

Enabling the power of quantum computers

QuSoft

ANNUAL REPORT  
2022

# ANNUAL REPORT 2022

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## CONTENTS

1. Executive summary
2. Foreword by QuSoft directors
3. Key organizational developments
  4. About QuSoft
  5. Research lines
6. Cryptography in a quantum world
7. Quantum algorithms and complexity
8. Quantum simulation and few-qubits applications
9. Quantum information science
10. Quantum for society and business
  11. Infographics
  12. Collaborations
13. Quantum Delta & Center for Quantum and Society
14. Quantum Amsterdam & Quantum Application Lab
  15. EuRyQa & EQSI
  16. Gilles Brassard
  17. Christian Schaffner
  18. Stacey Jeffery
19. Big Meetup (April 6th)
20. Big Meetup (November 3rd)
  21. QuSoft education 1
  22. QuSoft education 2
  23. QuSoft seminars
24. Prizes and honors
25. Financials
26. PhD defenses

QuSoft



# EXECUTIVE SUMMARY

We are proud to present the QuSoft Annual Report 2022. During the year 2022 people returned to QuSoft and more new people joined us filling the halls and offices, which are busy again with people coming together to do excellent research on quantum algorithms, protocols and software. Creating this common ground for people to meet and create new ideas is the reason why QuSoft exists in the first place. We hope this report reflects this goal.

The main points to take from this report are:

- QuSoft continues growing as a world-renowned research center, involving over 76 people performing groundbreaking research in the area of quantum information science;
- QuSoft researchers continue to disseminate high-quality research outcomes, as illustrated by the acceptance of 14 papers at the prestigious Quantum Information Processing (QIP) conference, as well as by the research output of well over 100 published articles and three excellent PhD theses;
- QuSoft attracts international talent, as illustrated by new tenure-track hires, the fact that half of the research members are from abroad, as well as by the returning visit of 2023 Breakthrough Prize in Fundamental Physics awardee Gilles Brassard as the QuSoft Turing Chair for Quantum Software;
- QuSoft is a cornerstone of the national Quantum Delta NL program, being involved in all of its parts, from the development of new quantum computing and quantum sensing platforms, through the development of applications and use cases with private partners, via the education of the next quantum researchers and new (applied) master tracks, to being crucial in understanding the societal impact of quantum technologies, especially in the area of governance and law;
- QuSoft keeps expanding its European collaborations, both through EU funded research projects and programs, as well as through the newly founded European Quantum Software Institute (EQSI), in which QuSoft initiates new European collaborations for quantum software research with 5 different partners from throughout Europe.

We are proud to facilitate these successes and happy to report on them here.



Giada La Gala - Coordinator communication & Impact for QuSoft  
Victor Land - Institute Coordinator for QuSoft

With the restrictions due to corona fading away, 2022 has been a year with a full hand of new and renewed activities at QuSoft.

Among the year's highlights was the celebration of the 2023 Breakthrough Prize in Fundamental Physics. It was an honor to virtually stand alongside esteemed laureates Gilles Brassard, Charlie Bennett, Peter Shor, and David Deutsch, celebrating this prestigious award. This served not just as an accolade for their groundbreaking work but as a testament to the potential of quantum computing and the promise it holds for the future. We enjoyed the extended visit of Gilles Brassard who held the Turing Chair for Quantum Software from June to November.

## BY QUSOFT



## DIRECTORS

## FOREWORD



The 2022 research output of QuSoft has, again, been excellent. This is witnessed by the remarkable feat of 14 papers accepted to the 2023 Quantum Information Processing (QIP) conference. The STOC Test of Time Award for a paper co-authored by Ronald de Wolf attests to the lasting impact of results obtained in the CWI and UvA research groups that form the backbone of QuSoft.

The quantum ecosystem that QuSoft is part of keeps developing. The Quantum Delta NL program entered its second phase in September 2022. The fall of 2022 also saw the launch of the European Quantum Software Institute (EQSI) in Paris. In this new institute, QuSoft joins forces with partners from Denmark, France, Germany, Latvia, and Portugal with the goal of accelerating quantum research in Europe and facilitating knowledge exchange among leading scientists in the field.

In June 2022 QuSoft held its first ever retreat, shaped as a 2-day event with a combination of scientific and social activities. Open problems in the field were presented and discussed, laying a foundation for future results of the collaborations that QuSoft facilitates.

**Kareljan Schoutens and Harry Buhrman**



# KEY ORGANIZATIONAL DEVELOPMENTS

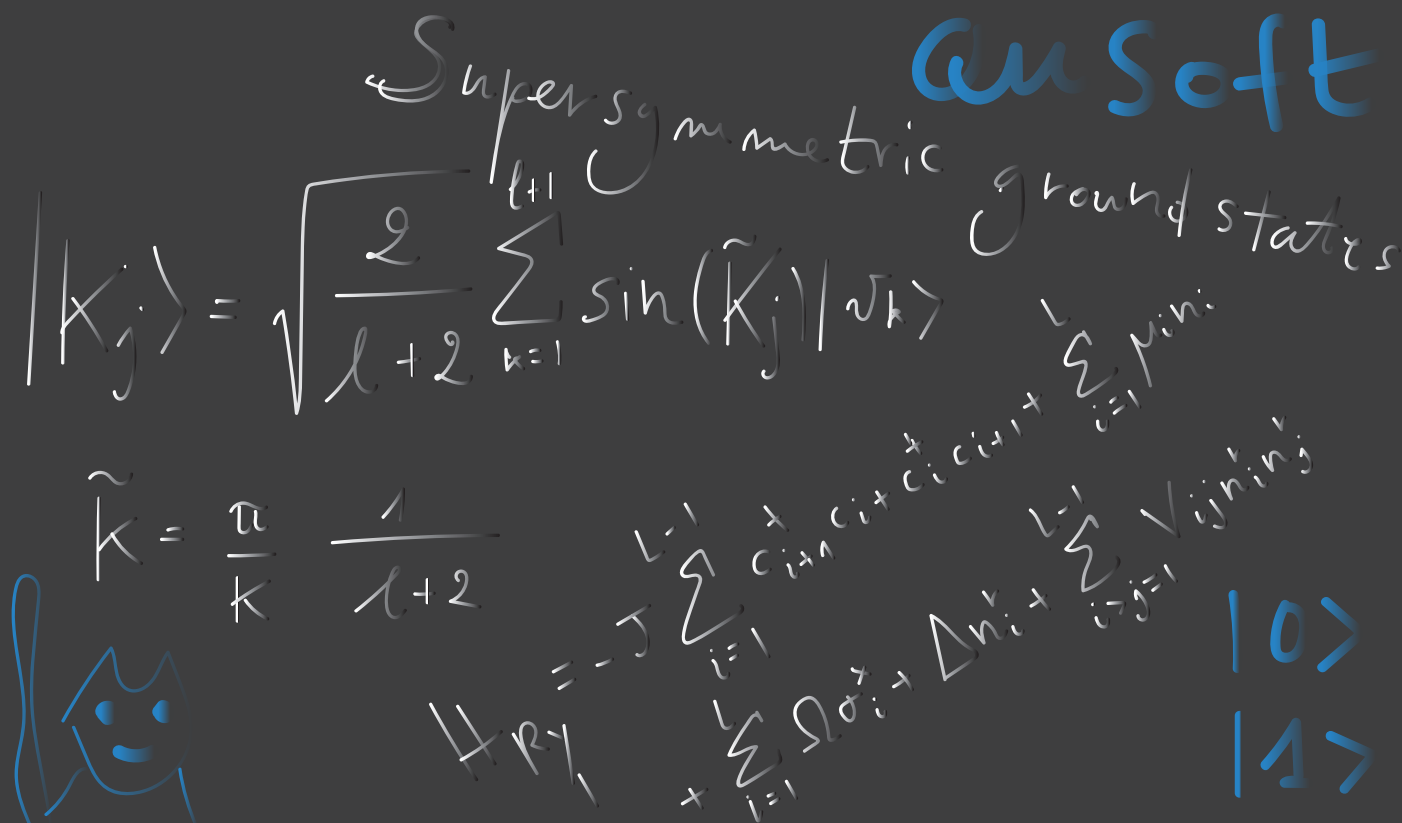
The year 2022 was a year of significant growth. Two tenure-track positions were filled: Ludovico Lami follows in the footsteps of Michael Walter, who accepted a professor position at Bochum University, and John van de Wetering started at the Informatics Institute, with the important task to help shape the future Quantum Computer Science Master at the UvA. Furthermore, Richard van Harderwijk started as the coordinator for the Quantum Application Lab and Business Developer for Quantum.Amsterdam, while Vania López Díaz is growing the Quantum.Amsterdam and Quantum & Society communities since August 2022. On top of that, more than 10 junior researcher started new positions within QuSoft.

On March 22 the Quantum Application Lab officially launched with a festive opening event at Amsterdam Science Park. The six partners (CWI, UvA, TNO, eScience Center, SURF, and Quantum Inspire) signed the collaboration agreement. The goals of the Quantum Application Lab is to develop useful quantum computing application with and for end-users, in line with the vision that a mature quantum computing ecosystem requires the hand-in-hand development of hardware with use cases and applications. QuSoft researchers are directly involved in the development of quantum algorithms and applications. Since then, several short-term projects have started, including one with Alliander on developing quantum computing approaches for future energy grids.

On April 14 (World Quantum Day), Quantum Delta NL received the news that the second phase of the QDNL funds – totaling M€ 228 – became available. QuSoft is one of the key developers and executors of this program. From these funds, quantum computing applications and cold atom based quantum computing infrastructure are developed in CAT-1, cold atom based quantum clocks for the quantum internet in CAT-2, a cold atom based sensor testbed as part of CAT-3; the Quantum.Amsterdam hub and ecosystem are further developed, including a new quantum building to be realized in 2027 as part of AL2, a Talent & Learning Center as well as the new Quantum Computer Science Master are developed in AL3 and finally, a large program on the Governance and Law of Quantum Technologies is expanded as part of AL4. (with \*AL = Action Line, \*CAT = Catalyst Program)

On November 8th, the European Quantum Software Institute (EQSI) was launched in Paris. QuSoft is one of the 6 founders, together with QuMath-Denmark, PQI-Portugal, TU Munich, University of Latvia and PCQC-France. EQSI aims to align quantum software development processes and jointly achieve responsible innovation in Europe for Quantum Software and Quantum Algorithms, through co-creation with industry and Quantum hardware partners.

In 2022, Gilles Brassard returned to QuSoft, acting as the first QuSoft Turing Chair, which was cut short before due to the COVID pandemic. Gilles performed research within QuSoft, gave special lectures to junior researchers and students both at CWI and UvA. A particular highlight of his Turing Chair appointment was a special seminar on November 11, where four of the “founding fathers” of quantum information science (Gilles Brassard, Charles Bennett, Peter Shor and David Deutsch) came together to give their perspectives on the development in this field.

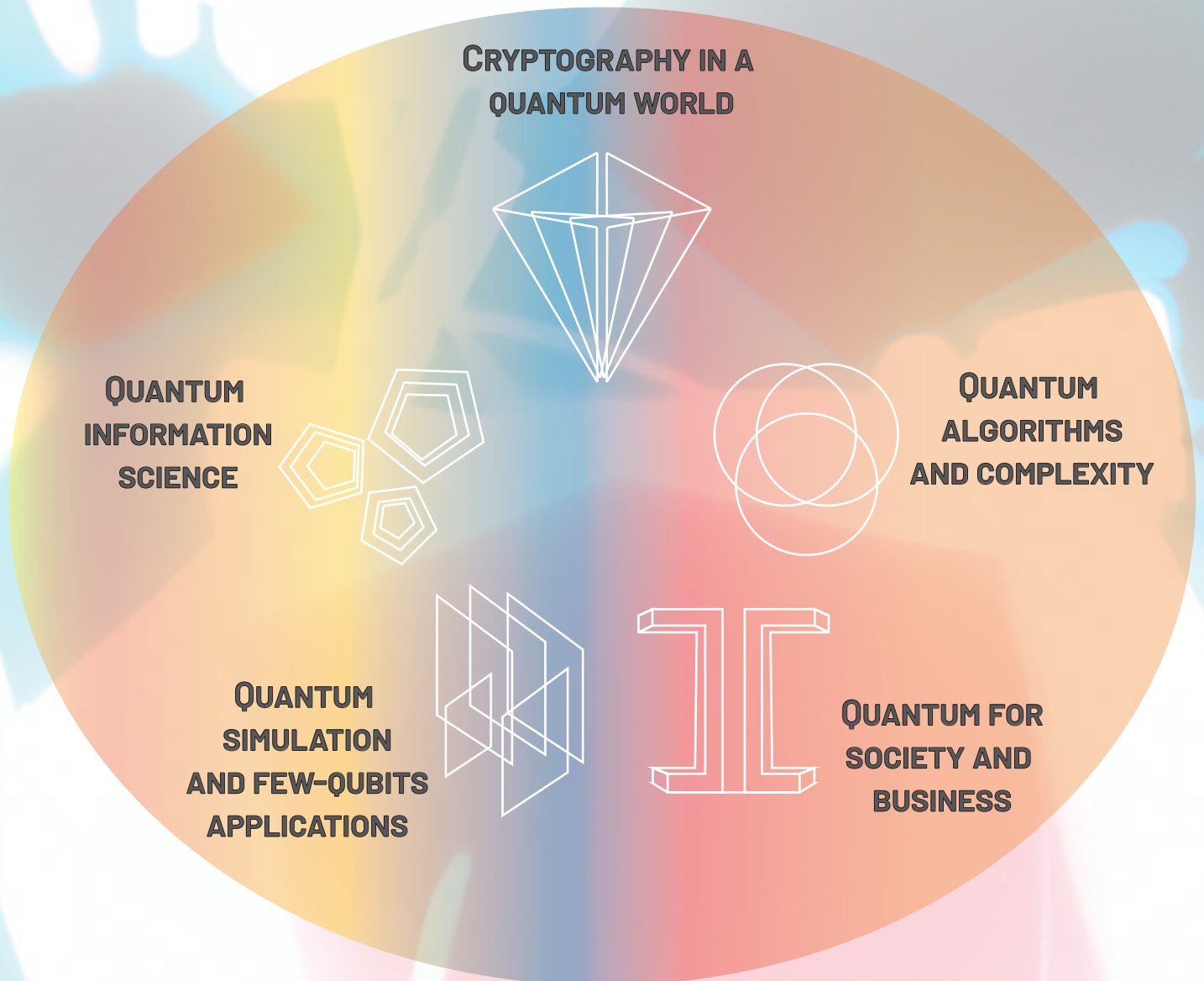


## ABOUT QUSOFT

Researchers at QuSoft perform ground breaking research in fundamental and applied aspects of Quantum research. As QuSoft researchers mostly focus on theory, the main body of research comes from mathematicians, computer scientists, theoretical physicists and chemists and regards areas such as cryptography, quantum information, quantum internet, quantum simulation and quantum algorithms. However part of QuSoft researchers are experimental physicists who do experimental research in the lab, with physical systems.

The overarching goal for QuSoft is to be pioneer in creating the “quantum software” for current and future quantum computers.

An increasingly important role within the organization is made of collaborations with other organizations and industry, as The Netherlands places itself at the forefront of quantum innovation. A generous funding scheme has been developed by the Dutch government and a larger quantum ecosystem of stakeholders is growing. In this context a large number of initiatives which are sprouting nationally and internationally are fuelled by the brilliant work of QuSoft people.



# RESEARCH LINES

QuSoft research can be divided into five research topics: quantum simulation and few-qubits applications, quantum information science, cryptography in a quantum world, quantum algorithms and complexity and quantum for society and business.

In the following pages we show the most relevant publications for each research line for the year 2022.





# CRYPTOGRAPHY IN A QUANTUM WORLD

The research line **cryptography in a quantum world** focuses on quantum cryptography and in particular on developing cryptographic protocols that utilize quantum data and communication to provide security guarantees based on fundamental principles of quantum mechanics, exploring the potential of quantum computing in cryptography. A branch of this research studies post-quantum cryptographic algorithms that can provide secure communication and protect sensitive data in a quantum computing era.

## Research highlights 2022

Don, J., Fehr, S., Majenz, C., Schaffner, C. (2022). Online-Extractability in the Quantum Random-Oracle Model. In: Dunkelman, O., Dziembowski, S. (eds) *Advances in Cryptology – EUROCRYPT 2022*. EUROCRYPT 2022. Lecture Notes in Computer Science, vol 13277. Springer, Cham. [https://doi.org/10.1007/978-3-031-07082-2\\_24](https://doi.org/10.1007/978-3-031-07082-2_24)

Don, J., Fehr, S., Majenz, C., Schaffner, C. (2022). Efficient NIZKs and Signatures from Commit-and-Open Protocols in the QROM. In: Dodis, Y., Shrimpton, T. (eds) *Advances in Cryptology – CRYPTO 2022*. CRYPTO 2022. Lecture Notes in Computer Science, vol 13508. Springer, Cham. [https://doi.org/10.1007/978-3-031-15979-4\\_25](https://doi.org/10.1007/978-3-031-15979-4_25)

Bluhm, A., Christandl, M. & Speelman, F. A single-qubit position verification protocol that is secure against multi-qubit attacks. *Nat. Phys.* 18, 623–626 (2022). <https://doi.org/10.1038/s41567-022-01577-0>







# QUANTUM ALGORITHMS AND COMPLEXITY

The research line **quantum algorithms and complexity** is focused on developing new quantum algorithms and identifying which computational tasks can be efficiently sped up using quantum computers. This research is particularly important in the many-qubit regime, where full-fledged error correction and fault-tolerant computation become possible. By developing new quantum algorithms and improving error correction techniques, researchers hope to unlock the full potential of quantum computing

## Research highlights 2022

Jeffery, S., Zur S. (2022). Multidimensional Quantum Walks, with Application to k-Distinctness. arXiv:2208.13492 [quant-ph]. <https://doi.org/10.48550/arXiv.2208.13492>

Jeffery, S. (2022). Quantum Subroutine Composition. arXiv:2209.14146 [quant-ph]. <https://doi.org/10.48550/arXiv.2209.14146>

Apers, S., Jeffery, S., Pass, G., Walter, M. (2022). (No) Quantum space-time tradeoff for USTCON. arXiv:2212.00094 [quant-ph]. <https://doi.org/10.48550/arXiv.2212.00094>

Bansal, N., Sinha, M., de Wolf, R.. Influence in Completely Bounded Block-multilinear Forms and Classical Simulation of Quantum Algorithms. In: 37th Computational Complexity Conference (CCC 2022), Leibniz International Proceedings in Informatics (LIPIcs) volume 234, 28:1-28:21, 2022. Also accepted for a talk at QIP 23. arXiv:2203.00212

Bravyi, S., Sharma, Y., Szegedy, M., de Wolf, R.. Generating k EPR-Pairs from an n-Party Resource State. Accepted for a talk at QIP 23. arXiv:2211.0.



# QUANTUM SIMULATION AND FEW-QUBITS APPLICATIONS



The research line **quantum simulation and few-qubits applications** focuses on studying small and medium-sized qubit platforms consisting of 10-100 qubits. One area of application for these systems is quantum simulation, where they can be used as analogue quantum computers to study complex problems in quantum chemistry and materials science, implementing few-qubit algorithms on 50 or more qubits which quickly become challenging for classical computers. Researchers study multi-qubit dynamics and quantum control, with potential applications in the design of quantum registers and in the study of quantum many-body physics.

## Research highlights 2022

Chen, CC., González Escudero, R., Minář, J., Pasquiou, B., Bennetts, S., Schreck, F. . Continuous Bose-Einstein condensation. *Nature* 606, 683–687 (2022). <https://doi.org/10.1038/s41586-022-04731-z>

Urech, A., Knottnerus, H. A. I., Spreeuw, J. C. R., Schreck, F. (2022). Narrow-line imaging of single strontium atoms in shallow optical tweezers. *Phys. Rev. Research* 4, 023245. <https://link.aps.org/doi/10.1103/PhysRevResearch.4.023245>

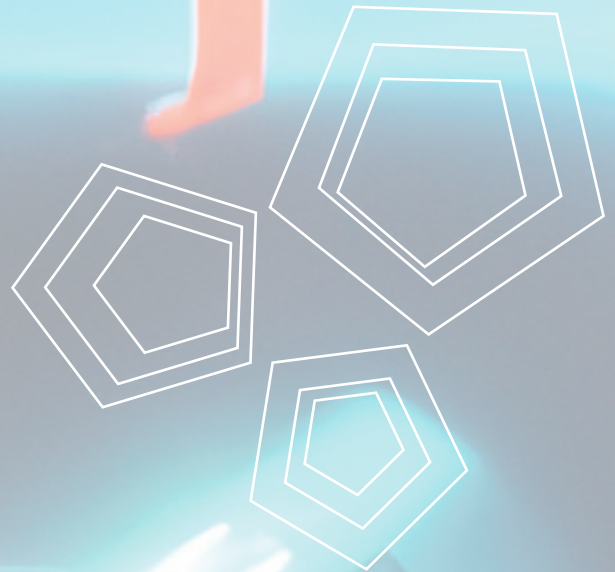
Minar, J., Voorden, van, B., Schoutens, K. (2022). Kink dynamics and quantum simulation of supersymmetric lattice Hamiltonians. *Phys. Rev. Lett.* 128, 050504. <https://doi.org/10.1103/PhysRevLett.128.050504>

Weggemans, J.R., Urech, A., Rausch, A., Spreeuw, R., Boucherie, R., Schreck, F. Schoutens, K., Minar, J., Speelman, F. (2022). Solving correlation clustering with QAOA and a Rydberg qudit system: a full-stack approach. *Quantum* 6, 687 (2022). <https://doi.org/10.22331/q-2022-04-13-687>





# QUANTUM INFORMATION SCIENCE



**Quantum information science** is a field that studies the fundamental principles of quantum mechanics and their application to information processing. In quantum information science, researchers aim to develop new algorithms, protocols, and hardware platforms that can harness the power of quantum mechanics for information processing tasks that are difficult or impossible to solve using classical computers. Researchers in quantum information science have developed new tools and techniques for analyzing and simulating complex quantum systems, which have provided insights into the behavior of quantum matter and the nature of spacetime.

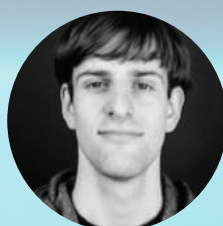
## Research highlights 2022

Buhrman, H., Linden, N., Mančinska, L., Montanaro, A., Ozols, M. (2022). Quantum majority vote. In: arXiv:2211.11729 [quant-ph]. <https://doi.org/10.48550/arXiv.2211.11729>

Grinko, D., Ozols, M. (2022). Linear programming with unitary-equivariant constraints. arXiv:2207.05713 [quant-ph]. <https://doi.org/10.48550/arXiv.2207.05713>

Cornelissen, A., Hamoudi, Y. (2022). A Sublinear-Time Quantum Algorithm for Approximating Partition Functions. Proceedings of the 34th Symposium on Discrete Algorithms (SODA), pages 1245-1264, 2023. <https://doi.org/10.1137/1.9781611977554.ch46>

Apeldoorn, van, J., Cornelissen, A., Gilyén, A., Nannicini, G. (2022). Quantum tomography using state-preparation unitaries. arXiv:2207.08800 [quant-ph]. <https://doi.org/10.48550/arXiv.2207.08800>



# QUANTUM FOR SOCIETY AND BUSINESS

In the research line **quantum for society and business**, QuSoft works with companies and societal organizations to explore, discover and develop applications and use cases. At the same time, the ultra-cold atom experiments offer unique opportunities to test actual applications in the near future. Current industrial partners include national bank ABN AMRO, BOSCH group, Toyota Europe, and ATOS. There is a close connection to the Quantum.Amsterdam innovation hub, as well as practical collaboration with partners like SURF, TNO, and the University of Applied Sciences Amsterdam.

## Research highlights 2022

Sebastian De Haro Ollé, QuSoft researcher affiliated with the Institute for Logic, Language and Computation and the Institute of Physics at the University of Amsterdam, won with a group of seven other principal investigators, an NWA-grant on Quantum Impact on Societal Security: <https://projects.illc.uva.nl/quantumimpact/>.

Quantum.Amsterdam started a pilot project with ASML.

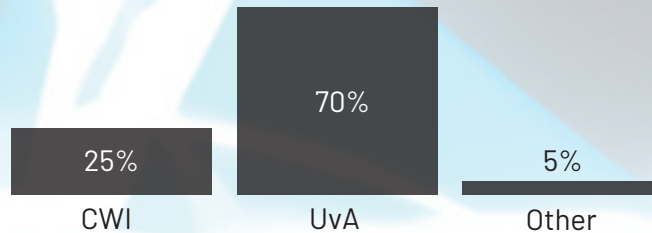
Ot van Daalen was awarded his PhD in Information Law.





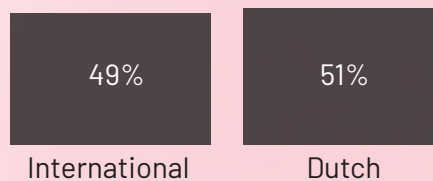
# INFOGRAPHICS

## INSTITUTE



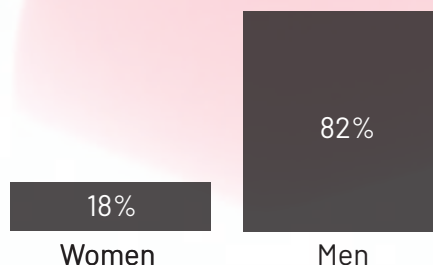
Researchers affiliated to QuSoft are employed mostly by the University of Amsterdam (53) and CWI (19) and in a smaller number belong to other organizations such as Vrije Universiteit Amsterdam (VU).

## NATIONALITY



QuSoft is a vibrant international research center, with almost half of the researchers originating from outside the Netherlands.

## GENDER



We believe that keeping track of gender equality is important. For this reason we want to give a glimpse to the actual numbers. Even though we don't mean to classify people based on a binary distinction of gender, collecting more accurate information about this sensitive topic is not allowed by law. Hence we opt for the compromise solution of reporting some statistics by only indicating Women and Men.

# COLLABORATIONS

The Dutch research center for quantum software, QuSoft, is well inserted in a larger ecosystem of other institutes, initiatives and organizations around quantum science and technology.

Importantly, as the Dutch government has launched the substantial Quantum Delta NL program to strengthen the relationships within the Dutch quantum ecosystem and initiate new collaborations, QuSoft is taking the lead when it comes to building the theoretical tools and frameworks of the “Quantum Software” of present and future quantum computers. In the context of Quantum Delta NL, QuSoft co-founded with the University of Amsterdam and CWI, the Amsterdam hub for quantum innovation: Quantum.Amsterdam. While Quantum.Amsterdam is mostly busy as an education and network organization, Quantum Application Lab has taken the role of finding possible applications of quantum computing and building collaborations between a consortium of public partners, including QuSoft, and industrial partners. The year 2022, saw the launch of the Center for Quantum and Society, part of the Quantum Delta NL program.

Within the Dutch academic quantum landscape, QuSoft is part of the Quantum Software Consortium.

The year 2022 has been important in the process of building international collaborations as well. The European Quantum Software institute EQSI was launched as well as EuRyQa, the European Infrastructure for Rydberg Quantum Computing.

Multiple members of QuSoft take part to the organization WIQD: Women in Quantum Development. Moreover QuSoft started an exchange program with Quantum Leap Africa (QLA), a research institute in Kigali, Rwanda, closely linked to AIMS, the African Institute for Mathematical Sciences.

In the next pages, more information about these organizations and the main events that relate to them can be found.



# QUANTUM ECOSYSTEM

## 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.

A large grant of 615 M€ was awarded on April 9th, 2021 from the Dutch government: with 54 M€ allocated for the first year.

On April 14 (World Quantum Day), Quantum Delta NL started entered the second phase of the QDNL funds – totaling 228 M€. QuSoft is one of the key developers and executors of this program. From these funds, quantum computing applications and cold atom based quantum computing infrastructure are developed in CAT-1, cold atom based quantum clocks for the quantum internet in CAT-2, a cold atom based sensor testbed as part of CAT-3; the Quantum.Amsterdam hub and ecosystem are further developed, including a new quantum building to be realized in 2027 as part of AL2, a Talent & Learning Center as well as the new Quantum Computer Science Master are developed in AL3 and finally, a large program on the Governance and Law of Quantum Technologies is expanded as part of AL4.

Philippe Bouyer, who was appointed this year as Professor in Amsterdam (UvA) and Eindhoven (TU/e), coordinates the CAT-3 program.

## CENTRE FOR QUANTUM AND SOCIETY

The world's first Centre for Quantum and Society kicked off in Amsterdam in 2022, launched as an initiative of Quantum Delta NL to boost quantum technology (<https://quantumdelta.nl/centre-for-quantum-and-society>). CQS stands as a co-creation Centre where businesses, governments, societal organizations, scientists, and citizens come together to research and co-create ethical, legal, and societal standards. It aims at guiding the development of quantum technologies and their applications to the benefit of society, and boost social readiness levels.

CQS is part of the Quantum and Society action line AL4. Several people from QuSoft are involved in the development of CQS: Joris van Hoboken, Sebastian de Haro Ollé, and Victor Land.

CQS has partnered with organizations like Qlimate and Quantum Application Lab (QAL) to support the ethical, legal, and societal embedding of early quantum computing use cases.

Read more on this report about the launch of CQS during the Big Meetup on November 3.

# QUANTUM ECOSYSTEM

## QUANTUM.AMSTERDAM

Quantum.Amsterdam, founded by the Dutch research center for quantum software QuSoft, Centrum Wiskunde & Informatica and the University of Amsterdam, is the innovation hub which connects academia, industry and society, within the quantum ecosystem, in the Amsterdam region. Beside the founding organizations, Quantum.Amsterdam has partnership with other institutes in Amsterdam such as the research center AMOLF and the University of Applied Sciences HvA. Quantum.Amsterdam is one of the five official hubs of Quantum Delta NL and it kicked off in late 2020 / early 2021. By facilitating knowledge exchanges and innovation, is the gateway to the quantum world for companies to explore and develop quantum software, technology and new applications.

During 2022, Quantum.Amsterdam (co-)organized two public meetups (Big Meetups, read more in the dedicated pages) and an event with Norea, one business meetup and several Awareness Workshops, a first-time Masterclass and many others activities. Quantum.Amsterdam is active in the following areas: education, community building/outreach, attracting start-ups, supporting spin-outs, setting up research collaborations, and in general being a spider in the web: connecting the right people with each other.

## QUANTUM APPLICATION LAB

The Quantum Application Lab (QAL) partnership was established in March of 2022, as a collaborative effort between CWI, UvA, TNO, SURF, eScience, and Quantum-Inspire. The primary objective of this alliance is to bridge the gap between fundamental quantum computing research and industry.

Throughout the year, QAL has had an exciting journey filled with conferences, learning how to navigate the complex field of quantum application development, managing the diverse needs of our partners, and starting our first projects. We are thrilled to explore potential use-cases of quantum computing in the energy grid and radio-astronomy sectors.

As time has progressed, the lab has grown considerably, both through the community attending our workshops and working on projects, and through our partnerships that provide us with access to quantum computing backends. Overall, it has been a fantastic year for QAL, and we look forward to an exciting future in the development of quantum computing applications.



# QUANTUM ECOSYSTEM

## 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. 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.

For the year 2022, QSC organised its 7th and 8th General Assembly, its 3rd Quantum Training Days on quantum bits. Gilles Brassard visited QuSoft and was keynote speaker at the 7th General Assembly on June 24 in Amsterdam. At the 5th Junior Day, Yvonne Smit gave a presentation on Science Communication: How to make an impact with your own research.

Koen Groenland, Philip Verduyn Lunel and Jordi Weggemans recorded explanatory videos for Quantum Quest.

## EQSI-EUROPEAN QUANTUM SOFTWARE INSTITUTE

The EQSI-European Quantum Software Institute was launched with a stakeholder event in Paris on November 8th. One of the founding members is the director of QuSoft, Harry Buhrman according to whom "this is an important step towards a strong European ecosystem in quantum software" and our continuous commitment to scientific excellence and responsible innovation at the European level. EQSI aims to further align development processes and jointly achieve responsible innovation in Europe for Quantum Software and Quantum Algorithms, through co-creation with industry and Quantum Hardware partners.

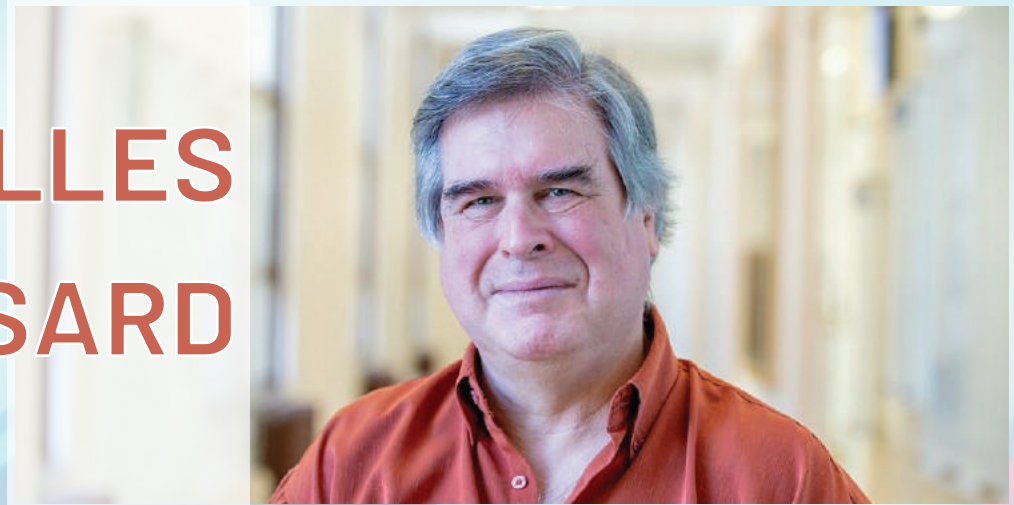
EQSI has six founding members: Harry Buhrman from QSoft, Matthias Christandl from QuMATH-Denmark, Yasser Omar from PQI-Portugal, Robert Koenig from TU Munich, Andris Ambainis from Univ Latvia and Iordanis Kerenidis from PCQC-France.

## EURYQA-EUROPEAN INFRASTRUCTURE FOR RYDBERG QUANTUM COMPUTING

Ultracold trapped atoms are one of the most promising platforms for quantum computing, having already demonstrated systems with more than 200 and showing a clear path to further scalability to thousands of qubits.

The European Commission has launched the "European infrastructure for Rydberg Quantum Computing (EuRy-Qa)" project aimed at establishing Rydberg quantum processors as a leading platform for scalable quantum computing in Europe. Assembling eleven partners from seven countries, EuRyQa is funded under the highly competitive Horizon Europe programme with a total budget of almost 5 million € over the next three years.

# GILLES BRASSARD



Besides laying the foundation for the research field many researchers within QuSoft are working on, Gilles Brassard has been involved in QuSoft from its inception in 2015. In 2022, Brassard ran the second term of his appointment on the “Turing chair for quantum software” at the University of Amsterdam and is part of QuSoft’s Scientific Advisory Board.

## Breakthrough Prize 2023

2023 Breakthrough Prize in Fundamental Physics was awarded to Gilles Brassard, Charles Bennet, Peter Shor and David Deutsch for their foundational work in the field of quantum information.

For the eleventh year, the Breakthrough Prize, renowned as the “Oscars of Science,” recognizes the world’s top scientists, awarding each prize \$3 million. By the time of the prize announcement, in 2022, Gilles Brassard is at QuSoft.

## BB84 Protocol

Professor Brassard is best known for his fundamental work in quantum cryptography, quantum teleportation, quantum entanglement distillation, quantum pseudo-telepathy, and the classical simulation of quantum entanglement. Some of the concepts he derived, have since then been implemented in the laboratory.

In 1984, together with Charles H. Bennett, he invented the ‘BB84’ protocol for quantum cryptography. This is generally considered the first quantum cryptography protocol. He later extended this work to include the Cascade error correction protocol, which performs efficient detection and correction of noise caused by eavesdropping on quantum cryptographic signals. These type of protocols are used nowadays for sharing public keys in a quantum secure way, in so called ‘Quantum Key Distribution’ (QKD) schemes.

## Celebrations

To celebrate Gilles Brassard and Charles Bennet winning the Breakthrough Prize, QuSoft organized a **Symposium on the 14th of November**. During the symposium, hosted at KNAW and moderated by QuSoft director Harry Buhrman, both Charles Bennett and Gilles Brassard gave talks together with Stacey Joffrey and Barbara Terhal (QuTech).

On the **11th of November** a special edition of **QuSoft seminars** was organized, in which Brassard and Bennet gave technical scientific talks. These latter have been recorded and are available on our website (see QR code).

Gilles also gave a lecture at ILLC on **December 13th** in the newly open Lab42 building, in the Amsterdam Science Park campus.





# CHRISTIAN SCHAFFNER



Christian Schaffner has been appointed professor of Theoretical Computer Science, with special attention to quantum computing, at the Informatics Institute of the Faculty of Science at the University of Amsterdam (UvA). The appointment came into effect on 1 December 2021.

On Friday, 30 September 2022, he gave his inaugural lecture as professor in theoretical computer science.

## Appointed Professor of Theoretical Computer Science

### Quantum Cryptography

Recent progress in building quantum computers lead to new opportunities for cryptography, but also endangers existing cryptographic schemes. Schaffner's research investigates both aspects of this double-edged sword. On the one hand, a large-scale quantum computer will be able to quickly factor large integer numbers, thereby breaking the security of currently used public-key cryptography. The research area of "post-quantum cryptography" investigates the possibilities for replacing currently used classical (i.e. non-quantum) cryptography with quantum-secure variants. On the other hand, quantum computers introduce new security scenarios involving quantum data, quantum communication and quantum networks.

### Career

Schaffner received a diploma degree in mathematics from ETH Zürich (Switzerland) in 2003 and a PhD degree in computer science from Aarhus University (Denmark) in 2007. After being a postdoctoral scholar at CWI Amsterdam, he joined the Institute for Logic, Language and Computation (ILLC) as assistant professor in 2013 and become associate professor in 2018. He is also a senior researcher at QuSoft. Schaffner obtained a NWO VENI grant in 2010 and a NWO VIDI grant in 2015. He has served on numerous program committees for conferences, PhD and NWO grant committees as well as on the steering committee of QCrypt. He is the chair of the talent and outreach committee of the Quantum Software Consortium and chair of the network organization Quantum.Amsterdam (see dedicated pages).

# STACEY JEFFERY



Stacey Jeffery, senior researcher at QuSoft and part of CWI's Algorithms and Complexity Group in Amsterdam, is awarded an ERC Starting Grant of 1.5 million euro for research on Algorithms, Security and Complexity for Quantum Computers (ASC-Q). The grant helps ambitious younger researchers launch their own projects, form their teams and pursue their best ideas.

## Wins ERC starting grant for quantum algorithms on quantum computers with limited memories

### Quantum Cryptography

For the coming years, Jeffery will consider how to design new quantum algorithms, that can be run in a secure way, on quantum computers with limited memories.

Jeffery explains: "While there are already some impressive proof-of-concept quantum algorithms that demonstrate the game changing power of quantum computers, most of them assume an arbitrarily large memory, and we don't have many algorithms for concrete real world problems that people want to solve in practice. We will work towards techniques for designing quantum algorithms that can be used by experts in a number of practical domains, who don't necessarily have expertise in quantum algorithmic theory, to design their own quantum algorithms. We will focus on techniques that only use a small amount of quantum memory."

The project, which has a duration of 5 years, is expected to start at the end of 2022. It will fund the

work of Jeffery, of two post-doctoral researchers and of two PhD students. More information on the grants awarded by the European Research Council (ERC) can be found at <http://erc.europa.eu/>.

### Career

In 2014, Stacey Jeffery received her doctorate in Computer Science from the University of Waterloo, under the supervision of Prof. Michele Mosca, and informal co-supervision of Prof. Frédéric Magniez. She was an IQIM Postdoctoral Scholar at Caltech until December 2016. Since January 2017, she has been a Senior Researcher at QuSoft & CWI, where she holds an NWO WISE Fellowship, and a Veni Grant.

Jeffery's research interests are in quantum cryptography and quantum algorithms. She is interested in secure delegation of quantum computation, frameworks for facilitating the design of quantum algorithms, and models of quantum computation.





## BIG MEETUP – 6 APRIL

Two times a year Quantum.Amsterdam organises the Big Meetup. The Big Meetup is a large event with talks from top experts in the field of quantum. The main motivation behind the event is to facilitate community building around quantum science and technology through knowledge exchange and networking sessions.

### **“How to build the Future Quantum Workforce?”**

The first Big Meetup in 2022 was focused around Quantum Education, with four speakers giving the topic special attention. Each speaker coming to the discussion with a different expertise, covered quantum education, from high school towards MSc programs and courses for business, giving answer to the question: “How to build the Future Quantum Workforce?”

Speakers for this edition are:

- Jacob Sherson, Professor (Aarhus University / EU Quantum Flagship)
- Miriam Blaauboer, Associate Professor (Delft University of Technology)
- Koen Groenland, Quantum Innovation Officer (QuSoft / Quantum.Amsterdam)
- Henk Buisman, High school liaison Physics & Astronomy (Leiden University)

Hosts: Marten Teitsma (Amsterdam University of Applied Sciences & Quantum.Amsterdam) & Yvonne Smit (QuSoft & Quantum.Amsterdam)

This Big Meetup event took place at Startup Village, Amsterdam Science Park and was fuelled with lots of interaction and chances for the audience to ask questions about the topic. The program ended with a vibrant networking event.



# BIG MEETUP – 3 NOVEMBER

Two times a year Quantum.Amsterdam organises the Big Meetup. The Big Meetup is a large event with talks from top experts in the field of quantum. The main motivation behind the event is to facilitate community building around quantum science and technology through knowledge exchange and networking sessions.

## **“How will Quantum impact Business and Society?”**

The second edition of the Big Meetup 2022 was jointly organized by Quantum.Amsterdam and the Centre for Quantum and Society and serves as a kickoff event for the CQS!

The focus of this session was about learning about the societal impact of quantum technologies.

The invited speakers answered the question: “How will Quantum impact Business and Society?”, giving special attention to the Ethical, Legal and Societal Aspects (ELSA) of Quantum.

Inspirational talks by:

- Jaya Baloo (Chief Information Security Officer Avast & Vice Chair of the EU Quantum Flagship Strategic Advisory Board)
- Daria Robinson (Executive Director Diplomacy Forum at Geneva Science & Diplomacy Anticipator (GESDA))
- Freeke Heijman-te Paske (Co-founder Quantum Delta NL & Director of ecosystem development)
- Eline de Jong (Working group member Quantum Impact Assessment and former member of the Project Group AI at the Scientific Council for Government Policy (WRR))
- Deborah Nas (Initiative lead for Centre for Quantum & Society and Professor at Delft University of Technology)

This big meetup took place at Startup Village, Amsterdam Science Park and remotely with a lot of interaction and a chance for the audience to ask questions about the topic.





# QUISOFT EDUCATION

## BSc Program: Quantum Information module

A BSc Quantum Information module can be followed as part of a BSc program in Physics and Astronomy, Mathematics or Computer Science. In the BSc programs, the course **Introduction to Quantum Computing** gives a first introduction to the subject.

Natural follow-up to this are (see table below):

BSc Program	Essential courses	Recommended courses
Mathematics	QUANTUMFYSICA 2I INTRO TO QUANTUM COMPUTING	QUANTUMCONCEPTEN ADVANCED QUANTUM PHYSICS MODERNE CRYPTOGRAFIE
Physics/ Astronomy	INTRO TO QUANTUM COMPUTING ADVANCED QUANTUM PHYSICS	LINEAR ALGEBRA MODERNE CRYPTOGRAFIE
Computer science	INTRO TO QUANTUM COMPUTING	LINEAR ALGEBRA MODERNE CRYPTOGRAFIE QUANTUMFYSICA 1 & 2
Chemistry	INTRO TO QUANTUM COMPUTING	LINEAR ALGEBRA QUANTUMCONCEPTEN QUANTUMFYSICA 2

## MSc Program: QuSoft Master Certificate

Since 2021, QuSoft offers a certificate for MSc students at the University of Amsterdam that have demonstrated extraordinary commitment to quantum information science and have carried out their MSc thesis research project at QuSoft.

Requirments for obtaining the certificate are:

- Successful completion of three courses coming from at least two categories (see below).
- Attendance of three QuSoft seminars.
- Successful completion of a MSc thesis research project at QuSoft.

Category 1	Category 2	Category 3
QUANTUM COMPUTING QUANTUM INFORMATION THEORY	BOSE EINSTEIN CONDENSATES QUANTUM OPTICS QUANTUM SIMULATIONS WITH ATOMS AND MOLECULES	QUANTUM IN BUSINESS AND SOCIETY COMPARABLE EXPERIENCE (such as company internship, contribution to a teaching or outreach effort)

## New MSc Program: Quantum Computer Science

The UvA Faculty of Science approved a new MSc Program at the UvA, called Quantum Computer Science. The new master will start in 2024/2025. These efforts are supported by Action Line 3.1 of QDNL. Partially funded by QDNL, the Informatics Institute has hired a new QuSoft tenure-tracker John van de Wetering, who will be the scientific lead of the new MSc program. He took over the baton from the initiators Kareljan Schoutens, Christian Schaffner and Paola Grosso. Almost all QuSoft senior staff members will be involved in the teaching activities in the new MSc program, and first pilot versions of the new quantum courses will be offered already in the coming academic year 2023/24.



# ★ QUSOFT EDUCATION ★

Besides BSc and MSc level education at the University of Amsterdam, QuSoft co-organizes a number of courses and produces education material for workshops aimed at different target groups. From high-school level education on quantum computing, to awareness workshops aimed at employees from start-ups and companies from the business sector, to educational material for the general public.

## Quantum Quest

visit us here:



[www.quantum-quest.org/](http://www.quantum-quest.org/)

The Quantum Quest is a web class for high school students. During 2018, 2020 and 2021, students from all over the globe learned about the mathematics behind Quantum Computers. The next edition will take place in November/December 2023, jointly organized by the University of Amsterdam, QuSoft, Ruhr University Bochum and CASA. The course will open for registration in Summer 2023. In the meantime, all previous course material is freely available. Feel warmly invited to browse these pages to get an impression of the Quantum Quest, or perhaps even complete the course by self-study!

## Quantum.Amsterdam workshops

As quantum computing develops rapidly, there is an increasing need for workforce who can understand and use quantum technology. For this reason, one of the main goals for Quantum.Amsterdam is to provide a broad palette of workshops and professional trainings, ranging from afternoon workshops to multi-day level deep dives. Experts at Quantum.Amsterdam are also available to create tailor-made courses to satisfy specific needs of special working groups. If you are an education, governmental or business entity interested in quantum, you might want to browse possibilities and get in contact with the Quantum.Amsterdam team!

visit us here:



[www.quantum.amsterdam/education/workshops-and-training/](http://www.quantum.amsterdam/education/workshops-and-training/)

## National Quantum Course

This course is intended as a solid introduction to quantum technologies (and all players involved) for the general public. It does not require any prior knowledge of mathematics or physics. QuSoft researchers (Koen Groenland, Stacey Jeffery, Christian Schaffner and Premjith Thekkepatt) focussed on showing especially the software and sensing side of quantum science and technology. The National Quantum Course will be made public during the month of June 2023. Stay tuned!



# QUISOFT SEMINARS

Every Friday of the week Jop Briët and Subhasree Patro organised the QuSoft seminars. Scientists from all over the world are invited to talk about their expertise in the field of quantum research. These seminars are aimed at a scientific audience. Attendants feel free to dive deeper into the subject matter. Everyone is encouraged to initiate discussions that strengthen collaborations and provide new insights. Many of the seminars were recorded and can be found on the QuSoft YouTube channel (see QR code). A few selected international speakers are listed below.

**Tudor Giurgica-Tiron (Stanford University)**

Efficient Universal Quantum Compilation: An Inverse-free Solovay-Kitaev Algorithm

**Tom Gur (Warwick)**

Quantum proofs & entropy estimation

**Francois le Gall (Nagoya University)**

Dequantizing the Quantum Singular Value Transformation: Hardness and Applications to Quantum Chemistry and the Quantum PCP Conjecture

**Suhail Sherif (Vector Institute)**

The quantum complexity of optimizing convex functions

**Makrand Sinha (Simons Institute & UC Berkeley)**

Influence in Completely Bounded Block-multilinear Forms and Classical Simulation of Quantum Algorithms

**Ojas Parekh (Sandia Labs)**

Approximating Quantum Max Cut and its 2-local friends

**Charles Bédard (University of Montréal)**

Teleportation Revealed

# PRIZES, HONOURS AND EVENTS

- ERC Starting Grant Stacey Jeffery, January 2023
- Signing of MoU Quantum Application Lab, March 23
- Symposium with Wigderson and Lovász, CWI, April 8
- Quantum Delta NL awarded 228 Mln for Phase 2 (Announced April 14th)
- QuSoft Retreat, June 7-9 [organized for the first time, with guests Gilles Brassard and Robert König, scientific program with Gem Session and Open Problem Session, social program]
- STOC 10-year test of time reward for Ronald de Wolf, June 2022
- Prof Gilles Brassard visiting professor on Turing Chair: June 2022 – December 2022
  - QuSoft seminar special edition with Brassard and Bennett, CWI, November 11
  - Symposium in honour of Gilles Brassard and Charles Bennett - Winners of the 2023 Breakthrough Prize in Fundamental Physics, KNAW, November 14
  - Symposium 'Turing Chair for Quantum Software', ILLC/UvA, December 13
- 2023 Breakthrough Prize in Fundamental Physics, Gilles Brassard (visiting professor on Turing Chair), announced September 2022
- Symposium Kj60, October 7 – OBA Amsterdam
- 2022 C&C Prize of the NEC C&C Foundation for Gilles Brassard, announced October 2022
- Launch of European Quantum Software Institute (EQSI), Paris, Nov 8
- Launch of Centre for Quantum & Society (CQS), November 3



# FINANCIALS

The structural funding for QuSoft is provided in part by UvA through the Quantum Matter & Quantum Information (QM&QI) Research Priority Area of the Faculty of Exact Sciences, and by CWI. Through it, tenure track researchers and junior research positions are funded, as well as support positions (including the QuSoft Institute Coordinator, the Coordinator Communication & Impact, Quantum Innovation Officer, as well as secretarial support). Furthermore, the office spaces, infrastructure and organizational support is provided for. The financial overview for 2021 is summarized in the table below.

In this overview, information about external funding is also included, such as additional NWO, and EU Grants. Income and expenditures related to Quantum.Amsterdam hub have been included as well.

## QuSoft budget turnover 2022 (CWI)

Benefits		Costs	
CWI Basic funding	€ 763.000	Personnel costs, Scientific Staff	€ 1.355.000
External project funding (NWO, EU, PPS, etc.)	€ 900.000	Personnel costs, Support Staff	€ 153.000
		Housing and others	€ 155.000
Total	€ 1.663.000	Total	€ 1.663.000

## QuSoft budget turnover 2022 (UvA)

Benefits		Costs	
QM&QI budget 2022	€ 547.000	Personnel costs, Scientific Staff	€ 1.210.514
Q.A services	€ 306	Personnel costs, Support Staff	€ 177.683
External project funding	€ 965.086	Personnel costs, Outsourced Staff (2)	€ 132.111
Extraction reserve (<2022) (1)	€ 150.097	Other Expenses	€ 142.181
Total	€ 1.662.489	Total	€ 1.662.489
Grand total	€ 3.325.489	Grand total	€ 3.325.489

(1) Over the first 5 years, not all QuSoft budget was allocated, now used as Reserve.

(2) This includes hiring external support and project management personnel.

# PHD DEFENSES

Quasirandomness in  
quantum information  
theory

Farrokh Labib

On January 26th 2022, Farrokh Labib defended his thesis titled "Quasirandomness in quantum information theory".

Farrokh's dissertation contributes to a large international research program that wants to map how information can be processed on quantum systems, understanding when this has or does not have advantages over 'classical' information processing.

On June 10th, 2022, Freek Witteveen defended his PhD thesis titled: "Quantum information theory and many-body physics".

"What is information?" and how does the essence of information change when we think quantum rather than classical?

"What is computation? And how does quantum computation differs from classical computation?" In his PhD thesis, F. Witteveen studies how to answer these questions within quantum information theory and applies the answers as a theoretical tool to improve our conceptual understanding of many-body physics.

[This thesis has been awarded the 2023 Stieltjes Prize. To be included in the next year report.]

Quantum information  
theory and many-body  
physics

Freek Witteveen

Making and Breaking  
with Science and  
Conscience

O.L. van Daalen

Ot van Daalen has been awarded a PhD (in the field of Information Law) on October 5th, 2022. His thesis, titled: "Making and Breaking with Science and Conscience: The human rights-compatibility of information security governance in the context of quantum computing and encryption" discusses how an attack with a quantum computer could expose the private information of millions of people. Governments must therefore invest in alternative technology to protect us.

This work is part of the Quantum for Society and Business research line within QuSoft.