WACQT - Wallenberg Centre for Quantum Technology Newsletter #8, 2022

WACQT | Wallenberg Centre for Quantum Technology

Dear reader,

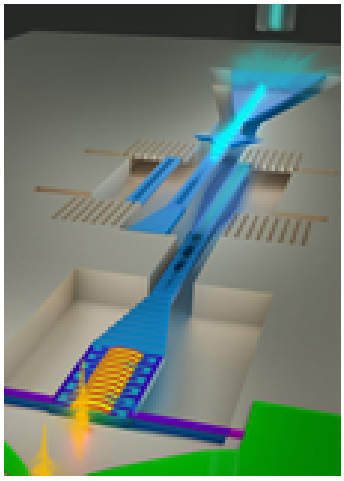
Despite the continuing pandemic, there are a lot of activities in WACQT. A new postdoc program started February 1st, facilitating collaborations between WACQT and Finnish quantum technology researchers. In our core project of building a quantum computer, the work with setting up the new 25-qubit platform is in full swing. We hope to test the first 25-qubit chips during the spring. I would also like to mention that WACQT researchers have recently found a faster way to create a wide range of continuous-variable quantum states, including the cubic phase state, a state that has previously not been demonstrated by anyone (read more in the preprint article).

In this 8th newsletter, you can read more about the activities in WACQT and developments worldwide. The theme article in this newsletter deals with quantum coherent interfaces between the microwave and optical domains. Such interfaces are crucial to be able to communicate between superconducting quantum computers and optical quantum communication systems.

I wish you happy reading.

Per Delsing
Director of WACQT

Theme: Conversion between microwaves and light



If several superconducting quantum processors are to be connected into a large quantum computer, one needs to find a way to efficiently convert between microwave and optical photons without losing any quantum information. A new research team is now being formed at Chalmers to solve this challenge.

Read more in the theme article: Conversion between microwaves and light

Picture: Artist impressions of a device converting between microwave (yellow) and optical photons (blue) via gigahertz sound. The superconducting circuit is not shown. This is one example from a vast design space. Credit: R. Van Laer

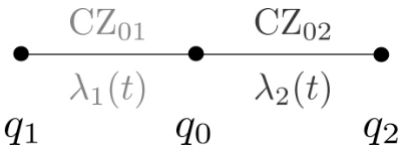
WACQT news

Radio-frequency field reduces noise in superconducting components

The qubits in superconducting quantum computers, like the one engineered at Chalmers, are extremely sensitive – the slightest disturbance impairs performance. For example, minimal defects in the qubit materials give rise to disturbing noise. But recently, a team of WACQT researchers showed that the noise from the defects can be reduced by exposing the materials to a radio-frequency electric field. These new results may play an important role in the production of quantum computers.

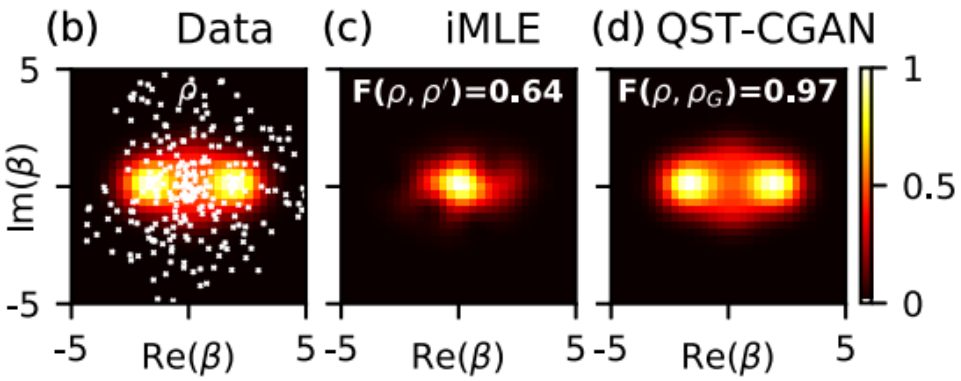
Read more at chalmers.se and in the scientific publication in Science Advances.

Fast multi-qubit gates enhance the performance of quantum computers



Available quantum computers struggle with noise that causes the qubits to quickly forget their values. Therefore, it is desirable to execute the algorithms swiftly.

A team of WACQT researchers have now shown how two-qubit gates can be run simultaneously to create multi-qubit gates, which are more powerful – but still take less time to execute – than the constituent two-qubit gates.
Read more at chalmers.se and in the scientific publication in PRX Quantum.



Machine learning for fast characterization of quantum states

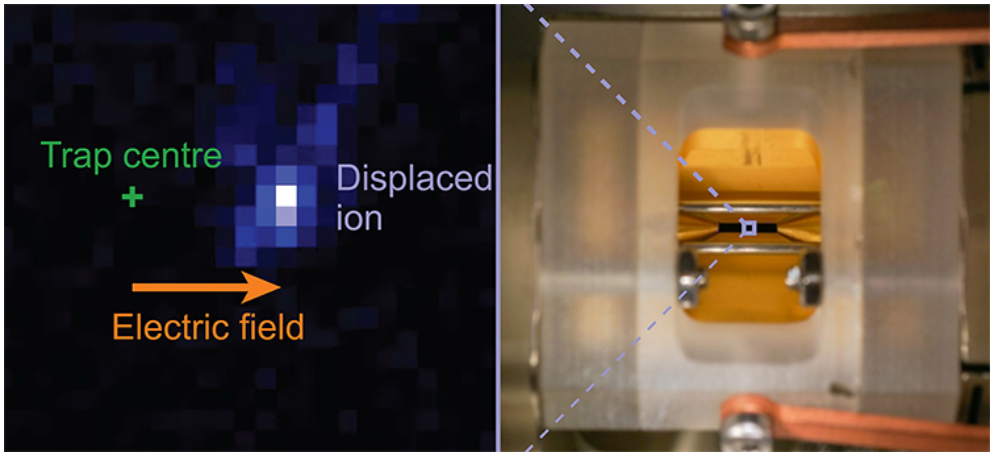
The amazing potential for parallel computing power in quantum computers is enabled by the fact that quantum systems can be in several different states at once – so called superposition. However, the large number of possible states also brings challenges for the characterization and description of these systems – it can take hours to do all the required measurements and reconstruct a full description of a quantum state. Therefore, substantial efforts are made on finding new, clever ways of extracting meaningful information from as few, often noisy, measurements as possible.

In two recent publications, WACQT researchers and a couple of international collaborators now show how a machine-learning technique, more specifically using so-called conditional generative adversarial networks, can be used to characterize quantum states quickly with a few noisy data points.

“Measurement data from a quantum computer is often noisy but can have many features and patterns. Therefore we have trained our neural network to reconstruct quantum states by having it compete with a second neural network, using the conditional generative adversarial network framework,” explains Shahnawaz Ahmed, PhD student at Chalmers and first author of the publications.

The approach resulted in significantly quicker and more reliable reconstruction of quantum states, needing around 100 times fewer iterations and 10 times fewer data points than conventional maximum-likelihood estimation methods.

Read more in Physical Review Letters and in Physical Review Research.



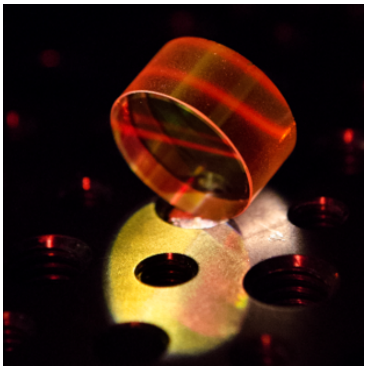
New technique to measure electric forces acting on a trapped ion

Trapping ions by using carefully controlled electrical fields is a method used in precision spectroscopy, atom clocks and prototype quantum computers. However, this platform is sensitive to stray electric fields that reduce performance. Now, researchers at Stockholm University and Chalmers have developed a new technology that can measure the unwanted fields with greater accuracy and precision, and thus compensate for them.

Read more at chalmers.se and in the scientific publication in New Journal of Physics.

Quantum sensing company started in Lund

The WACQT quantum sensing project *Development of instruments for deep tissue clinical imaging with molecular specificity* investigates how quantum structures that reduce the speed of light to a few tens of kilometers per second can be used for enabling optical imaging deep inside the human body.



Slow light crystal

“We hope to be able to measure oxygenation at several centimetres depth in the body, for example in the front cardiac wall and in the brain. This would be very helpful

especially when diagnosing stroke. If it turns out really well, every accident and emergency department would benefit from having such an instrument," says Stefan Kröll, one of the principal investigators of the project and leader of the Quantum Information Group at Lund University.

Therefore, the researchers involved in the project have founded a start-up company – Deep Light Vision AB – together with a business developer, with the goal of developing a commercial oxygenation measurement instrument.
"We are still in a very early phase. Our plan is to have a demonstrator instrument ready in February, which we will test first on phantom objects and later on humans. It's really exciting – seeing that this may become a real, useful product adds an extra dimension to our work," says Kröll.

Read more about the research

Postdoc programme in collaboration with Finland

Knut and Alice Wallenberg Foundation has allocated SEK 15 million for a postdoc programme in collaboration between WACQT and quantum technology researchers in Finland.

"Finland has very strong research in quantum technology and also important companies, for example the dilution refrigerator manufacturer Bluefors and the quantum computing company IQM. We already have good relations with many Finnish research groups, and we expect this postdoc programme to further strengthen our cooperation and that we can jointly solve problems that are too big for a single research group," says Per Delsing, director of WACQT.

Each postdoc project will have two principal investigators, one Swedish and one Finnish. The postdocs, which are to be recruited in the spring 2022, will be employed in Sweden, but spend 25–49 percent of their time in Finland.

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List of projects in the WACQT-Finland postdoc programme

Quantum technology becomes new profile in master's programme

Quantum technology becomes a new specialization profile within the physics master's programme at Chalmers from the autumn 2022. The profile is developed in close collaboration with the WACQT research effort to build a superconducting quantum computer.

"Hopefully, this will result in many more physics students discovering the joy of quantum technology. Today, the industry is both curious and interested, so a master's degree focused on quantum technology can lead to both basic research and work with applications in industry," says Göran Johansson, director of studies for WACQT's graduate school.

KTH already, since 2018, offers a Quantum Technology track in its master's programme in Engineering Physics. Stockholm University started a Quantum Matter track, which includes quantum technology, within its Physics master's programme in 2021.

Read more about the Physics master's programme at Chalmers, the Quantum Technology track at KTH, and the Quantum Matter track at SU.

Quantum computer team days

In November, all research groups that are part of WACQT's core project – to engineer a quantum computer – met during a full day to discuss the status of the different parts of the project, the challenges that the different groups face, and what they need from each other in order to be able to proceed.

"The quantum-computer project is really large now, with several different groups and many new employees. Therefore, we needed a joint meeting with focus on our overall goals. Despite the pandemic, we have made large progress during the past year – that becomes especially visible during a day like this," says Jonas Bylander who leads the engineering of a quantum computer together with Per Delsing.

In December, a similar full-day meeting was held with a focus on quantum algorithms.

"It turned out that we have many interesting quantum algorithms to run when the new, larger chip with 25 qubits is ready to use. Many of these algorithms have been developed in collaboration with our industrial partners. We also look forward to getting our QAL9000 system – a quantum chip available online for theorists to test run algorithms – up and running. That will speed up our work," says theoretical research scientist Anton Frisk Kockum, who is also scientific coordinator of WACQT.

Selected Swedish news

Strengthening the growth of research-intensive start-ups

The Swedish government has commissioned the Swedish Innovation Agency (Vinnova) and the Swedish Agency for Economic and Regional Growth (Tillväxtverket) to improve the conditions for research-intensive startup companies with long development cycles, so-called deep tech, to grow in Sweden. A special focus will be placed on companies that contribute to the green transition and on companies in advanced digitization such as artificial intelligence, microelectronics and quantum technology.

"The Swedish Government's initiative is in line with the agenda of Horizon Europe for 2022–2029, emphasizing the Big Picture of new and emerging technologies. In particular, it coincides with the ramp-up phase of WACQT's core project at Chalmers to build a powerful quantum processor. This requires a wide range of advanced expertise, from cleanroom fabrication of superconducting qubits and quantum circuits, to electronic control systems and software. Start-up companies are mushrooming, especially in the US, and Sweden has

much of the scientific and technological know-how to hang on and compete. What has perhaps been lacking is venture capital and entrepreneurship. This may be changing now, and the Government's initiative is a long-awaited push in a good direction," says Göran Wendin, senior advisor in WACQT.

Read more

Support to commercialisation of quantum technology

The Swedish Innovation Agency, Vinnova, has completed its first call in quantum technology, 'Quantum Kick-Start'. The aim is to support projects which lead to commercialisation of innovative quantum technology. Seven companies were granted funding, the total funding amounting to SEK 9.7 million. Most of the funded companies have a connection to WACQT.

"The funding from Vinnova gives us momentum to start commercialising a sample holder which we have developed in our project of building a large quantum computer," says Robert Rehammar, research scientist within WACQT.

When the quantum computer project was moving on to quantum processors with 20–25 qubits, there were no sample holders for chips with that many qubits available on the market. Therefore, Robert Rehammar and three colleagues designed and built one themselves. Apart from mechanically holding the chip, the holder also provides electrical contact for microwave signals to each qubit, and shields the chip from electromagnetic radiation and magnetic fields.

"As groups and companies all over the world start to build big quantum computers, there will surely be a need for a device like this," Rehammar predicts.

The present version of the sample holder can take chips with up to 25 qubits, but the design can be scaled up. The money from Vinnova will mainly be used for business development to start building a company and analyse the market.

Read more about Vinnova's Quantum Kick-Start call

Selected world-wide news

Quantum memory reduces the need for qubits in computations. Research on quantum memory – units for storing quantum information – has so far largely focused on its use in quantum communication and networks. Now, two French researchers have investigated its use in computations. They found that a quantum computer architecture incorporating a quantum memory could perform calculations with three orders of magnitude fewer qubits in its processor than standard architectures require, however at the cost of 500 times longer computation time.

"This is an interesting alternative approach worth investigating further. The hope is that the increased computation time can be made lower by refined versions of this pioneering

study," says Giulia Ferrini, one of the principal investigators for quantum computing within WACQT.

Read more in Physics and in Physical Review Letters.

IBM and Rigetti unveil new, large quantum processors. In November, IBM announced its new 127-qubit superconducting quantum processor, namned 'Eagle'. It is the first processor available online with more than 100 qubits. IBM's previously largest processor has 65 qubits. The significant increase in the number of qubits was enabled by placing the control wiring on multiple physical levels within the processors while keeping the qubits on a single layer, according to a press release from IBM.

In December, Rigetti Computing announced its new-generation superconducting quantum computer, a processor with 80 superconducting qubits. The processor, which builds on Rigetti's proprietary multi-chip technology, is assembled from two 40-qubit chips.

"This is good progress. It's a hard engineering problem to scale up the size of the quantum processors while keeping very good qubit performance. But don't forget that neither group has demonstrated that they can use all of the qubits on the chip within a quantum algorithm, though. That is much harder than showing many qubits with individually good performance," says Jonas Bylander, one of the leaders of WACQT's quantum-computer project.

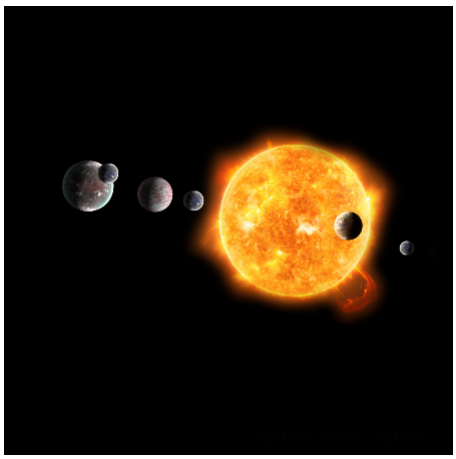
Second pure-play quantum computing company to go public. Rigetti Computing, an American company building superconducting quantum computers, is the second pure-play quantum computing enterprise to be traded on the stock exchange. The company goes public via a so-called special-purpose acquisition company (SPAC), and is valued at approximately USD 1.5 billion.

"This is the latest step in a development that seems to be leading towards a situation with about 10 large, well-funded manufacturers of quantum hardware. The competition between these companies is likely to be fierce; I hope and believe that this will speed up the emergence of useful quantum computers," says Anton Frisk Kockum, scientific coordinator of WACQT.

The first pure-play quantum computing company to go public was the trapped-ion quantum computing company IonQ, as reported in WACQT Newsletter #6 in 2021. The value of the IonQ share soared just after the introduction on the stock exchange, but then fell back to around the initial price.

Read more in Rigetti's announcement

Quantum imaging can help finding exoplanets. Planets outside our own solar system– exoplanets – are very hard to directly image, as the dim light scattered from these planets is hard to recognise amid the glare of the parent star. However, researchers in Australia and the UK now predict that quantum imaging could significantly improve the chances of directly detecting an exoplanet. Their approach is to treat the task as a problem of discriminating between two quantum states, where the two quantum states "star plus planet" and "star



Artist's conception of the Delta Pavonis system with its theorized planets.
Pablo Carlos Budassi

only" are linked to the spatial distribution of detected photons collected by a telescope.
"Interestingly, the approach is not only limited to detecting weakly emitting objects close to a strong emitter in astronomy, but should equally well be applicable to equivalent imaging complications in general, for example in microscopy," says Stefan Kröll, principal investigator for quantum sensing within WACQT.

Read more in Physics and in Physical Review Letters.

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