WACQT - Wallenberg Centre for Quantum Technology Newsletter #10, 2022

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Dear reader,

As you know, within WACQT, we are working hard to   nd solutions to real problems using quantum technology. In this letter you can   nd several articles stretching from photon sources to new architectures for error correction of quantum computers.

Applications of quantum technology is one of the focuses of WACQT and we are now seeing several spin-o   companies being started in the quantum technology area by WACQT researchers. Below you can read about two of the six companies that have recently been started.

We also feel strongly that Sweden needs to coordinate activities in the quantum technology area and form a national strategy for quantum technology. To this end we are taking part in di   erent meetings both nationally and internationally. One of the articles describes the meeting that was held in Washington this spring and another the visit of the minister of education, Anna Ekström.

Per Delsing

Director of WACQT

WACQT news

Quantum meeting in the White House

In May, the U.S. hosted a roundtable meeting with its eleven partner countries in quantum technology: Canada, Japan, Australia, Sweden, Denmark, Finland, the Netherlands, Switzerland, Germany, France, and Great Britain.

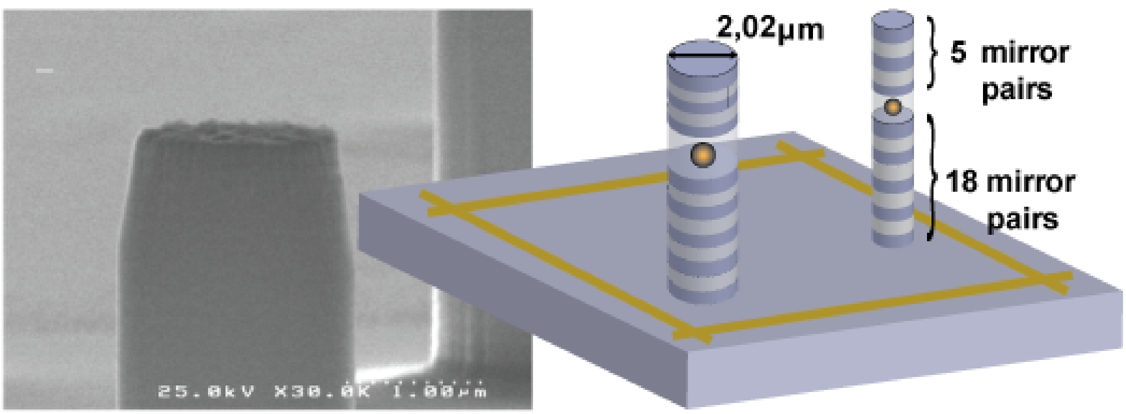
WACQT director Per Delsing was invited as one of two representatives from Sweden to attend the meeting (the other was Birgitta Modig from the Ministry of Foreign A airs), which serves as a recognition of the impact of WACQT.

The meeting started with all countries presenting their national strategies for quantum technology.

“Sweden has no strategy, which became clear to everyone in the meeting. Hopefully, this will hurry the government to create one. A national strategy is important to coordinate Swedish e orts in quantum technology. Also, KAW should not bear all the nancing,” says Per Delsing.

The roundtable meeting continued with discussions on collaboration with industry, education, and outreach.

“The idea was to learn and borrow good ideas from each other,” says Delsing.



Novel, highly e cient photon-pair source

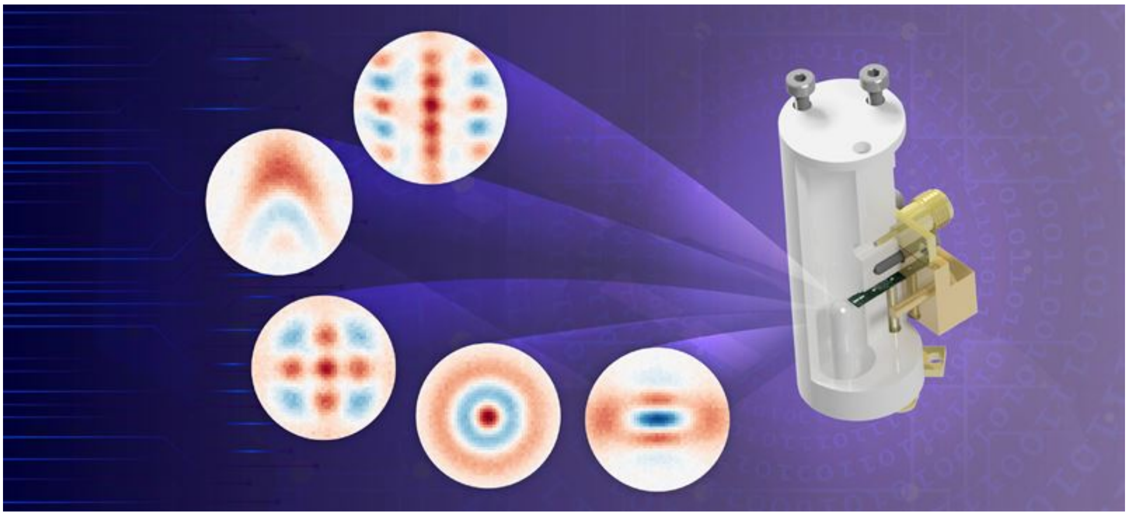
Sources of entangled photon pairs are a key enabler of quantum communication with applications in both fundamental quantum science as well as in quantum technologies. A team of researchers at Stockholm University has now demonstrated a photon-pair source – a quantum dot inside a tiny so-called micropillar cavity – with one of the highest e ciencies ever demonstrated. Also, it is simpler to manufacture than similarly e cient sources based on quantum dots.

“Usually, a lot of e ort is placed on getting high enhancement in the cavity. However, we have looked a bit deeper into the physics and concluded that very high-performance structure can also be achieved by suppressing the light modes outside the cavity. This gives the photon pairs, so to say, no choice but to leave via the cavity,” explains Ana Predojević, who led the work.

These new insights resulted in a broadband, easily manufacturable micropillar cavity suitable for extraction of entangled photons and with almost 70 percent e ciency.

“Our next step is trying to improve on this result. We already got an excellent e ciency number, but we know that we can get out a few percent more by slightly modifying the design of the micropillar cavity,” says Predojević.

Read more at the Stockholm University website and in Physical Review Letters.

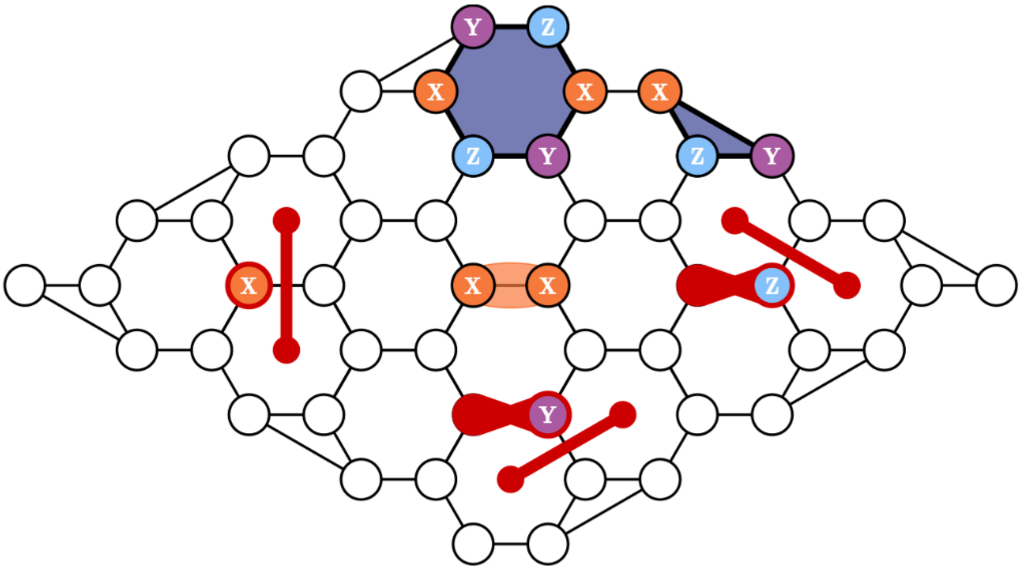


Unprecedented control over captured light

A team of WACQT researchers have succeeded in developing a technique to control quantum states of light in a three-dimensional cavity. In addition to creating previously known states, the researchers are the rst ever to demonstrate the long-sought cubic phase state. The breakthrough is an important step towards e cient error correction in quantum computers.

“We have shown that our technology is on par with the best in the world,” says Simone Gasparinetti, one of the study’s senior authors.

Read more at Chalmers website and in PRX Quantum.



Honeycomb structures allows for e cient error correction

Quantum computers are much less tolerant to noise than classical computers. Qubit state errors tend to occur frequently and must be handled in order not to ruin the computations. The most common approach for error correction is to encode each logical qubit in several physical qubits, which are compared to each other in repeated local measurements. Most commonly, the physical qubits are placed on a square lattice, but honeycomb (hexagonal) lattices are also considered interesting.

A team of WACQT researchers has now investigated a new error-correction code – which they named the XYZ2 code – implemented on physical qubits on a nite honeycomb grid. The team showed that the code worked well, especially for biased noise, and concluded that quantum computers with hexagonal qubit structures may provide an advantage over square lattice structures.

"We hope that this code that can be implemented at WACQT," says Mats Granath, who led the work.

Read more in their publication in Quantum.

Quantifying qubit magic

One of the resources that give a quantum computer advantage over classical computers is referred to as "magic". Attaining magic can be more complicated than just using superposition or entangled quantum states and computing the magic of a qubit system is a di cult task, yet very valuable as it is a measure of how powerful the quantum computer is.

Now a group of WACQT researchers have come up with a new magic measure, by mapping qubit states into the continuous-variables states of a harmonic oscillator using so-called bosonic error correction codes, more speci cally the Gottesman-Kitaev-Preskill encoding.

"We ended up with a magic measure that can address systems of up to 12 qubits on a regular laptop, compared to the typical limit of 5 qubits for previous measures. We have also been able to connect our magic measure to known magic quanti ers, such as the st-norm, which promotes the latter to a fully- edged magic measure," says Giulia Ferrini who led the project together with Laura García-Álvarez.

Read more in the publication in Physical Review Letters.

Noisy measurements impair error correction

Due to the sensitivity of quantum systems, it is likely that errors occur during the execution of an algorithm in a quantum computer. Therefore, quantum error-correcting codes are used to identify and correct the errors while the algorithm is run. However, the performance of a broad class of such codes, so-called rotation-symmetric codes, has only been examined to date using an idealistic noise model.

A team of WACQT researchers has now assessed the performance of di erent realistic measurement schemes to shed light on their role when decoding the information. They found that extraction of information during error-correction protocols limit the reliable operation of continuous-variable quantum computers.

"Our results show that highly e cient measurement protocols are instrumental for error-corrected quantum information processing with bosonic continuous-variable systems," says Giulia Ferrini, leader of the theoretical e orts in continuous-variable quantum computing within WACQT.

Read more in PRX Quantum.

May meeting with the Scientific Advisory Board

Every year in May, WACQT has a two-day evaluation – with presentations from the entire WACQT – and a one-day symposium with its Scienti c Advisory Board (SAB). Almost 100 persons attended the meeting.

In its evaluation report, the SAB wrote that "WACQT – now in its fth year – has made remarkable progress in its goal to develop quantum technologies and to build a quantum this progress, especially in the light of the challenges due to COVID-19 over the past two year. ... The QAL9000 is now online and has been successfully operated remotely. In addition, the Center has developed 3D integration technology that will form the foundation for the 20-qubit chip and beyond."

The SAB also provided advice and suggestions, for example to create a strategic plan jointly between theory and experiment to set target performance metrics that the qubits and gates need to reach.

"We listen to their advice and incorporate them in our plan for the next year," says Per Delsing, WACQT director.

Quantum outreach at Vetenskapsfestivalen and UR Play

This year, WACQT researchers Anton Frisk Kockum, Raphaël Van Laer, and Witlef Wieczorek all gave popular science talks at Gothenburg's annual science festival, Vetenskapsfestivalen. The talks were lmed by Utbildningsradion and are available on UR Play via the links below.

- Vad är kvantteknologi? by Anton Frisk Kockum
- The quantum internet by Raphaël Van Laer
- What is quantum sensing? by Witlef Wieczorek

Spin-o company aiming for fault-tolerant quantum computers

Atlantic Quantum is a spin-out of MIT and Chalmers, headquartered in Cambridge, Massachusetts, with activities in Gothenburg. The company aims to develop fault-tolerant quantum computers based on superconducting qubits, however of a somewhat di erent type than those currently used at WACQT.

"Atlantic Quantum's mission is to develop much better hardware than what's available today, as this is the bottleneck for quantum computers. The fast-paced work in our engineering team is focused on a single common goal — building fault-tolerant quantum computers. Within the academic research at WACQT, on the other hand, we can take larger risks and explore more long-term research questions, which may lead to new breakthroughs," says Jonas Bylander, co-founder of Atlantic Quantum and WACQT principal investigator.

Within Atlantic Quantum he is responsible for the manufacturing of quantum processors and to secure some funding. The company recently secured a SEK 95 million seed investment, money which will fund the expansion of Atlantic Quantum's team both in the U.S. and Sweden.

Read more in The Quantum Insider, at the Atlantic Quantum website, in Ny Teknik (in Swedish and behind paywall), and in Dagens Industri (in Swedish).

Minister for education visited WACQT

As reported in WACQT Newsletter #9, the Swedish minister for education, Anna Ekström, signed a joint statement on quantum information science and technology with the US ambassador in April. By the end of August, she came for a half-hour visit at the quantum computer project at WACQT.

“She was interested and expressed herself positively about what we are doing,” says Per Delsing, director of WACQT.

WACQT company commercialises intellectual property

A company – WACQT-IP – has been formed to secure and commercialise intellectual property (IP) created within WACQT.

“For researchers who don’t have the interest or resources to commercialise their ideas themselves, WACQT-IP is a very good alternative,” says Mats Rydehell, operational manager of WACQT-IP.

Researchers who join WACQT-IP transfer the right to their intellectual property within quantum technology to the company. WACQT-IP then handles and takes all expenses for any patent applications, while the researcher gets a monetary kickback. After some analysis, a decision is taken on whether the patent is to be sold, licenced, or if a spin-o company is to be started. In the case of a spin-o , the researcher is o ered to start it.

“Working with IP could also strengthen one’s research. Having patented is a merit and it gives you increased knowledge about the research going on in industry. You could also join WACQT-IP without having any ideas to patent, just to bene t from the long-term increase in value of the company,” says Rydehell.

To date, 33 researchers have joined WACQT-IP. The company is owned to 70% by the participating researchers, and to smaller extents by Chalmers Holding and the Wallenberg company Navigare Seed.

For more information, please contact Mats Rydehell.


Two WACQT researchers appointed Research Leader of the Future

The Swedish Foundation for Strategic Research has appointed 16 new “Research Leader of the Future”. The selected researchers receive a grant of SEK 15 million each over a ve-year period, as well as leadership training. Among the appointed Research Leaders of the Future are two WACQT researchers at Chalmers: Anton Frisk Kockum with the project “Quantum simulation and communication with giant atoms” and Raphaël van Laer with the project “Attojoule-per-bit acousto-optics”.

Read more

Science writer becomes part of WACQT

Ingela Roos, a science writer who has previously worked for WACQT on a freelance basis, has now been employed part-time. She has a degree in engineering physics, with a master’s thesis in quantum computing, and a master’s degree in science journalism.

Ingela is located at Chalmers and can be reached at ingela.roos@chalmers.se or 031-772 5066.

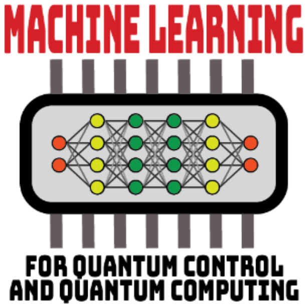
Selected Swedish news

Nobel Symposium on quantum technology. In August, a Nobel Symposium on emerging quantum technologies, partly funded by WACQT, was held in Malmö. A Nobel Symposium is an international conference – approved by the Nobel Foundation – at the highest scienti c level, with invited speakers and audience.

“The list of speakers was impressive – international top researchers tend to accept when they get an invitation to a Nobel Symposium. I was really impressed to hear about the progress in reducing the size of trapped-ion quantum computers,” says WACQT director Per Delsing, who chaired one of the sessions on quantum computing.

The energetic footprint of quantum technologies has so far been a non-question. But at the symposium, Alexia Auffèves, head of Quantum Engineering Grenoble, presented a transverse quantum energy initiative to create a path towards energy-efficient, sustainable quantum technologies.

"This is an excellent initiative, to make sure that the solutions emerging from the world-wide effort on quantum technology will contribute to a sustainable use of our resources and not the opposite," says Göran Johansson, WACQT principal investigator and chair of a theory and software session.



Nordita workshop on machine learning and quantum technology. The five-day workshop Machine learning for Quantum Control and Quantum Computing gathered researchers and PhD students at the Nordic Institute for Theoretical Physics, Nordita, in Stockholm at the end of August. Two WACQT researchers were in the organizing committee, two were invited speakers, and WACQT also supported the event financially.

Quite a few people from WACQT attended the workshop, for example the industrial PhD student David Fitzek at Volvo, whose doctoral work is about exploring the connection between quantum computing and machine learning, in both directions.

"There were many good discussions during the workshop, as well as ideas about future collaborations," says Anton Frisk Kockum, one of the researchers on the organization committee and scientific coordinator at WACQT.

New funding calls from Vinnova. After a first, successful call in quantum technology in 2021, the Swedish Innovation Agency now has two new quantum technology calls (both of them mention WACQT in the call text):

Quantum Step-up 2022 has the purpose to stimulate and support innovative project from small and medium enterprises for commercialization of quantum technology. The funding amounts to maximally one million SEK per project, and the application deadline is October 4.

Quantum Sweden Feasibility studies has the purpose to stimulate pilot studies that will lead to a Swedish platform for sustainable innovation with quantum technology. The funding amounts to maximally 500 000 SEK per study, and the application deadline is October 5.

"We received support in the previous Vinnova call, and it really gave us a kick-start on our commercialization idea. Our project resulted in the start-up company Scalinq which is now rapidly transforming into a new business in the quantum market," says WACQT researcher Robert Rehammar.

Selected world-wide news

Xanadu's Borealis beats classical computers. The newest photonic quantum computer of the Canadian company Xanadu – Borealis – has recently proven to computationally beat classical supercomputers at a task called Gaussian boson sampling. The task was estimated to take more than 9000 years for the best supercomputer, but only required 36 μs from Borealis. This is the first time a dynamically programmable, photonic quantum computer demonstrates quantum computational advantage, as reported in a Nature paper.

In contrast to other quantum computers which have attained quantum computational advantage, Borealis is publicly accessible via the cloud.

“The increase in the number of input squeezed states as well as in the photon-resolving detecting capability that are demonstrated in this work is really significant as compared to previous Gaussian boson sampling experiments, and makes the case for quantum advantage even more convincing,” says Giulia Ferrini, one of the principal investigators for quantum computing within WACQT.

Read more at the Xanadu website.

Rydberg atoms solve optimisation problem. Realizing quantum speedup for solving practical, computationally hard problems is a central challenge in quantum information science. A team of researchers mainly from Harvard University, USA, has now used arrays with up to 289 Rydberg atom qubits – each trapped at the focus of a laser beam – to experimentally investigate quantum algorithms for solving a hard combinatorial optimization problem called the “maximum independent set”.

On the hardest instances of the problem, they could observe a superlinear quantum speedup in solving the problems compared to classical computers, the team reports in Science. According to an accompanying Perspective article, the demonstration is a milestone in the broad effort to understand which computational problems stand to benefit from quantum computers.

NIST announces post-quantum cryptos. Future quantum computers are expected to be able to break the encryptions used in e.g. online banking and email software today. Therefore, large efforts are made on finding new encryption methods. After a six-year long competition, the U.S. National Institute of Standards and Technology (NIST) now announces four encryption methods designed to resist an attack from a future quantum computer. The selected algorithms will become part of NIST’s post-quantum cryptographic standard, which is expected to be finalized in about two years.

“This is very important work, to make sure that we can communicate both openly and securely also after quantum computing is realised,” says Göran Johansson, principal investigator in WACQT.

However, shortly after the announcement, Ars Technica reported that one of the selected back-up algorithms was shown to be easy to break for a classical computer.

Read more at the NIST website.

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