Editorial

Markus Krutzik*, John Close and Daniel Oi

Answers for some of the biggest questions may be given by the very smallest

https://doi.org/10.1515/aot-2020-0056

"I think I can safely say that nobody understands quantum mechanics".

Richard P Feynman, Chapter 6, "Probability and Uncertainty — the Quantum Mechanical View of Nature," p. 129.

Though some people may disagree with the above famous quote, it is undeniable that the rules by which quantum mechanics plays are unlike anything that govern our everyday "classical existence". Phenomena such as quantum superposition and entanglement define fundamentally new ways by which we can compute, communicate, measure and sense have, for the past few decades, led to the rapid development in what we now call quantum technologies.

The most publicly visible of these is quantum computation with tech giants joining the game, along with a slew of other established companies and startups racing to produce industrially useful quantum computers and algorithms that could solve certain problems that are intractable on even the most powerful of conventional computers. But quantum technologies have the potential to revolutionize many other areas such as communications, timing, sensing and metrology. And right now, exactly these branches of quantum technologies are emerging from out of the laboratory and into the wider world. This special issue is thus a timely distillation of some of the advances in their application and deployment.

Arguably, one of the most mature quantum technologies is quantum key distribution (QKD). Commercial QKD systems are now available and have been deployed in applications that would allow measurable security in communication and data transfer, despite the threat of quantum computers that could break existing methods of public key encryption. In this light, Brendon Higgins et al. are studying the performance of polarization-frame alignment schemes for practical implication of QKD, and give an estimate of the required resources. When it comes to QKD over global scales, space-borne operation of QKD systems are necessary, and Christopher Pugh et al. are highlighting their work on the benefit of adaptive optics for uplink communication from ground to space. Driven by the need of a quantum-safe networking, Francesco Raffaeli et al. are reporting on combining a quantum random number generator and quantum-resistant algorithms into open-source software to, for example, allow digitally signing documents.

As another class of already commercialized quantum technology, quantum sensors involve preparing quantum states and reading out their interaction with the environment. Coherent interactions and quantum superposition allow unprecedented sensitive measurements of physical quantities, such as frequency, time, inertial forces as well as electric and magnetic fields. In their views, Ravi Kumar et al. give an overview on atom interferometry, its history, and shed some light onto the important applications such as navigation and inertial sensing. Pei-Chen Kuan et al. present a novel type of atomic motion sensor using slow-light under electromagnetically transparency conditions, where atoms are trapped in optical lattices. Going from micro to macroscale, Markus Rademacher et al. describe the features of experiments with optically levitated nanoparticles and their proposed utility for acceleration sensing.

Further on, devices that are based on atoms and their specific interaction with magnetic and electric fields are discussed by three dedicated articles of this issue.

Tilmann Sander et al. report on the importance of optically pumped magnetometers for biomagnetic field sensing in new regimes. Vicor Lebedev et al. focus on the technical implementation of a fast and robust magnetometer based on thermal Cesium atoms in a table-top system, whereas Ryan Cardman et al. show an all optical

***Corresponding author: Markus Krutzik**, HU Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin, Germany,
E-mail: markus.krutzik@physik.hu-berlin.de
John Close, Australian National University, Research School of Physics, Canberra, Australia, E-mail: John.Close@anu.edu.au
Daniel Oi, University of Strathclyde, Physics, 107 Rottenrow, Glasgow, UK, E-mail: daniel.oi@strath.ac.uk. https://orcid.org/0000-0003-0965-9509

spectroscopic RF electric field readout based on Rydberg-atoms to obtain 2D field distribution using a portable instrument.

If, on the other hand, the quantum system is well isolated from the environment, one can probe the intrinsic quantum mechanical properties and, for example, use suitable narrow linewidth transition to stabilize external sources of electromagnetic radiation to it. Markus Gellesch et al. review recent progress on so called optical clocks, with a focus on compact and transportable neutral atom and single-ion optical atomic clocks for use out of the laboratory. Rachel Elvin et al. describe their version of a compact microwave clock using laser cooled atoms in a compact grating-based magneto-optical trap assembly.

As it can already be seen by the selection of articles in this special issue, a particularly notable characteristic of quantum technologies is the range of physical systems in which these can be implemented. From optical, microwave, atomic, mechanical, to condensed matter, progress has been made in the precision control and manipulation of quantum states of matter and energy and allow us to exploit their behavior. Each system has their own unique characteristics that lend themselves to different roles, photons for undisturbed propagation over long distance, atomic systems for sensitivity to fields, nanomechanical systems for the detection of forces, or condensed matter systems for integration and device density.

As noted in the beginning, for many of us, the questions quantum physics poses as well as the answers it delivers may surpass our imagination. So there is a great chance that even after reading this issue, "(…) nobody (still) understands quantum mechanics". But we sincerely hope that you enjoy this collection of viewpoints and research articles, and it might pave the way for a further interest in this topic.

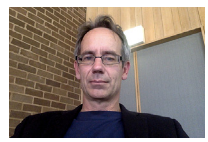
Answers for some of the biggest questions may be given by the very smallest. Now is the time to get in touch with quantum technology.

We would like to thank the AOT team as well as the authors who contributed to this issue.

Bionotes

Markus Krutzik
HU Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin, Germany
markus.krutzik@physik.hu-berlin.de

Markus Krutzik, Ferdinand-Braun-Institut, Leibniz Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Strasse 4, 12489 Berlin Humboldt-Universität zu Berlin, Institute of Physics, Newtonstr. 15, 12489 Berlin Markus Krutzik is head of the Joint Lab Integrated Quantum Sensors (IQS) operated by Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) and the Humboldt-Universität zu Berlin (HU Berlin). R&D activities focus on the development of integrated atomic systems for frequency metrology, timing and field sensing applications, especially for operation in a space environment. He got his Ph.D. in 2014 from HU Berlin, worked at the University of California, Berkeley, and NASA Jet Propulsion Laboratory, Pasadena.



John Close
John.Close@anu.edu.au
Australian National University, Research School of Physics, Canberra, Australia

John Close, Department of Quantum Science, Research School of Physics, Building 38A, The Australian National University, Canberra 2601 John Close received his PhD in physics from the University of California, Berkeley in 1991 and was an Alexander von Humboldt Fellow at the Max Planck Institüt für Strömungsforschung in Göttingen from 1995 –1998. He returned to Australia and was awarded a Queen Elizabeth II Fellowship in 2000. He is now Head of the Department of Quantum Science at the Australian National University and Head of ANU Defence Engagement. His expertise is in experimental atom interferometry and quantum sensor design with an emphasis on quantum-augmented inertial navigation both for terrestrial and space applications, mineral exploration and groundwater mapping and monitoring.

Daniel Oi
daniel.oi@strath.ac.uk
University of Strathclyde, Physics, 107 Rottenrow, Glasgow, UK
https://orcid.org/0000-0003-0965-9509

Daniel Oi, Computational Nonlinear and Quantum Optics Group, SUPA Department of Physics, University of Strathclyde, John Anderson Building, 107 Rottenrow, Glasgow, Scotland, G4 0NG, UK Daniel Oi is a senior lecturer at the University of Strathclyde, Glasgow, Scotland, specialising in quantum information. His research interests include fundamental aspects of quantum theory, quantum engineering, and quantum science & technologies. He obtained his DPhil at the University of Oxford (2002), previously obtaining his BSc Hons in Physics (1995) and BEng Hon in Mechanical Engineering (1997) from the University of Western Australia, and MASt (Part III Mathematics) from the University of Cambridge (1999). He has worked at the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge and was a research fellow at Sidney Sussex College before being appointed as a SUPA Research Fellow in Quantum Information at the University of Strathclyde in 2006.