First Workshop of the ERCIM Working Group on Quantum Technologies

Internal ERCIM Report

Francisco Chicano (Univ. Malaga), Carlo Mastroianni (ICAR-CNR), Marco Pota (ICAR-CNR)

1. Introduction

On December 2, 2025, the inaugural workshop of the newly established ERCIM Working Group (WG) on Quantum Technologies (QT) took place at the Lloyd's Baia Hotel in Vietri sul Mare, Italy. Held as a central component of the XXI ICAR-CNR workshop, this event brought together experts and stakeholders to discuss the future of quantum computing, communication, and sensing. The meeting was sponsored by the National Quantum Science and Technology Institute (NQSTI) and supported by the newly formed WG, marking a significant milestone in ERCIM's commitment to the emerging quantum economy.

The establishment of the QT Working Group[1] is a response to the rapid reshaping of information processing and sensing driven by quantum technologies. The working group, led by Francisco Chicano (University of Malaga) and Carlo Mastroianni (CNR), aims to foster European research by integrating expertise across academia and industry to address critical "bottlenecks" such as scalability, error correction, system integration, and benchmarking.

The group, guided by the chairpersons and a Steering Committee (SC) aims to accelerate the transition from laboratory experiments to practical, deployable quantum technologies. This synergy is essential for Europe's leadership in the emerging quantum economy. More specifically, the working group aims to focus on a series of activities (e.g., projects, workshops, dissemination of knowledge) for fostering European research and development on quantum computing, communication, sensing and hardware platforms. These will be among the main issues of current and future research efforts for "quantum technologies" in a broad sense in Europe[2]. One main source of possible funding will be EU research programs. In particular, the scope of the WG matches the objectives of the Quantum Flagship[3] and the funding opportunities offered by EU calls[4].

[1] More info at https://ercim-qt-wg.icar.cnr.it/

[2] See https://qt.eu/ and https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci

[3] https://qt.eu/about-quantum-flagship/

[4] https://qt.eu/funding-opportunities/

The workshop was structured to provide a comprehensive overview of current research and innovation trends from academia, research and technology organizations, industry, and policy-making bodies. The day opened with a welcome and introductory session with the participation of Emilio Fortunato Campana (Director of the DIIET Department of CNR) and Han La Poutré (CWI and Elected-President of ERCIM). Then, the ERCIM Working Group on Quantum Technologies was presented by Carlo Mastroianni, setting the strategic and collaborative context of the event.

The morning session was devoted to research trends in academia and RTOs (see Section- 2), with invited talks from leading European research institutions. After the lunch break, the workshop continued with a policy-oriented contribution from the European Commission, represented by Oscar Diez (DGCONNECT). This intervention highlighted the alignment of the WG's goals with major European initiatives such as the Quantum Flagship and the development of the European Quantum Communication Infrastructure (EuroQCI). This was followed by a session focused on research and innovation trends from industry, featuring representatives from major companies and startups active in quantum computing hardware, software, and applications (see Section 3).

The event concluded with a wrap-up and closing session (see Section 4) dedicated to discussing future trends in quantum computing, synthesizing the main insights of the day and outlining challenges and opportunities for continued collaboration between academia, industry, and European research networks.

In the next sections we will focus on each of these three main parts of the event, providing more details on their contents.

2. Research Trends in Academia and RTOs

The first main session of the workshop focused on research trends within academia and research institutes, featuring contributions from a wide range of ERCIM and external institutions including NQSTI (Italy, Francesco Saverio Cataliotti), University of Malaga (Spain, Francisco Chicano), FORTH/University of Crete (Greece, George Stamatiou), King's College of London (UK, Mohammad Reza Mousavi), CNR (Italy, Carlo Mastroianni), NTNU (Norway, Asle Sudbø), SBA (Austria, Sebastian Raubitzek), and RISE (Sweden, Miroslav Dobsicek). In the next subsections we provide a summary of the presentations of the institutions.

2.1 University of Malaga (Spain)

The Institute of Software Engineering and Technologies (ITIS Software) from the University of Malaga has three research groups working on quantum computing: SCENIC, NICS, and NEO. Regarding research, the contributions of three groups were presented. The SCENIC research group focuses on Quantum Software Engineering, addressing topics such as quantum circuit compositionality, distributed quantum computing, optimization of circuit execution, hybrid quantum-classical architectures, and service-oriented tools for quantum software development. The NICS Lab works on quantum and post-quantum cryptography, including the integration and benchmarking of quantum-resistant protocols, post-quantum TLS, cryptographic primitives, and quantum key distribution. The NEO research group is working at the intersection of artificial intelligence and quantum computing, with significant contributions in quantum optimization (notably QAOA), circuit transformation and optimization, machine-learning-based techniques to improve quantum computation reliability, and the development and analysis of quantum platforms and simulators.

These research groups are also involved in the Quant·UMA initiative of the University of Malaga, which aims to coordinate and promote education, research, and dissemination in quantum computing across the university, offering seminars, courses, summer schools, and a university extension diploma covering topics such as quantum fundamentals, algorithms, software, security, artificial intelligence, and industrial applications.

The presentation concluded by highlighting future challenges, including distributed quantum computing, quantum programming, quantum cryptography, the development of more effective quantum optimization algorithms, and progress toward fault-tolerant quantum computing.

2.2 FORTH (Greece)

The presentation of FORTH-ICS overviews Quantum Computing and Quantum Technology activities within FORTH and its broader research and educational ecosystem. It highlights ongoing efforts to bridge near-term quantum capabilities with practical computing needs through hybrid quantum/classical workflows. First, it introduces DEDALUS, an end-to-end framework that targets database query optimization by encoding join ordering as an optimization problem, enriched with statistics-aware cost modeling and search-space pruning, and solved via quantum/classical/hybrid backends. Second, it introduces HellasQCI, Greece's national Quantum Communication Infrastructure within EuroQCI, aiming to deploy quantum-secure links across major metro networks to protect critical data services. Third, it discusses QUADS, which explores quantum-enhanced optimization for control and resource management in adaptive computing systems, comparing quantum methods against classical baselines. The presentation concludes with key challenges for real-world impact, including problem transformation to quantum amenable formulations, real-time decision constraints, decoherence and readout errors, limited qubit connectivity, and the transition from NISQ devices toward broader quantum utility.

2.3 King's College (United Kingdom)

Dr. Mousavi starts by providing an overview of King's Quantum, an inter-disciplinary research centre at King's College London, with the vision to bring quantum technology to its early adopters. He presents some of their ongoing projects in areas such as healthcare, material science, and secure communication. Then, he focuses on their specific contributions in establishing a rigorous discipline of quality assurance for quantum software. In this context, they are witnessing the increased availability of powerful quantum computing facilities as a service; also, there are promising prospects of applying quantum computing in fields such as material- and drug discovery, as well as scheduling, and optimisation. With these prospects comes an inherent challenge of quality assurance of complex quantum programs. Quantum programs and programming frameworks are becoming more complex, and this complexity creates a gap, calling for novel and rigorous testing and debugging frameworks. In this talk, Dr. Mousavi presents an overview of the fascinating emerging field of software engineering and its numerous challenges and opportunities. In particular, he reviews their recent research on characterising faults in hybrid quantum-classical architectures. This has led to a taxonomy of real faults in hybrid quantum-classical architectures. They also present their long-standing effort to establish a mature property-based testing framework for quantum programs both for fault-tolerant and for noisy architecture. An automated debugging framework based on property-based testing is also presented. Finally, they conclude with a roadmap of the ongoing and future research and collaborations and an overview of the fundamental challenges ahead.

2.4 CNR (Italy)

The talk introduces the Quantum and Continuum Computing (QCC) group at ICAR-CNR. The group specializes in the Continuum Computing paradigm, which integrates IoT, Edge, Cloud, and Quantum Computing into a distributed intelligent ecosystem. Led by Carlo Mastroianni, the group develops intelligent algorithms for optimization and data analysis across diverse heterogeneous platforms. A significant portion of their research involves Variational Quantum Algorithms, such as QAOA and VQE, applied to solve NP-hard problems like energy optimization in prosumer communities and resource allocation in Cloud-Edge architectures. To enhance performance, the group focuses on tailoring quantum circuits to exclude infeasible solutions and reduce the search space. Furthermore, they explore Quantum Reservoir Computing for chaotic time-series prediction and Projected Quantum Kernels for classifying real-world IoT data, such as office occupancy. Their work also extends to Quantum Cryptography Networks, utilizing hybrid Quantum Key Distribution to ensure secure communication over large-scale infrastructures. These efforts aim to create cognitive environments capable of self-learning and adaptation to improve overall quality of life. Moving forward, the group plans to assess and improve these optimization and machine learning algorithms as quantum hardware evolves and provides more available qubits. Future research will specifically target advancements in neuromorphic computing and the application of quantum simulation to quantum chemistry and molecular modeling through strategic interdisciplinary collaborations.

2.5 NTNU (Norway)

The talk summarises the scientific activities at the Center for Quantum Spintronics in the Department of Physics at the Norwegian University of Science and Technology. The research focuses on utilizing other quantum degrees of freedom than the charge of the electron, such as spin and orbital degrees of freedom, to build a theoretical foundation for emerging quantum technologies such as quantum sensing, quantum communication, and quantum computing. Systems of interest in this context, which are being studied, are superconductors, unconventional quantum magnetic systems, and topological quantum states of matters such as topological insulators and topological superconductors. A substantial effort is also directed at studying spin based qubits for quantum computing applications.

2.6 SBA

SBA Research is the Austrian cyber security research center and national representative in ERCIM, and contributes to a broader Austrian landscape of quantum and cyber security activities. In Austria, Quantum Key Distribution is developing along hardware and software lines, driven by European programs such as EuroQCI and by work on deployment concepts, network integration, and operational monitoring. Satellite-based QKD is part of this trajectory, alongside ground-based infrastructure such as optical telescope capabilities. Post-quantum cryptography work in Austria covers quantum-safe scheme design, cryptanalysis, hybrid key exchange concepts, and migration planning for operational environments. Quantum information processing efforts include quantum machine learning, quantum feature maps for data encoding, and symmetry-based approaches for robustness, explainability, and data obfuscation. Cross-cutting topics include noise modeling and the question of whether external physical effects, such as magnetic field fluctuations, can measurably affect quantum hardware. The overall direction targets security use cases in government, medical environments, and critical infrastructures.

2.7 RISE

As a broad and multidisciplinary organization, the Research Institutes of Sweden (RISE) serves as a key node within the Swedish and European quantum ecosystems. Building upon established expertise

in quantum metrology and sensing, RISE is expanding its capabilities through the formation of a dedicated quantum information group within the computer science department. The current strategic focus lies at the intersection of space applications, quantum sensing, and hybrid HPC-AI-QC computation. This includes a specific interest in leveraging advances in quantum technology to improve distributed systems, ranging from high-performance computing clusters to secure satellite communication. By aligning with the EuroHPC JU and Nordic initiatives, RISE is accelerating the scale-up of competence required for a quantum-native world. A primary objective is to support Swedish industry, which shows a growing interest and capability to produce high-end quantum components and a need for expert guidance in quantum cryptography and quantum computing. Through technology transfer and pilot deployments, the focus remains on delivering strategic value and achieving quantum utility across the defense, space, and industrial sectors.

3. View of Industrial Players

A pivotal part of the workshop was the afternoon session, chaired by Marco Pota of ICAR-CNR, and dedicated to industrial research trends. The session featured a robust dialogue with representatives from major industrial players and specialized quantum firms. The goal of this interaction was to identify industrial challenges that can be tackled through academic research and vice versa. Industry experts and researchers discussed the development of diverse hardware platforms, such as superconducting, photonic, and ion-trap systems, while emphasizing the need for best practices in scientific reproduction and performance benchmarking. In the next subsections we summarize the content of the presentations provided by the participating companies.

3.1 D-WAVE

Mansour Zarrin and Mayowa Ayodele outlined D-Wave’s technological offering, focusing on quantum annealing as the preferred method for solving complex combinatorial optimization problems by searching for the lowest-energy states. Unlike gate-based models, this technology addresses concrete industrial challenges, such as logistics planning and machine learning, by translating problems into mathematical formulations known as QUBOs. Through its Leap cloud service, the company offers a hybrid quantum-classical infrastructure capable of handling millions of variables with extremely fast response times. In short, the company promotes an ecosystem ready for commercial production, supported by acceleration programs to integrate quantum computing into today’s business workflows.

3.2 QUANTUM-2-PI

Speaker Prof. Salvatore Cuomo introduced the start-up he heads and analyzed the growing threat quantum computing poses to current cybersecurity standards, such as the RSA system. While traditional computers would take millennia to crack complex keys, future quantum machines could do so in a matter of hours. Major technology companies such as IBM and IonQ are already developing processors with thousands of logical qubits expected within the next decade. An immediate danger is the "harvest now, decrypt later" strategy, where criminals steal encrypted data today to decrypt it in the future. To counter this risk, it is essential to adopt new cryptographic solutions capable of withstanding both classical and quantum computing power. In short, Quantum-2-Pi provides a rapid technological evolution, which is urgently required to update data protection protocols.

3.3 LEONARDO

Dr. Dragoni delivered a presentation on Leonardo SpA's, positioning in the quantum computing domain. In his talk, he illustrated the company's agnostic approach to quantum technologies, describing how the Leonardo Quantum Computing Laboratory evaluates different hardware platforms currently available for building quantum computers. He highlighted Leonardo's strategy based on benchmarking existing NISQ systems to ensure rapid and effective adoption as the technology matures. He also illustrated the company's focus on developing quantum and quantum-inspired algorithms and applications. Several application domains were presented, including combinatorial optimization, quantum AI, simulation of physical systems and cryptography. Dr. Dragoni also provided concrete examples of industrially relevant use cases tackled through a full-stack methodology—combining quantum, quantum-inspired and classical computing approaches. In particular, he described how quantum computing can support computational fluid dynamics through a hybrid Lattice Boltzmann Method accelerated by a quantum subroutine based on the HHL algorithm. He discussed both the challenges encountered and the opportunities that emerged when applying this approach to a standard benchmark system.

3.4 IQM

Max Haeberlein in his presentation outlined the strategic path of IQM, a leading quantum computing company aiming to evolve from today's noisy systems to a fault-tolerant future. Through a detailed roadmap, he highlighted how integrating quantum computing processors (QPUs) with classical supercomputers will enable the solution of complex optimization problems, as demonstrated by the superior results achieved in financial portfolio management. Beyond technical progress, he emphasized the importance of building a collaborative ecosystem between industry and academia, carefully managing intellectual property to translate fundamental research into practical applications. In short, he described IQM strategy in the transition to quantum utility, promising significant impacts in fields ranging from molecular chemistry to biological simulation.

3.5 FUJITSU

Almudena Justo Martinez positioned Fujitsu as a global leader in quantum computing, pursuing an ambitious roadmap to reach the 10,000-qubit threshold by 2030. The company is not limited to superconducting hardware, but is also exploring alternative technologies such as diamond spins and innovative architectures that dramatically reduce the resources required for complex calculations. To facilitate practical adoption, Fujitsu integrates powerful quantum computers with the world's largest simulators, offering a hybrid platform powered by artificial intelligence and open-source software. The ultimate goal is to accelerate the development of real-world industrial applications, enabling partners in the medical, financial, and materials sectors to solve challenges that are currently insurmountable for classical systems.

3.6 QUANTUMNET

Alfredo Massa outlined the profile and activities of QuantumNet, an organization dedicated to integrating hybrid quantum-classical solutions into modern industrial processes. Through its membership in the IBM Quantum Startup Program, the organization gains access to advanced computing systems to develop transformative research projects, such as intelligent transportation optimization and image recognition using quantum machine learning. Beyond technical innovation, QuantumNet promotes professional training through its Quantum Computing Academy, aiming to bridge the skills gap in emerging technologies. Its strategic vision is complemented by cultural

heritage monitoring initiatives, demonstrating a versatile commitment that ranges from algorithmic efficiency to social impact on the local community.

3.7 QTI

Alessandro Zavatta outlined the profile and activities of QTI (Quantum Telecommunications Italy), a pioneering company founded in 2020 as a spin-off of the CNR-INO to drive innovation in cybersecurity. The company specializes in the development of industrial systems for Quantum Key Distribution (QKD), a cutting-edge technology designed to ensure the absolute integrity of digital communications. Through a strategic partnership with the TIM Group, QTI has consolidated its presence in Italy, establishing research centers in Florence and development offices in Rome. The presenter also highlighted the success of experimental free-space QKD links established in Florence, demonstrating the practical feasibility of quantum networks for data protection over various distances.

4. Future activities of the Working Group

The last session of the workshop was an open session where all the attendees were invited to participate proposing future activities of the Workshop Group. The organizers provided some ideas for activities and also research questions to focus the activities around. The activities discussed were the following.

- **Joint application for European projects**. One of the primary focal points was the discussion on grant proposals and participation in EU research programs. The WG is encouraging its members to prepare joint proposals targeting the funding opportunities offered by the Quantum Flagship and other EU calls (e.g., Horizon Europe and Marie Skłodowska-Curie Actions)
- **Working group expansion**. There was a clear consensus on extending the group's membership. Plans are in motion to expand the WG beyond its initial core to include other ERCIM institutions, external research entities, and industrial partners. This expansion is intended to create a more comprehensive and inclusive ecosystem for quantum research in Europe.
- **Dissemination**. A Special Issue of ERCIM News dedicated to Quantum Technologies is currently in the planning stages, aiming to showcase the latest breakthroughs and strategic directions from the community.
- **Annual Workshop**. The current leadership is already planning the next workshop, which is expected to further solidify the group's role as a cornerstone of European quantum innovation.
- **Invited talks**. Members of the different research groups and industrial partners could be invited by other members to give invited talks in courses, events, master classes, etc.
- **Co-advised PhDs**. It is also encouraged to collaborate in the joint supervision of PhD students. The complementary expertise of two advisors from different institutions of the working group can benefit the quality and depth of the resulting PhD theses.
- **Industry-Academy collaboration**. During the workshop it was clear that Industry and Academia should work together to pursue the common challenges in the context of quantum technologies.

The workshop ended with a list of questions that could guide future research on quantum technologies. We reproduce here the list of questions.

- What will be the killer applications (in which domain) of quantum computing (showing an advantage over classical computing)? (drug design, molecular simulations, machine learning, optimization, security, quantum cryptography)
- In which domain could we have a quantum advantage in the NISQ era? (any of the previous ones?)
- What are the most difficult technical challenges of fault-tolerant quantum computing? (fault-tolerance protocols, algorithms for decoding QECs, magic distillation, error rate)
- What are the pros and cons of gate-based (digital) quantum computers and quantum annealers? (in terms of qubits, computation, flexibility, noise, etc.)
- What are the pros and cons of quantum-inspired hardware and algorithms?
- When will fault-tolerant quantum computing be a reality? (10, 15, 20 years, never?)
- How many logical qubits do we need to solve real-world problems with quantum advantage? When will those qubits be available in quantum computers?
- How can we compare the performance of quantum and classical hardware? What benchmarks and methodologies should be used to compare quantum and classical (possibly parallelized) algorithms?
- What are the challenges in terms of quantum software? What are the advances in methodologies, programming languages, testing, etc., and what are the challenges ahead?
- What are the differences and similarities between the goals of research in industry and academia? How can we create synergy and strengthen the collaboration?

5. Conclusion

The first Workshop of the ERCIM Working Group on Quantum Technologies successfully established a platform for innovation and collaboration. The workshop was characterized by intense engagement and productive networking, including several collaborative initiatives on specific scientific themes, which will help to define the WG's trajectory in the coming years. Some of these key research areas discussed included:

- Foundations and Algorithms: investigating quantum algorithms for optimization, information retrieval, and machine learning.
- Networking and Security: exploring Quantum Key Distribution (QKD) and the protocols necessary for a future Quantum Internet.
- Hybrid Systems: analyzing the interplay between quantum hardware and classical High Performance Computing (HPC).
- Quantum Software Engineering: adapting and creating new methodologies to design, test, and debug quantum and hybrid systems.

The Working Group motivates its members to develop joint proposals aimed at funding opportunities within the Quantum Flagship and other European calls. In addition, there is strong agreement on broadening the group's membership. Preparations are underway to expand beyond the original core to include additional ERCIM institutions, external research organizations, and industrial partners. The objective of this expansion is to foster a more comprehensive and inclusive ecosystem for quantum research across Europe.

Beyond its research objectives, the Working Group is also committed to dissemination. A Special Issue of ERCIM News focused on Quantum Technologies is being prepared to highlight recent advances and emerging strategic priorities within the community. Building on the success of the inaugural event, the leadership will soon prepare the next workshop, which is anticipated to further strengthen the group's position as a key driver of quantum innovation in Europe.

By supporting the growth of young researchers, stimulating mobility, and fostering deep ties between academia and industry, the WG is well-positioned to drive the transition of quantum technologies from theory to reality. The foundations laid in Vietri sul Mare promise a vibrant and productive future for the ERCIM quantum community.