



Research Center for Quantum Software

ANNUAL REPORT 2020

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UNIVERSITEIT VAN AMSTERDAM



Centrum Wiskunde & Informatica



EXECUTIVE SUMMARY

Before you lies the annual report 2020 by QuSoft. You can read in detail all the activities that were undertaken and results that were achieved.

The main take aways are:

- ◉ QuSoft has grown to a thriving community of 71 people coming together to work on excellent and innovative quantum research.
- ◉ QuSoft has actively contributed to bring quantum research to a national priority. Resulting in the National Agenda for Quantum Technology (NAQT). Already six new research positions started as a result of this in close collaboration with industry and societal organisations.
- ◉ Over a 100 research papers were published by QuSoft and there were three successful PhD defences.
- ◉ QuSoft is a driving force behind multiple high-impact initiatives on a national scale, like: The Quantum Software Consortium, innovation hub Quantum.Amsterdam and diversity platform 'Women in Quantum Development'.
- ◉ On an international scale QuSoft expands its collaboration, e.g. in Quantum Leap Africa and the Turing Chair.

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INTRODUCTION ANNUAL REPORT

On behalf of all colleagues within QuSoft, we are proud to present the annual report for 2020.

At QuSoft, we work together on radically new software and technology with world-changing potential: based on the fundamental laws of quantum physics, we aim to keep up our excellent track record in quantum computing and quantum information. And to explore and develop uses of quantum computers and other quantum technologies at large, for the benefit of society.

Quantum technology is labelled by the Dutch government as a key technology because it is considered a potential

game-changer in many social and economic sectors, including health, agriculture, climate, and safety.

This report presents a brief overview of what we achieved in 2020, in terms of research, collaboration and community building, education and outreach, and people and prizes. We are happy to report strong results.

We hope you will enjoy reading this annual report.

Victor Land & Yvonne Smit



FOREWORD BY DIRECTORS QUSOFT

On March 12 2020, those of us present at the QuSoft hub at CWI discussed the rapidly progressing Corona pandemic, and we decided to cancel our regular QuSoft seminar scheduled for the day after: Friday the 13th. During the rest of 2020, we had to make do with difficult circumstances and concerns for how the pandemic affected colleagues, friends and family and how the necessary precautions disrupted our research and teaching.

Despite all this, we managed to stay close as a group and to get many things done. The weekly on-line QuTea sessions provided a substitute for our daily contacts and after some time we managed to reinstate activities such as the QuSoft seminars using on-line platforms. For long we hoped that the festivities for the first QuSoft lustrum could take place as planned. While this hope had to be abandoned, the on-line lustrum events were a true and worthy celebration. Many thanks to all who made these initiatives possible.

During 2020 we saw a healthy growth of QuSoft as a research centre, an important strengthening of the support QuSoft team, the signing of the QuSoft collaboration agreement, and the start of the foundation Quantum Delta NL and of the innovation hub Quantum.Amsterdam. We look forward to the continuing development of QuSoft, which hopefully soon will open its door again for physical meetings, but above all to a bright and prosperous quantum future!



**HARRY BUHRMAN &
KARELJAN SCHOUTENS**



KEY ORGANISATIONAL DEVELOPMENTS IN THE LAST YEAR INCLUDE:

- QuSoft is a partner in Quantum Delta NL and shares in the initial investment (Startsubsidie) of 23.5 ME, which was awarded in early 2020 to make a start with the implementation of the National Agenda Quantum Technology.
- The new quantum innovation hub founded by QuSoft, Quantum.Amsterdam, was launched in May 2020. From that point on multiple events were organised varying from public meetups to a collaboration with all Dutch Banks in the form of a general awareness workshop in quantum computing.
- On September 30, 2020, after five years, director of CWI, Jos Baeten and Peter van Tienderen, dean FNWI, signed the agreement that continues the collaboration between CWI and UvA governing QuSoft.
- Finally, we celebrated five years of excellent, innovative and fundamental research done and made possible by all our colleagues at QuSoft. During our one-month **lustrum event**. The aim was to showcase every aspect of QuSoft to a broad audience - from companies to scientists and policymakers. We can conclude it was a big succes with more than 500 attendants.



ABOUT QUSOFT

Researchers at QuSoft perform excellent, foundational and multidisciplinary research in the science domains of Physics and Chemistry, Mathematics and Computer Science, but also potential other research areas on the topics of quantum simulation, quantum information sciences and cryptography.

The overarching challenge for QuSoft is to harness the power of quantum information, through the study of quantum information science and the development of new protocols, algorithms and applications that can be run on small to full-scale prototypes of a quantum computer.

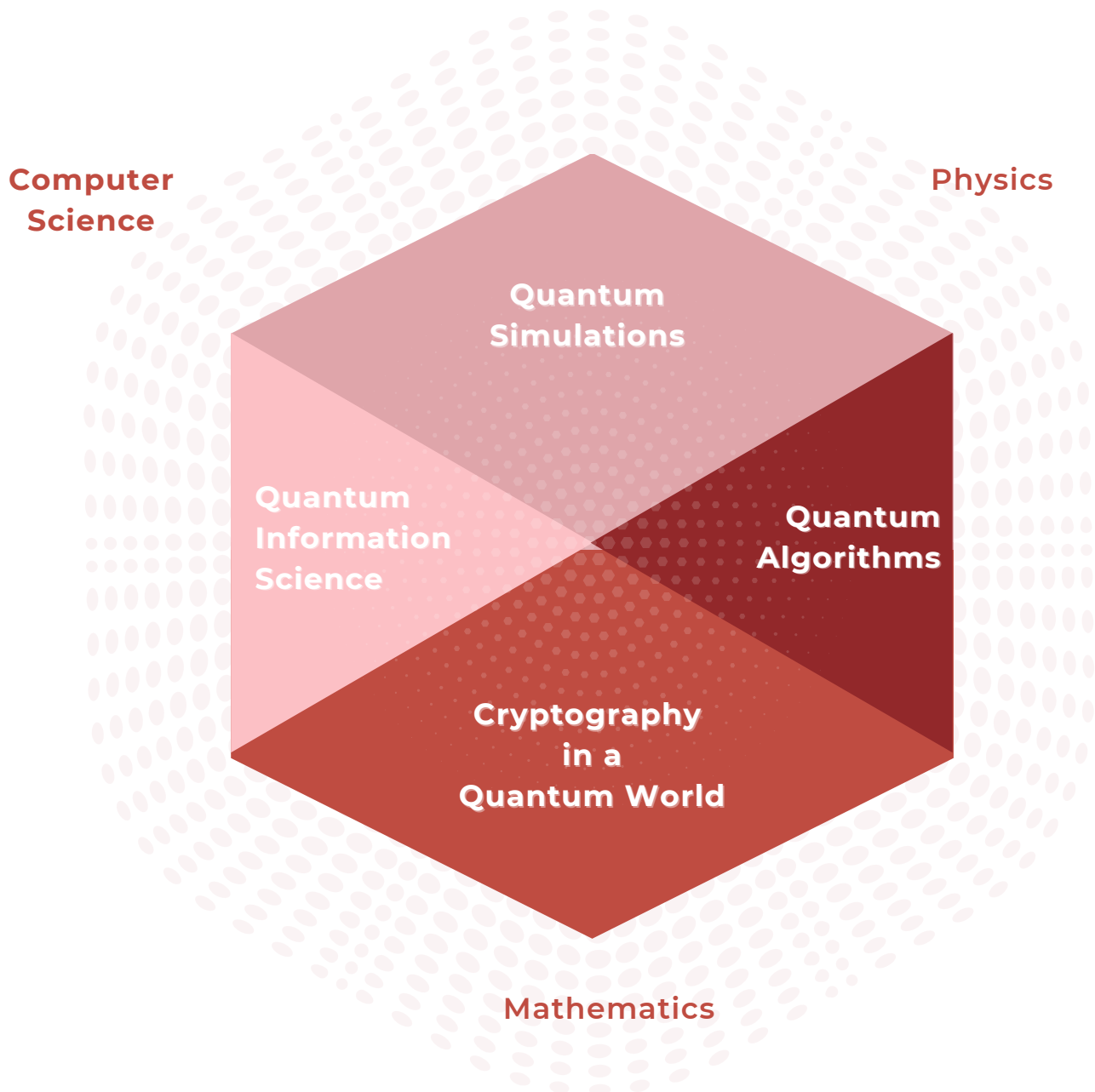
The research at QuSoft can be divided into four lines:

- Quantum Simulations
- Quantum Information Science
- Cryptography in a Quantum World
- Quantum Algorithms

In the following chapter research highlights per research line are presented. Over 2020 more than 100 research papers were published by affiliated researchers of QuSoft.

"QuSoft has an excellent track record in quantum computing and quantum information" - Anonymous referee

QUSOFT'S RESEARCH LINES VISUALIZED IN A DIAMOND





QUANTUM SIMULATIONS

This research area addresses applications of small and medium-sized qubit platforms (10-100 qubits). In quantum simulation one uses such systems as analogue versions of quantum computers, allowing the study of problems in quantum chemistry and material science, among others. Few-qubit algorithms implemented on 50 or more qubits quickly become intractable for classical computers. This research line also addresses multi-qubit dynamics and quantum control, with applications in the design of quantum registers and in quantum many-body physics.

RESEARCH HIGHLIGHTS

- Single-step implementation of high fidelity n-bit Toffoli gate.
 S. E. Rasmussen, K. Groenland, R. Gerritsma, K. Schoutens, N. T. Zinner. Phys. Rev. A 101, 022308 (2020), <https://arxiv.org/abs/1910.07548>
- Signal processing techniques for efficient compilation of controlled rotations in trapped ions.
 Koen Groenland,, Freek Witteveen, Kareljan Schoutens and Rene Gerritsma 2020 *New J. Phys.* 22 063006, <https://iopscience.iop.org/article/10.1088/1367-2630/ab8830>
- Florian Schreck and his team, Chun-Chia Chen, Rodrigo González Escudero, Jiří Minář, Benjamin Pasquiou, Shayne Bennetts, submitted one major result: "An ultracold Bose-Einstein condensate in steady state", <https://arxiv.org/abs/2012.07605>
- Florian Schreck and his Strontium Quantum Gas team trapped ultra cold atoms in optical tweezers and recently proved that these are indeed single atoms. More information is found here <http://www.strontiumbec.com>



QUANTUM INFORMATION SCIENCE

This research line addresses the broad range of insights and questions that arise as soon as information is processed according to the rules of quantum mechanics. Reasoning based on quantum notions such as superposition and entanglement leads to applications in computer science, mathematics, logic and physics that do not always need an actual physical device. Some successful examples: an optimal algorithm for matrix multiplication, solving problems in operator algebras and functional analysis, and error-correcting codes. In the realm of physics, quantum information can be used in the study of non-locality, quantum thermodynamics, condensed matter systems, and even the structure of space-time itself. This research line also addresses quantum network and communication protocols, and distributed quantum computation. We study quantum-classical systems as well as architecture, interfaces and control.

RESEARCH HIGHLIGHTS

- A converse to Lieb-Robinson bounds in one dimension using index theory
Daniel Ranard, Michael Walter, Freek Witteveen. arXiv:2012.07605 (2020), <https://arxiv.org/abs/2012.00741v1>
- Quasirandom quantum channels
Tom Bannink, Jop Briët, Farrokh Labib, and Hans Maassen. *Quantum* 4, 298 (2020), <https://doi.org/10.22331/q-2020-07-16-298>, [arXiv:1908.06310v3](https://arxiv.org/abs/1908.06310v3)
- Multipartite Entanglement in Stabilizer Tensor Networks
Sepehr Nezami and Michael Walter. *Phys. Rev. Lett.* 125, 241602 – Published 10 December 2020, <https://arxiv.org/abs/1608.02595>



CRYPTOGRAPHY IN A QUANTUM WORLD

This research line is double-edged. One edge, known as post-quantum cryptography, is the development of cryptography that is difficult to break for attackers armed with large quantum computers. The goals are to improve existing schemes for this, to develop new efficient quantum-safe protocols and to analyse attacks that can be run on large quantum computers. The other edge, known as quantum cryptography, is the design and investigation of protocols

SELECTED RESEARCH HIGHLIGHTS

- Secure Multi-party Quantum Computation with a Dishonest Majority
Yfke Dulek, Alex B. Grilo, Stacey Jeffery, Christian Majenz, Christian Schaffner
In Advances in Cryptography -- EUROCRYPT 2020 (pp. 729-758). Lecture Notes in Computer Science, vol 12107. Springer, Cham. DOI: 10.1007/978-3-030-45727-3_25
- Breaking the decisional Diffie-Hellman problem for class group actions using genus theory. Wouter Castryck and Jana Sotáková and Frederik Vercauteren.
Crypto 2020, Best Paper Award
- QuSoft had a (very) strong presence at the "Quantum Wave in Computing," program held at Simons Institute at UC Berkeley: Chris Schaffner was invited Visiting Scientist in 2020. Yfke Dulek, Alex Grilo were Simons research fellows, as well as Andras Gilyen (ex student of Ronald de Wolf). Stacey Jeffery co-organized two important workshops: quantum algorithms, and quantum cryptanalysis and post-quantum cryptography. More information can be found here <https://simons.berkeley.edu/people/fellows?program=10558>
- At QIP 2020 four presentations were programmed with (co)authors from QuSoft: Stacey Jeffery, Christian Schaffner, Serge Fehr, Christian Majenz and Alex Bredariol Grilo. A total of five presentations were selected with QuSoft (co)authors.
- Stacey Jeffery had an interview in the popular science magazine De Ingenieur with the title "REKENREGELS VOOR QUANTUMCOMPUTERS" and can be found here <https://www.deingenieur.nl/artikel/rekenregels-voor-quantumcomputers>



QUANTUM ALGORITHMS

Which computational tasks are amenable to quantum speed-up? This research line addresses this fundamental question and develops and investigates new quantum algorithms. This activity is focused on the many-qubit regime, where full-fledged error correction and fault tolerant computation becomes possible. Important research questions are the verification and debugging of quantum algorithms – the very nature of quantum computing preempts methods known from classical computer science and calls for fundamentally new strategies and protocols.

RESEARCH HIGHLIGHTS

- Simon Apers and Ronald de Wolf, "Quantum speedup for graph sparcification, cut approximation and Laplacian solving", *FOCS2020 - 61st Annual IEEE Symposium on Foundations of Computer Science* (637-648), doi:10.1109/FOCS46700.2020.0065
- H. Buhrman, S. Patro, F. Speelman. A framework of Quantum Strong Exponential-Time Hypothesis. *15th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC'20)*, 2020. [arXiv:1911.05686](https://arxiv.org/abs/1911.05686). See also: THEORY DISH, Stanford's CS Theory Research Blog.
- QIP 2020 presentation Anurag Anshu, Naresh Goud Boddu, Makrand Sinha, Dave Touchette and Ronald de Wolf. *Exponential Separation between Quantum Communication and Logarithm of Approximate Rank*.
- Interview with Harry Buhrman for the national newspaper 'Volkskrant' written by George van Hal and published on March 13, 2020 with the title 'Radicaal nieuwe supercomputer zoekt naar nuttige toepassing'



ORGANIZATION

QuSoft is not a legal entity, but a collaboration between University of Amsterdam (UvA) and Centrum Wiskunde & Informatica (CWI) which is governed by the "Samenwerkingsovereenkomst QuSoft".

Since 2015, QuSoft has grown into a leading research institute where 71 scientists of the UvA and CWI work together on fundamental and multidisciplinary quantum research.

On September 30, 2020, after five years, director of CWI, Jos Baeten and Peter van Tienderen, dean FNWI, signed the agreement that continues this collaboration.

"I am very glad that nine years ago, when I started as director of CWI, Harry Buhrman convinced me to invest in his idea of a new research institute for quantum software" - Jos Baeten.

Back in 1996, CWI started research in quantum computing. It was among the first groups worldwide to pioneer this field. Currently, this research resides in CWI's Algorithms and Complexity group, headed by Prof. Harry Buhrman. Other specialised research on quantum condensed matter theory was already done by the Theoretical Physics Group of the University of Amsterdam, headed by Prof. Kareljan Schoutens.

Nowadays, quantum research in Amsterdam is bundled in the QuSoft research center, which is hosted at CWI. This agreement underlines the fact that all parties feel the commitment and urgency to further develop quantum software and applications together. The results we have achieved up until now certainly motivates us to further explore the future that quantum computing has in store

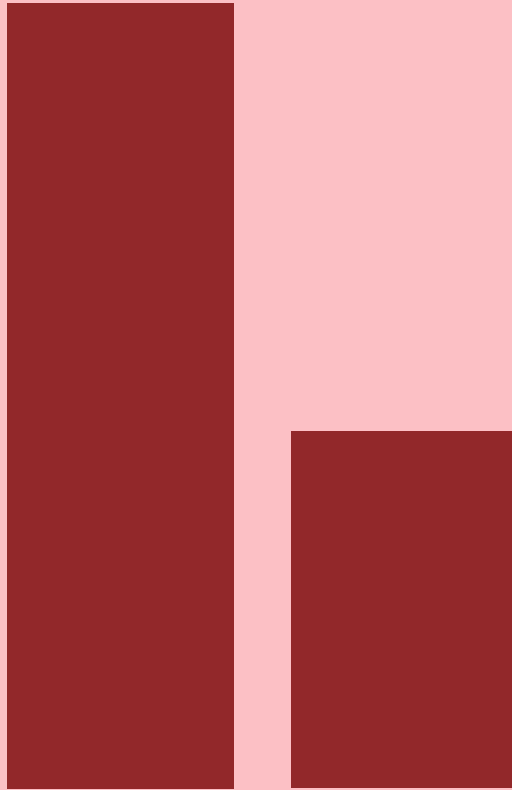
INSTITUTE

67.6%

of QuSoft's affiliated staff are employed by the University of Amsterdam (UvA). The number of UvA colleagues is 48.

32.4%

of QuSoft's affiliated staff are employed by Centrum Wiskunde & Informatica (CWI). The number of CWI colleagues is 23.



GENDER

84.5%

*Male
(60 out of 71)*

15.5%

*Female
(11 out of 71)*



NATIONALITY

54.9%

*Dutch
(39 out of 71)*

45.1%

*Non-Dutch
(32 out of 71)*





COLLABORATION AND COMMUNITY

Quantum technologies are complex. So complex, that no single research group or organization can realize the promise of quantum computing alone. Collaboration is essential for innovation, and leaders from academia and industry are looking to work together to realize the promise of quantum computing. In 2020, QuSoft worked hard on strengthening its community of collaborators.

"Even though we have known for decades that some real-world business problems could be solved by quantum computers, it is still unclear whether they can offer an advantage over conventional computers for most industrial problems. That is why it is so great that scientists are working together with companies to identify industrial use cases. We are very excited to be developing new and more industrially relevant quantum algorithms." - Harry Buhrman

WORKING TOGETHER WITH INDUSTRY

QUSOFT & ABN AMRO

Project DisQover is a two-year collaboration between QuSoft and ABN AMRO that explores potential applications of quantum computing in the financial industry. DisQover aims to do the following: identify the complex computing problems ABN AMRO is currently tackling or would like to tackle in the near future as part of the financial services they provide, and research if and how these problems can be solved more efficiently on a quantum computer.

QUSOFT & BOSCH

QuSoft is working together with the Bosch Group in a two-year collaboration. The goal is to investigate potential quantum computing use cases at Bosch. The topics range from optimization, which has many applications in product design and logistics, to machine learning. The collaboration involves an exploratory study of the use cases, as well as in-depth analysis and proof-of-concept simulations of the most promising applications.

QUSOFT & ATOS

Knowledge partner QuSoft and business partner Atos joined forces in a new collaborative course “Quantum in Business and Society”. Quantum in Business and Society discusses the benefits that quantum technology can offer, but also the dangers. The focus is on developing new use cases, engaging business markets & the challenges and knowledge gaps that companies are currently experiencing. It teaches students to transform academic knowledge into useful use cases for business.

QUANTUM INNOVATION

Since May 2020, Koen Groenland is the Quantum Innovation Officer for QuSoft, and therefore focused on making our academic research useful for society at large.

As a research institute, QuSoft has an option to quietly work on novel mathematics that may be recognized by a very limited group of experts. However, as quantum computing reaches the agendas of governments and businesses, we see a demand from society to better understand the opportunities and threats of quantum technology, and QuSoft is the perfect source of reliable expertise.

That's why QuSoft mingles in the international discussions, and collaborates with various external parties. Over the last year, QuSoft organized mutual events with European Patent Office and KLM, discussed new directions for research and education with the financial sector, and set up new lines of research with SURF, Bosch and Toyota.

On top of this, our series of Meetups reach a broad audience, hopefully transferring an enthusiastic yet realistic view of the quantum future. All done with the great commitment of our new Quantum Innovation Officer.



We are now at a tipping point, as the concept of 'quantum computer' moves from an academic idea to a concrete commercial product.

KOEN GROENLAND
*Quantum Innovation
Officer*



BUILDING A COMMUNITY

QUANTUM SOFTWARE CONSORTIUM

Together with CWI, Leiden University and QuTech, QuSoft is part of the Quantum Software Consortium (QSC). Developing new quantum software, by exploiting the counterintuitive effects of quantum mechanics, requires a unison of ideas from computer science, mathematics, and quantum physics. Large-scale efforts in the Netherlands and around the world are in progress to develop quantum technologies, as a full-blown quantum computer and large-scale quantum internet will have unprecedented computational and communication abilities. In order to achieve this move forward, forces must be combined. Therefore QSC is building a new research community in the Netherlands in Quantum Information Science.



WOMEN IN QUANTUM DEVELOPMENT

WIQD (pronounced “wicked”) is a professional network for quantum technology enthusiasts from industry, academia and policy. its mission is to bring together women in quantum in the Netherlands, and beyond, for support, networking, and community growth.

WIQD was founded by Stacey Jeffery (QuSoft, CWI) and Julia Cramer (Leiden University). The chair of the organising committee is Yvonne Smit (QuSoft, UvA).

As from 2020 WIQD is organising monthly events and started a mentoring program with over 50 participants!



BUILDING A COMMUNITY



QUANTUM LEAP AFRICA

We started an exchange program between QuSoft and Quantum Leap Africa (QLA), which is a newly founded research institute in Kigali, Rwanda, closely linked to AIMS, the African Institute for Mathematical Sciences. QuSoft hosted Chanelle Matadah Manfouo from January 24 till July 15, 2020. During this time she worked on her MSc research project, under the guidance of Christian Majenz, Maris Ozols and Stacey Jeffery. Having now completed her Research Master, Chanelle will continue on a PhD position at QLA.





QUANTUM.AMSTERDAM

Quantum.Amsterdam, founded by the Dutch research center for quantum software, QuSoft, Centrum Wiskunde & Informatica and The University of Amsterdam, is the gateway to the quantum world for companies to explore and develop quantum software, technology and new applications.

The hub's mission is to connect academia, industry and society in a quantum ecosystem in the Amsterdam region by facilitating knowledge exchanges and innovation.

We prepare companies for the quantum age by providing in-depth knowledge about this fascinating technology and by helping to identify and validate high-impact use cases. Building on the strong research infrastructure in Amsterdam, we can set up joint research and development projects with our scientific partners to create new quantum applications for your company.

As one of the five innovation hubs of Quantum Delta NL, Quantum.Amsterdam acts as liaison to the national quantum activities as described in the national agenda on quantum technology and beyond.

QUANTUM DELTA NL

The Netherlands is a vibrant international hotspot for quantum technology, with leading science, technology and talent. With Quantum Delta NL, we are creating a fully functional national ecosystem for excellence in quantum innovation, for highly talented professionals to bring quantum computers, quantum networks and quantum sensors to the market. Quantum.Amsterdam is one of the five hubs through which QuSoft is actively contributing to the ecosystem.

The Startimpuls program, totalling 23,5 M€, started July 1st 2020. At QuSoft, six PhD positions funded from this program have started, or are about to start: four on developing use cases for quantum computing, one on the development of a quantum simulator based on ultracold atoms, and one on the development of use cases for a quantum Internet. On top of that, a business developer for Quantum.Amsterdam is to be hired, 50% paid for by this Startimpuls grant.



HIGHLIGHTED EVENT: QUSOFT LUSTRUM

To celebrate its first lustrum, QuSoft organised a full month of great events to look back to all the (research) highlights of the past five years and also peak into the revolutionary future of quantum technology. This was a great opportunity for the institute to profile itself, take full advantage of the outreach possibilities and show the world what QuSoft is doing. With great financial support of the UvA and CWI, this was an event to remember.

Opening Day featured all QuSoft's highlights: from the Quantum Software Consortium to the Quantum Quest, Women in Quantum Development and Quantum.Amsterdam. This day showed that QuSoft is so much more than 'just science'. The day ended with the Turing Chair Ceremony to officially appoint Professor G. (Gilles) Brassard, from the Université de Montréal, to this Chair for the period of six months, starting December 1, 2020.

To dive deeper into the material a **Science Week** was programmed. This week was a great succes with keynote speakers Ignacio Cirac, Dorit Aharonov, Joris van Hoboken, Ronald Cramer and Florian Schreck talking about Quantum algorithms for finite energies and temperatures, Quantum Algorithmic Measurements, Governance of Quantum Technologies: From Theory to Adoption, Compressed Σ -Protocol Theory and Quantum sensing with ultracold atoms. Five impressive lectures about quantum technology from five different points of view. Most of the participants were scientists and could indulge themselves with this high-quality program.

Last but not least, a **Business and Society Day** was organised to show how important quantum technology can be for your company and why you should not wait to hop on the quantum-revolution-train. We welcomed founding director of Quantum Delta NL, Freeke Heijman, to talk about the Dutch quantum ecosystem. Christian Schaffner was present to talk about the new quantum innovation hub Quantum.Amsterdam, which is part of the Quantum Delta NL foundation. And from different companies Adil Acun (ING), Maran van Heesch (TNO), Frederik Kerling (Atos) and Dimitri van Esch (ABN AMRO), talked about the impact of quantum on their business and what it can mean for the near future.

COMMUNICATION & IMPACT

After five successful years QuSoft decided to actively start with communicating about its activities to make an impact on society with its innovating, fundamental and multidisciplinary quantum research. Therefore, in April 2020 QuSoft hired a new coordinator communication & impact, Yvonne Smit, who will enforce QuSoft's branding in the national and international quantum field.



I am excited to be part of QuSoft, an inspiring organization! Together, we will work on awareness, outreach, sharpening the external positioning of QuSoft and developing a powerful and recognizable identity.

YVONNE SMIT

*Coordinator
Communication
and Impact*



WWW.QUSOFT.ORG & NEW WEBSITE QUANTUM.AMSTERDAM



APRIL 2020: **991** FOLLOWERS

APRIL 2021: **1494** FOLLOWERS



APRIL 2020: **90** FOLLOWERS

APRIL 2021: **321** FOLLOWERS



APRIL 2020: **156** FOLLOWERS

APRIL 2021: **363** FOLLOWERS

QUSOFT EDUCATION (BSc)

Through the University of Amsterdam a variety of courses in the general area of Quantum Information are available. They range from introductory to advanced. By including some of these courses in their BSc or MSc study program, students can get ready for research projects (BSc or MSc theses) or PhD studies in the field.

Quantum information science is interdisciplinary between Physics, Mathematics and Computer Science and the optimal choice of courses depends on what has been learned in preceding course work.

BSc program: Quantum Information (QI) module

A BSc Quantum Information module can be followed as part of a BSc program in Physics and Astronomy, Mathematics or Computer Science. The details depend on the embedding BSc program. In the BSc programs the course Introduction to Quantum Computing gives a first introduction to the subject. Natural follow-up to this are found in the table on the right

BSc program	Essential courses	Recommended courses
Mathematics	• Introduction to quantum computing	• Lineaire Algebra • Stochastiek 1 • Klassieke Mechanica / quantum mechanica
Physics / Astronomy	• Quantumfysica • Introduction to quantum computing	• Lineaire Algebra • Klassieke Mechanica / quantum mechanica 2
Computer Science	• Introduction to quantum computing	• Lineaire Algebra • Modern cryptography
Chemistry	• Introduction to quantum computing	• Mathematics for quantum chemistry

QUSOFT EDUCATION (MSc)

MSc program: The QuSoft Master

The QuSoft Master, which can be followed as part of an MSc in Logic, Physics, Mathematics or Computer Science, combines a coherent choice of electives with an MSc thesis project in the area of QI, guided by one of the Principal Investigators at QuSoft. The program is an excellent preparation for PhD studies and for a further professional career in the field.

The core curriculum of the QuSoft Master consists of Quantum Information Theory (Ozols and Walter), Quantum Computing (de Wolf), and Quantum Cryptography (Schaffner). Depending on the embedding MSc program additional courses are added to cover all enabling knowledge in (quantum) physics, mathematics and information theory.

The soft skills course on Quantum in Business and Society is a recommended choice in the QuSoft Master.

MSc program	Recommended track	Essential courses	Recommended courses
Logic	Logic & Computation	- Quantum Computing - Quantum Cryptography - Quantum Information Theory - Quantum in Business and Society	- Basic Probability; theory & programming - Computational complexity - Information theory
Mathematics	Mathematical Physics	- Quantum Computing - Quantum Cryptography - Quantum Information Theory - Quantum in Business and Society	- Semidefinite optimization - Symmetry and quantum information
Physics / Astronomy	Theoretical Physics	- Quantum Computing - Quantum Cryptography - Quantum Information Theory - Quantum in Business and Society	- Statistical physics and condensed matter - Mathematical methods in theoretical physics - Fermi quantum gases

MORE EDUCATION AND OUTREACH



QUANTUM QUEST

The Quantum Quest is a web class for high school students from 16-18 years, organised by QuSoft, UvA and QSC. This course takes high-school students on a four-week adventure to learn the basics of quantum computing.

After a successful start in 2018, the course is also available for international students this year. Between October 30 and December 11, 2020 more than 100 Dutch high school students, 15 teachers, and 20 selected international students discovered more about quantum entanglement and quantum circuits.

They are supervised by a team of teaching assistants lead by junior teacher Mees de Vries.

The idea of the curriculum comes from Maris Ozols and Michael Walter. They are assistant professors at the Korteweg-de Vries Institute for Mathematics and conduct research on quantum algorithms and quantum information theory at the QuSoft research center in Amsterdam. The aim of the course is not primarily to introduce students to programming for the next generation of computers, but to discover the kind of mathematics taught at the university.

QSC TRAINING DAYS

On November 30 and December 1, 2020, the Quantum Training Days were organised.

PhD students and postdocs from the three QSC nodes were trained and educated on cooperation between the nodes and team building.

Ronald de Wolf and TT Wolfgang Löffler

were the key lecturers. The aim was to consider how the software of de Wolf's course could be implemented using the hardware of Löffler's course.

For this online training there were registrants from international universities and industry as well, adding up to 70 persons.

Seminar

QUSOFT SEMINARS

Every Friday of the week Jop Briët and Subhasree Patro organised the, now well-known, QuSoft seminars.

Scientists from all over the world are invited to talk about their expertise in the field of quantum research.

These seminars are closed and only for a specific scientific audience. In this way all attendant feels the freedom to dive deeper into the material. Everyone is encouraged to initiate discussions that strengthen collaborations and provide new insights.

A lot of the seminars were recorded and can be found on the QuSoft YouTube-channel.

A few selected International speakers are listed here:

Ryan O'Donnell (Carnegie Mellon University)
Fiber bundle codes: Breaking the $N^{1/2}\text{polylog}(N)$ barrier for quantum LDPC codes

Laura Mančinska (University of Copenhagen)
Quantum majority and other basis independent functions

Shalev Ben-David (University of Waterloo)
Symmetries, graph properties, and quantum speedups

Adam Bene Watts (MIT)
3XOR Games with Perfect Commuting Operator Strategies Have Perfect Tensor Product Strategies and are Decidable in Polynomial Time

Daniel Ranard (Stanford University)
Emergent classicality in multipartite states and channels

PRIZES AND HONORS

- Harry Buhrman has been installed as a new member of the Royal Netherlands Academy of Arts and Science (KNAW). He received the KNAW membership for his exceptional scientific achievements.
- Marten Teitsma has been appointed as special lecturer for Applied Quantum Computing. The new lectorate facilitates QuSoft in exploring which quantum computing applications are feasible in the future. It will study how quantum algorithms and protocols developed within QuSoft can be further turned into applications.
- Michael Walter has been awarded the KNAW Early Career Award. His work connects quantum computers to black holes to gain new insights into how they work. With his research at the interface of mathematics, physics and computer science, he plays a pioneering role in international projects
- Jana Sotáková, PhD student at QuSoft and UvA, won the best-paper award at the IACR flagship conference CRYPTO 2020 for her article “Breaking the Decisional Diffie-Hellman Problem for Class Group Actions Using Genus Theory”.
- Jop Briët and Farrokh Labib, together with Tom Bannink and Hans Maassen have been awarded the TQC Outstanding Paper Award 2020 for their paper on “Quasirandom quantum channels”.



PRIZES AND HONORS

- Michael Walter won an NWO KLEIN Grant for his project 'Taming tensors – an optimization approach to computational invariant theory'. Using this grant, he will involve a PhD student in this project and also organise an international workshop on the topic.
- Yfke Dulek has been granted the Ada Lovelace Fellowship from the Quantum Software Consortium. Her research interests include quantum cryptography, homomorphic encryption, delegated quantum computation, quantum
- Professor Gilles Brassard of the Université de Montréal is the first to be appointed on the new Turing Chair for Quantum Software at the University of Amsterdam (UvA). This special chair is an initiative of the Stichting Bèta Plus, which aims to further strengthen the position of the natural sciences at the UvA. Brassard will join QuSoft, the Dutch research centre for quantum software of which the UvA is one of the partners, for a period of six months.



APPENDIX FINANCIALS

QuSoft is financed in part by UvA, via funds from the Quantum Matter & Quantum Information (QM&QI) Research Priority Area, and in part via CWI. They provide funds for tenure track researchers and junior research positions as part of the tenure track startup packages, support positions (including the QuSoft Institute Coordinator) and office space/infrastructure. The financial situation at the start of 2020 is summarized in the table below.

At the start of 2020, roughly 444 k€ surplus budget existed from the QM&QI funds, which will quickly diminish, however, via the continuation of existing positions (the Quantum Innovation Officer and the Coordinator Communication and Impact), as well as the hiring of the Business Developer for Quantum.Amsterdam. Furthermore, a plan for new research positions for the period 2021-2025 will be made by the QuSoft Management in 2020. The expectation is that the budget surplus will be allocated in 2022 at the latest.

QuSoft Budget turnover 2020 (CWI)

Benefits		Costs	
CWI basic coverage	€307,000.00	Personnel costs WP	€839,000.00
Externa, project financing (NWO, EU PPS, etc.)	€747,000.00	Personnel costs OP	€115,000.00
		Housing charges	€100,000.00
Total	€1,054,000.00	Total	€1,054,000.00

QuSoft Budget turnover 2020 (UvA)

Benefits		Costs	
Allocation 2020	€547,000.00	Personnel costs WP	€565,876.00
Services (1)	€3,500.00	Personnel costs OP	€120,575.00
Surplus allocation (<2020)	€693,744.00	Personnel extern (2)	€87,060.00
		Other expenses	€26,689.00
Total	€1,244,244.00	Total	€800,200.00
Grand total	€444,04.,00		

(1) This money was generated by several workshops given by QuSoft to external parties.

(2) These costs include funding for project management support by IxA, as well as for contracting external support - mostly related to Quantum.Amsterdam activities.

APPENDIX PHD DEFENSES 2020

Koen Groenland

Defended his thesis, titled 'Quantum Protocols for Few-qubit Devices', on January 17, 2020.

Tom Bannink

Defended his thesis, titled 'Quantum and Stochastic Processes', on January 30, 2020.

Joran van Apeldoorn

Defended his thesis, titled 'A Quantum View on Convex Optimization' on February 6, 2020.

