le (UQ)
Dominic Williamson (USYD)
Edgar Tanuarta (USYD)
Eric He (UQ)
Evan Hockings (USYD)
Fatemeh Mohit (UQ)
Glen Harris (UQ)
Graeme Flower (UWA)
Guangqi Zhao (USYD)
Haider Zulfiqar (USYD)
Jemy Geordy (MQ)
Jeremy Bourhill (UWA)
Joseph Pham (USYD)
Jue Zhang (ANU)
Kerstin Beer (MQ)
Lauren McQueen (UQ)
Lawrence Cohen (USYD)
Maarten Christenhusz (UQ)
Marcelo de Almeida (UQ)
Markus Rambach (UQ)
Maverick Millican (USYD)
Namisha Chabbra (ANU)
Nathaniel Bawden (UQ)
Raji Bhaskaran Nair (ANU)
Raymond Harrison (UQ)
Riddhi Ghosh (MQ)
Salini Karuvade (USYD)
Samuel Bartree (USYD)
Sebastian Malewicz (UQ)
Simeon Simjanovski (UQ)
Stefan Zeppetzauer (UQ)
Thomas Smith (USYD)
Tim Newman (USYD)
Tina Jin (UQ)
Tomas Navickas (USYD)
Tyler Jones (UQ)
Vanessa Carolina Olaya Agudelo (USYD)
Walter Wasserman (UQ)
Will Campbell (UWA)
Xanda Kolesnikow (USYD)
Zachary Kerr (UQ)

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