Theme: Big players in quantum technology

WACQT | Wallenberg Centre for Quantum Technology

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Dear reader,

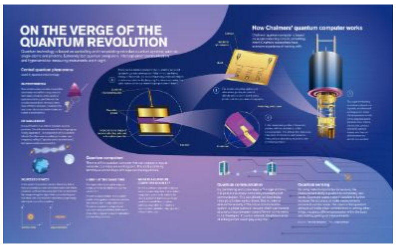
WACQT is a 12-year effort and we are now approaching the end of its first three-year period. Since the last newsletter, the principal investigators of WACQT have been busy working out the plans for the coming four-year period. These plans, which include the operation of a 20-qubit processor by the end of next year and an increased effort in quantum communication, have been detailed in the re-application that we submitted to the Knut and Alice Wallenberg Foundation on September 1st.

In May, Simone Gasparinetti started his assistant professor position at WACQT. He and his group will work on continuous variable quantum computing and quantum thermodynamics. Welcome onboard!

The theme article for this newsletter is called "Big players in quantum technology". In this article you get the latest news about major initiatives worldwide and prominent companies in quantum technology. I hope that you find this newsletter interesting.

Per Delsing
Director of the Wallenberg Centre for Quantum Technology

Recap for newcomers



Not familiar with quantum technology and WACQT – the Wallenberg Centre for Quantum Technology? Don't worry, we'll guide you through the basics.

Quantum technology is about controlling and using the strange and marvellous properties of individual quantum systems, such as electrons and photons, in order to make completely new things possible. The progress of research in quantum technology in recent years has brought the world to the brink of a new technology revolution – the second quantum revolution. Extremely powerful computers, intercept-proof communications, and hypersensitive measurement methods are in sight. Learn more in the Discover quantum technology section of our website and in the graphic On the verge of a quantum revolution from Chalmers magasin.

The **Wallenberg Centre for Quantum Technology (WACQT)** is a twelve year SEK-1-billion investment programme that aims to take Swedish research and industry to the forefront of the second quantum revolution. Read more at wacqt.se.

THEME: Big players in quantum technology

A coming technological revolution – expected to create stunning breakthroughs, large economic values, and security advantages – motivates governments as well as companies to invest heavily in quantum technology. In this issue's theme article, we provide an overview of the most powerful and interesting players.

Theme article Big players

WACQT news

Quantum radar requires better photon detectors

A quantum radar utilises quantum phenomena – more specifically entanglement of photons – in order to achieve improved performance over classical radar systems, especially in conditions with bright background and weak signals.

In a theoretical work, researchers within WACQT and Saab have now quantified the possible advantage of a quantum radar compared to a purely classical radar for a specific radar technology, so-called noise radar. They found that a significant advantage is possible, but the advantage is destroyed when the returning radar signal is detected by measuring its electrical field. However, if changing the detection method to counting the incoming photons instead, the quantum advantage would be preserved. Low-noise microwave photon detectors could do the job, but are not commercially available yet. Thus, the development of such detectors is fundamental to realise the full potential of quantum noise radar.

This work was presented at the 2020 IEEE Radar Conference 21–25 September, where a special session on quantum radar was held. The paper is available as a pre-print at arxiv.org.

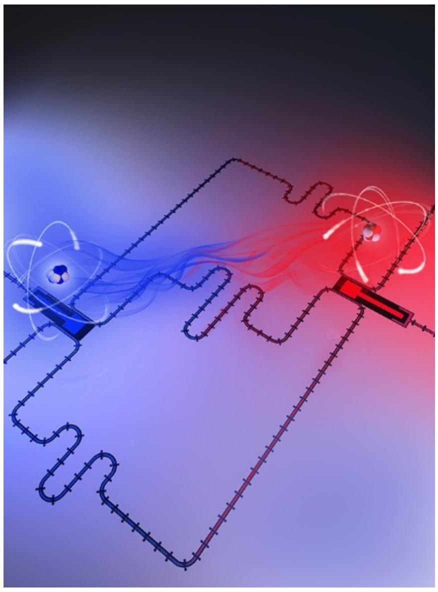
A very similar quantum radar concept – using pairs of entangled photons – was recently experimentally demonstrated in Austria, read more in Scientists demonstrate quantum radar prototype. Furthermore, a recent work by Italian and Chinese researchers shows that the spatial precision of a quantum radar can be increased by increasing the number of entangled photons used, as described in A quantum metrology protocol for locating noncooperative targets in 3-D space.

“Giant atoms” allow distant qubits to interact without losses

One of the main challenges in scaling up quantum computers is to enable qubits to interact with other qubits at distant locations in the processor. Just coupling qubits to a long waveguide is usually detrimental, since it provides a channel through which quantum information can leak out.

But now an international group of researchers – including Anton Frisk Kockum at WACQT – have found a solution: Construct giant artificial atoms from superconducting qubits and connect them to the waveguide at multiple points.

“Interference effects between the ‘giant atoms’ protect the quantum information from being lost, while still allowing them to communicate with each other via the waveguide,” explains Frisk Kockum, researcher at the Applied Quantum Physics Laboratory at Chalmers, who contributed with the theoretical work.



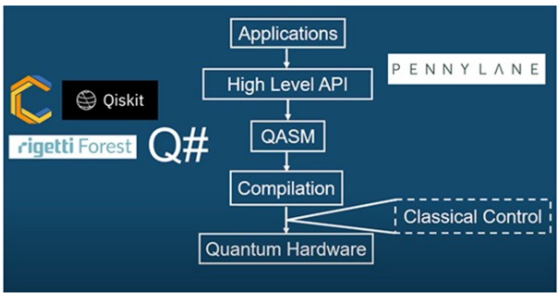
Two superconducting qubits acting as giant artificial atoms by coupling to a waveguide at multiple points. Illustration: Krantz NanoArt

An experiment carried out at MIT has successfully demonstrated that this approach allows for high-fidelity quantum-computing operations to be carried out on qubits coupled to a waveguide.

The work was recently published in an article in Nature, and confirms theoretical predictions which Frisk Kockum et al published in Physical Review Letters in 2018.

Also read more in Chalmers' news article Giant atoms merge quantum processing and communication.

New translation layer brings algorithms closer to quantum hardware



Nowadays, there are several powerful and useful tools for developing quantum software, for example Qiskit, Cirq, and PyQuil to name a few. However, these tools are generally developed by and for theorists, and therefore focus high up in the computing stack for implementing quantum algorithms.

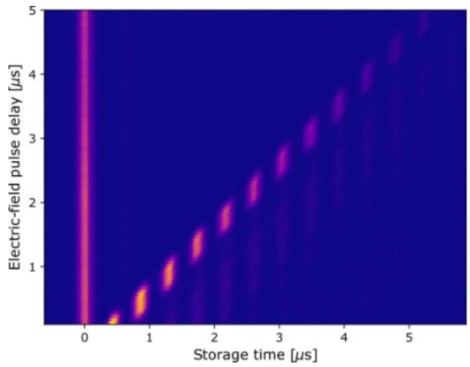
Unfortunately, this means that experimentalists cannot use these tools to run algorithms on their own quantum hardware – a translation layer is needed which bridges the gap between the software tool and the lab equipment that controls the hardware at the bottom of the computing stack.

Now researchers at the Quantum Technology Laboratory at Chalmers have developed such a translation layer that allows them to take advantage of existing tools (more specifically Qiskit) and run algorithms, including benchmarking algorithms which give an indication of the overall performance of the hardware, on their own quantum processors.

"This is the first time that Qiskit, an open source project for running algorithms on IBM's quantum computers, has been used on another hardware. We plan to release this translation layer so that any quantum computing lab around the world could use it for their hardware, hopefully within the next year" says Christopher Warren, PhD student at the Quantum Technology Laboratory at Chalmers.

Learn more in the video QTL Qiskit Integration Demo.

Demonstration of low-noise on-demand quantum memory



Output from the quantum memory at Lund University

Losses in optical fibres limits the distance of fibre-based quantum encrypted communication to a few tens of kilometres. Longer distances require the development of so-called quantum repeaters that amplify and forward the signals (read more about quantum communication). An integral part of quantum repeaters are optical quantum memories that can store quantum states and recall them on demand.

Recently, the Quantum Information Group at Lund University has experimentally demonstrated an essentially noise free on-demand quantum memory based on a crystal doped with rare-earth metal ions.

In the experiments, the researchers achieved storage times ranging from 0.8 to 5 microseconds. "We have plans for how to extend towards 100 microseconds – a storage time which would be useful in certain quantum repeater schemes", says group leader Stefan Kröll.

Read more in the pre-print Noise Free On-Demand Atomic-Frequency Comb Quantum Memory.

Companies share their view on quantum technology in new seminar series

Recently, a new seminar series – WACQT Industrial webinars – was launched by WACQT Graduate School. The purpose is to give PhD students and postdocs – but also others within the WACQT community – insight into how WACQT's industrial partners think about quantum technology. The first seminar was held by Azimeh Sefidcon from Ericsson on 11 September.

"It was really good! It was impressive to hear about Ericsson's broad interest and activity within both quantum communication and quantum computing," says Göran Johansson, director of studies of WACQT Graduate School.

The next industrial webinar is scheduled for 2 October at 14–15 with a talk by Anders Broo on how AstraZeneca look at quantum technology in life science and drug development, followed by Petter Bedoire from Saab on 23 October. If you did not receive an invitation to the first seminar but would like to have one for the coming seminars, please email Linda Brånell.

Two students selected for exclusive quantum week

In November, selected students from 30 European countries will gather in Berlin for the one-week conference Quantum Future Academy 2020. The idea of the event is to offer European top students an opportunity to gain new knowledge and contacts in order to boost the development of future commercial applications of quantum technology.

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Chalmers participates in proposal for hybrid quantum computation

Chalmers is at the moment participating in an EU application for a project that combines quantum computing with high-performance computing. The proposed project, called LUMI-Q, is coordinated by the LUMI exascale computer project in Finland (an exascale computing refers to the capability to perform at least 10^{18} operations per second).

The goal of LUMI-Q is to link Chalmers' upcoming web-connected quantum computer as a backend to the LUMI exascale computer. The quantum processor efficiently complements the architecture of the supercomputer and accelerates the computations. Such a hybrid system is expected to be able to address applications related to complex simulation and optimisation problems, notably for materials development, drug discovery, transportation and other real-world problems of high importance to industry.

"We believe that this can be the beginning of a very strong long-term Nordic collaboration at the global forefront of hybrid quantum computation," says Göran Wendin, principal investigator in WACQT, who keeps his fingers crossed for the proposal to be granted.

Quantum Technology Laboratory on Twitter

The Quantum Technology Laboratory (QTL) at Chalmers is now on Twitter, follow them at QTL_Chalmers.

Selected world-wide news

Five new national quantum research centres in the US. In August, the US Department of Energy announced the establishment of five new national quantum information science centres, as part of the US National Quantum Initiative. The aim of the centres is to create and to steward the ecosystem needed to foster and facilitate advancement of quantum information science, with major anticipated national impact on national security, economic competitiveness, and leadership in science.
One of the centres, the Co-design Center for Quantum Advantage, will be directed by the chairman of WACQT's scientific advisory board, Professor Steve Girvin.
"This is a major initiative in the US, at least three of the funded centers are using technologies similar to those pursued in WACQT. We are of course happy to see that Steve Girvin, the chairman of the WACQT advisory board, is leading one of the funded centers," says Per Delsing, director of WACQT.
Read more about the new US quantum information science centres.

First photonic quantum computer available in the cloud. In the beginning of September, the Canadian company Xanadu announced its release of the world's first publicly available photonic quantum computers. Developers can now access Xanadu's 8-, 12-, and soon 24-qubit photonic quantum processors via the cloud.
The classic approach to photonic quantum computing relies on qubits each based on a single photon. However, this strategy is generally limited to a handful of photons. Instead, Xanadu relies on superpositions of multiple photons and codes information into their electromagnetic field – an example of so-called continuous-variable quantum computing.
"I think it is great to have a first cloud continuous-variable quantum computer available, as it can spark further interest in this type of quantum computing. And it is still too early to bet on a single technology for a general-purpose quantum computer – photonic quantum computers are valuable candidates in the race together with superconducting systems, trapped ions, and others," says Guilia Ferrini, one of the principal investigators for quantum computing within WACQT.
Xanadu's quantum computer can – due to its architecture – only address special-purpose problems, such as computing the vibronic spectra of some molecules or enhancing the performance of certain stochastic algorithms.
Read more about Xanadu's quantum computer in IEEE Spectrum and about photonic quantum computing in general in Fact Based Insight.

Entangled quantum cryptography via satellite. Quantum encrypted communication has been demonstrated in unbroken optical fibres up to 400 km and over 1200 km using a satellite-to-ground communication link. Although impressive, these setups require the devices of both the sender and receiver to be fully characterized and trusted. However, if entangled photons are used for the distribution of quantum encryption keys, the need for trust would be greatly alleviated (read more in WACQT's quantum communication webpage).
A Chinese satellite-based experiment has now succeeded in demonstrating entangled quantum key distribution over a distance of more than one thousand kilometres. According to Eleni Diamanti, member of WACQT's scientific advisory board, this is the most advanced demonstration of quantum key distribution so far. However, it is still too slow to be relevant for practical security applications.
Read more in the research publication in Nature and in Diamanti's Nature News & views article.

New wiring scheme opens the door to large-scale quantum computing. One challenge of scalability of superconducting quantum computers arises from the fact that each qubit needs wiring and connections that produce controls and readouts with minimal crosstalk. Researchers at the Japanese research institution RIKEN have therefore invented a new wiring scheme, where the connections to each qubit are made vertically from the backside of a chip, rather than the conventional method of bringing the wiring pads to the edges of a quantum chip. The new scheme has been tested in a four-by-four array of qubits. It involves some sophisticated fabrication with a dense array of superconducting electrical connections through a silicon chip, but it should allow for scaling up to much larger devices, according to the researchers at RIKEN.

"It is indeed a large engineering task to wire up a quantum computer and different groups use different schemes. It is too early to say which method is best and which one that indeed can be scaled up to a large number of qubits," says Per Delsing, director of WACQT.

Read more in Wiring a new path to scalable quantum computing at RIKEN's website.

IBM reaches quantum volume of 64. In August, IBM announced having achieved the company's highest quantum volume this far. Combining a series of new software and hardware techniques, IBM upgraded the performance of one of its newest cloud-accessible 27-qubit chips to a quantum volume of 64. The higher the quantum volume, the more complex the tasks a quantum computer should be able to solve.

Recently, IBM has also released a 65-qubit processor with a quantum volume of 32. "Quantum volume is a metric that allows for comparing different quantum computers. A quantum volume of $64=2^6$ means that you have the same capability as a processor with six perfect and fully connected qubits. It should be mentioned that this is a metric invented by IBM and not necessarily used by everyone," explains Per Delsing, director of WACQT.Read more in IBM's press release.Earlier this year Honeywell announced a coming ion-trap quantum computer with a quantum volume of 64, as reported in WACQT Newsletter #3. That quantum computer was released this summer and is now available in the cloud via Microsoft Azure Quantum.

Atoms becomes heavier when excited. According to Einstein's famous mass-energy equivalence formula ($E = mc^2$), an atom should become heavier when absorbing energy to enter an excited state. In a joint effort, researchers in Germany, France, Russia and Japan have now been able to measure this infinitesimal change in mass for individual atoms for the first time. This remarkable experimental feat, similar to measuring the mass of an ant by measuring the difference in weight of an elephant with and without the ant walking on its back, was achieved using a high-precision mass spectrometer.

"There are a number of potential applications for the exceptionally sensitive experimental technique demonstrated, including optical clocks, testing theories of dark matter and searching for unknown particles," says Stefan Kröll, one of the principal investigators in WACQT.

Read more at phys.org or in Nature.

Amazon's quantum cloud service open to anyone. Amazon has now announced general availability of its quantum cloud service – Amazon Braket. Previously, a beta version was offered only to selected customers. The service is currently offering access to a quantum annealing processor by D-Wave, a superconducting processor by Rigetti, and an ion trap processor by IonQ, along with tools for algorithm development and simulators. Read more about Amazon Braket in Quantum Computing Report.

Microsoft is also developing a cloud-based quantum computing platform, named Microsoft Azure Quantum, where users can access quantum computers from Honeywell, IonQ and Quantum Circuits. However, it is still a preview version for selected users.

"We are now seeing multiple companies making small quantum computers from several hardware platforms available on the cloud. WACQT is also working on a similar setup for our quantum computers, but with access limited to our researchers and industry partners," says Anton Frisk Kockum, project coordinator and researcher in WACQT.

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