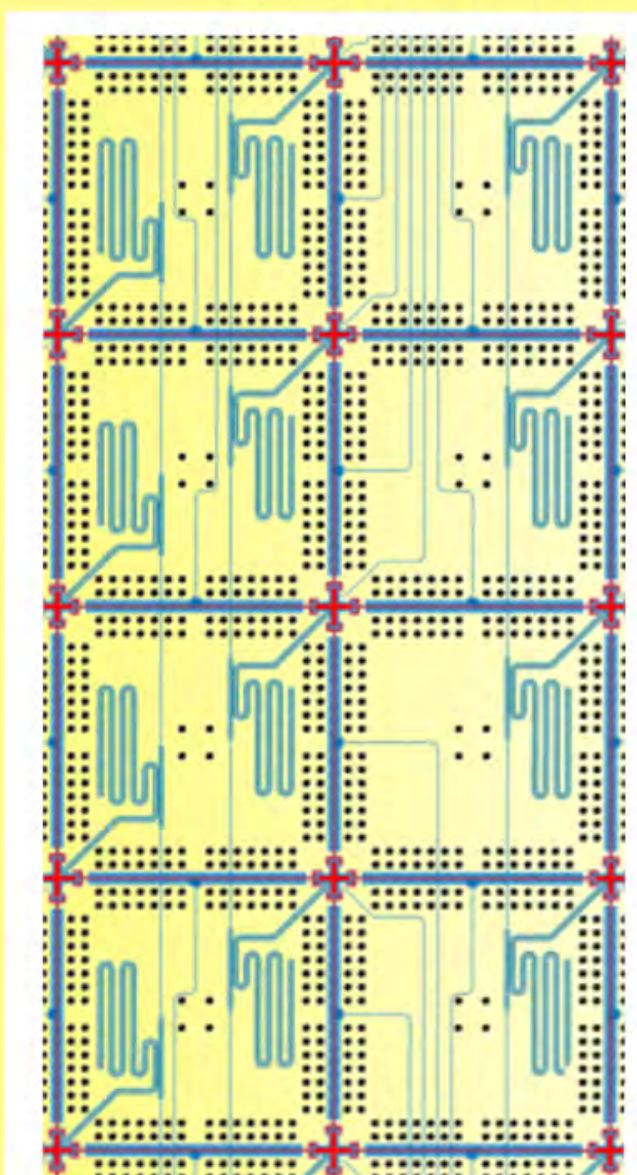


QTQM 2025

*Quantum Technology
meets*

Quantum Materials



Embassy of Italy
Stockholm

Göteborg, 9-10 October 2025



CHALMERS
UNIVERSITY OF TECHNOLOGY

Quantum Technology meets Quantum Materials (QMQT 2025)

Göteborg, 9-10 October 2025



Embassy of Italy
Stockholm



CHALMERS
UNIVERSITY OF TECHNOLOGY

Scientific Committee

Thilo Bauch - Chalmers University

Simone Gasparinetti - Chalmers University

Floriana Lombardi - Chalmers University

Giovanna Tancredi-Sammarco - Chalmers University

Augusto Marcelli - Embassy of Italy to Stockholm

Andrea Giachero – Università Milano Bicocca

Quantum Technology meets Quantum Materials (QMQT2025) is a thematic workshop jointly organized by Chalmers University and the Scientific Office of the Embassy of Italy to Stockholm with the aim of fostering collaboration between Italy and Sweden.

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Foreword

We cannot yet know with certainty if, and when quantum computers and quantum technologies will become part of everyday life. Due the incredible progress made in academic and industrial laboratories something already appeared in advanced mobile phones and computers. The pace of research is fast, but because of the challenge the road ahead is still long. Many technological and theoretical obstacles must be overcome, but the challenges promise to stimulate the creation of new communities and professionals, who will combine scientific and technological expertise for the benefit of industry and society.

Italy introduced a national strategy on quantum technology in mid-2025. Quantum hardware exist in Turin and Bologna and Italy already hosts the EuroHPC quantum infrastructure. The strategy defines a roadmap across the five quantum pillars: computation, simulation, communications, sensors, and basic science and it is coordinated by the Ministry of Universities and Research (MUR) in collaboration with the ministries of Defense; Enterprise; Digital Transformation and Foreign Affairs, and the National Agency for Cybersecurity (ACN) together with the National Institute for Metrological Research (INRiM). In September Italy has become the first country in the EU to approve a comprehensive law regulating the use of artificial intelligence.

Sweden has been investing in quantum technologies for several years and presented a national quantum strategy (Swedish Quantum Agenda). The Wallenberg Center for Quantum Technology (WACQT) here at Chalmers University in Goteborg hosts the construction of a national superconducting quantum computer, contributing to the development of unique skills for Swedish academia and industry. This center that is hosting this workshop, soon will operate a quantum computer able to create the national expertise system for quantum technologies. This is one of the main reasons to cooperate with the academic-industrial Swedish system to consolidate our common role as a key producers and consumers of knowledge in the global arena over the coming years. Indeed, in Sweden, the Embassy of Italy works to strengthen interactions between research, higher education and large infrastructures joining key actors from academia, industry and the innovation ecosystems.

This initiative is timely because scientific collaborations on these topics, and the potential of a bilateral agreement on quantum technologies and the use of quantum computing will be certainly a strategic opportunity for both countries. Cooperation offers great potential, certainly commensurate with our common ambitions in this strategic area for research and for high-tech companies. A strengthened collaboration will offer opportunities for the development of new quantum devices, the development of dedicated quantum algorithms and unique opportunities for testing quantum devices and processors.

As European member States we need to work together to develop these new technologies within a common framework of rules that focus on people, rights and needs.

In the framework of a day by day strengthened cooperation, the Italian Embassy is strongly committed to enhance the dialogue between our countries, and our Scientific Office is daily working to trigger new opportunities among scientists and institutions. This workshop that brings together Italian and Swedish scientists engaged in quantum technologies, quantum materials and quantum computing is a clear example that we can effectively dialogue and work together in strategic areas contributing to establish a competitive European space of research and trigger real innovations.

The event has been co-organized by the Scientific Office of the Embassy of Italy with the Area of Advance Nano at Chalmers University and the Wallenberg Centre for Quantum Technology funded by Knut and Alice Wallenberg Foundation. I like to acknowledge all persons at Chalmers University that made this initiative possible, and in particular, Maria Messing Dean of the Department of Microtechnology and Nanoscience (Mc2), Susanne Aalto, Prorector and Heidi Holst, Master of Ceremonies of the Chalmers university. I would like to acknowledge also the participation of Sergio Strozzi, Head of Innovation, Technology and Startups at the Italian Ministry of Foreign Affairs and International Cooperation

Michele Pala

Ambassador of Italy to Sweden



Embassy of Italy
Stockholm

Introduction

2025 is the International Year of Quantum Science and Technology (IYQ), a strategic technology for achieving the 17 Sustainable Development Goals of the 2030 Agenda adopted by all United Nations Member States in 2015. In the same year more than three thousand scientists, academics, and researchers, not only from Europe, signed the Quantum Manifesto¹, an appeal to Europe with an explicit request to support the development of emerging quantum technologies and keep our continent competitive on the global stage of strategic technologies. However, October 4, 2022, was perhaps the decisive day in the history of quantum technologies. On that day in Stockholm, the Royal Swedish Academy of Sciences announced the Nobel Prize in Physics to Alain Aspect, John Clauser, and Anton Zeilinger "for their experiments with entangled photons," which, by demonstrating the violation of Bell's inequalities, paved the way for quantum information science.

This recognition, along with theoretical, experimental, and technological advances has changed the perspective of the scientific community working on quantum physics, as well as several other communities. Indeed, these technologies require the contribution of physicists, engineers, biologists, computer scientists, educators, business leaders, policymakers, and regulators, to implement and develop all tools necessary to make these technologies available in academia, industry, and everyday life.

In the approximately ten years since the publication of the Quantum Manifesto, we have seen the birth of the "Quantum Flagship," a program funded by the European Union with €2 billion Euro, in addition to dozens of national strategic grants. These initiatives made Europe competitive in all pillars of quantum technologies: computation, simulations, communications, and sensors, with researches that will revolutionize medicine, finance, cybersecurity, and everyday life in the coming years. The Quantum Industry Consortium (QuIC)², a European industrial consortium for quantum technologies that aims to stimulate and support collaboration between companies, investors, universities, and research centers within an ecosystem capable of fostering European innovation has been also founded. In the space sector, the European Commission, and the European Space Agency (ESA) are also working to launch in the next months a constellation of satellites dedicated to quantum communication. Finally, between the end of 2023 and 2024, in recognition of the revolutionary potential of these technologies, European countries signed the Quantum Pact³, a concrete commitment to support and promote quantum technologies, to guarantee the scientific and industrial competitiveness of EU, with the ambitious goal of making our continent a leader in quantum research and innovation. We are truly at the dawn of a technological revolution that will undoubtedly radically transform our world beyond any possible discrimination.⁴

Italy is well-positioned in the field of quantum technologies and is actively working to build a competitive quantum ecosystem. The National Recovery and Resilience Plan (PNRR), part of the European Recovery Plan (NextGenerationEU), has dedicated significant investments to quantum technologies, both in high-performance computing and research. The National Center for HPC, Big Data and Quantum Computing (ICSC Foundation) and the National Quantum Science and Technology Institute (NQSTI) are leading the transformation with several projects such as a new supercomputer (a top-10 supercomputer is currently operational in Bologna) and a quantum computer to be operational soon at the Bologna Technopole. Quantum science, combined with supercomputing and, in the future, AI will be able to support and further enhance the strategic role of data centers, offering opportunities to companies operating in high-tech sectors and beyond.

In July 2025, the Interministerial Committee for Digital Transition (CitD) presented the "Italian Strategy for Quantum Technologies," a document developed by experts and coordinated by the Ministry of University and Research, the Ministry of Foreign Affairs and International Cooperation, the Ministry of Defense, the Ministry of Enterprise, the Department for Digital Transformation, and the National Agency for Cybersecurity. This strategy is aligned with the objectives of the Quantum European Strategy⁵, published by the European Commission in July 2025. This is a clear political declaration by which Italy intends to contribute to this technological revolution.

To stay at the forefront of quantum technology, Sweden will secure competence in this new emerging technology, through high-quality undergraduate and graduate education as well as training and skills development within both industry and society. The benefits could potentially have a significant impact on economy and society, which is why Sweden wants to become an active player in the rapid international development. Here at Chalmers, the Knut and Alice Wallenberg Foundation (KAW) finances the only major quantum technology venture in Sweden through the Wallenberg Centre for Quantum Technology (WACQT) that involves more than 200 researchers distributed among several Universities around the country. Other funding agencies have recently launched a few smaller programs. To take advantage of the opportunities of quantum technology, coherent national objectives are planned, and a well-funded national quantum strategy is on the way that on the long term will take over the KAW contribution, increasing over time.

The present quantum technology efforts are concentrated within WACQT, a SEK 1.4 billion project 12-year long, started in 2018. WACQT has two main parts: the Core project, which has the overall goal of developing the 100 superconducting qubits quantum computer; and the Excellence programme, with the overall goal of building a broad competence base for quantum technology. The Excellence part is where most of the industrial collaborations are concentrated; but there is also a guest researcher programme aiming at strengthening collaborations with relevant actors in the field. A Quantum Technology testbed is now in operation to allow Swedish industries and Universities to access the quantum processor developed at Chalmers. The mission of the center and of the future quantum initiatives is to increase the awareness of the revolutionary impact of quantum technology in the society.

This bilateral workshop is an additional demonstration of the extraordinary interest of both Italy and Sweden in this area and can be also relevant to contribute to the drafting of the EU Quantum Act⁴, a strategic tool to transform into economic value startups, patents, and concrete applications, expected in the coming months to support research in quantum technologies. Quantum technologies offer opportunities in terms of economic growth, industrial innovation, and global competitiveness, a real challenge for looking to and addressing the future, as stated in Bologna on July 2, 2025, by Executive Vice President of the European Commission Henna Virkunnen while presenting the quantum strategy: "Quantum technologies will change our economy by helping us solve complex challenges, create new medicines, and protect critical infrastructure".

1) <https://ec.europa.eu/futurium/en/content/quantum-manifesto-quantum-technologies.html>

2) <https://www.euroquic.org/>

3) <https://digital-strategy.ec.europa.eu/en/library/european-declaration-quantum-technologies>

4) <https://physicsmagazine.buzzsprout.com/1961683/episodes/17060270-a-manifesto-for-women-in-quantum>

5) <https://digital-strategy.ec.europa.eu/en/library/quantum-europe-strategy>

Program Day 1 - October 9, 2025

*Location: Department of Microtechnology and Nanoscience - MC2
Kollektorn (A423) 4th floor MC2 building
University of Gothenburg, Kemivägen 9, 412 58 Göteborg*

*13:00 h **Welcome** - Embassy of Italy in Stockholm and Chalmers University*

*Maria Messing (Mc2 - Head of department)
Michele Pala (Ambassador of Italy in Sweden)*

***First session** Chair: Floriana Lombardi - Chalmers University, Sweden*

*13:30 – 13:55 Caterina Braggio - University of Padova and INFN Padova, Italy
Superconducting circuits in axion dark matter search: microwave photon counting with transmon qubits*

*13:55 – 14:20 Laura Cardani - INFN Roma 1, Italy
Impact of ambient radioactivity on transmon qubits*

*14:20 – 14:55 Sergey Kubatkin - Chalmers University, Sweden
Towards Quantum limited Sensing of microwave photons with scalable epitaxial graphene*

Coffee break.

***Second session** Chair: Simone Gasparinetti - Chalmers University, Sweden*

*15:30 -15:55 Saroj Dash - Chalmers University, Sweden
Spin on 2D Quantum matter*

*15:55-16:20 Andrea Giachero - University Milano-Bicocca and INFN Milano-Bicocca, Italy
Broadband Quantum-Limited Traveling-Wave Microwave Parametric Amplification for Quantum Sensing and Computing*

*16:20 -16:55 Thilo Bauch - Chalmers University, Sweden
Nanoscale YBCO devices for quantum sensors*

*16:55 -17:20 Francesco Tafuri – University of Napoli Federico II, Italy
The 25 -> 64 qubits superconducting quantum computer of the HPC national center @unina: physics, implementation, operation & hardware evolution*

*17:20 – 18:00 **Round Table** – Italy Sweden opportunities on quantum technologies*

*18:00 – 19:00 **Lab tour, Mc2 clean room tour***

Program Day 2 – October 10, 2025

*Location: Department of Microtechnology and Nanoscience - MC2
Luftbryggan (A810), 8th floor MC2 building
University of Gothenburg, Kemivägen 9, 412 58 Göteborg*

Third session Chair: Giovanna Tancredi - Chalmers University, Sweden

*09:00 – 09:25 Simone Gasparinetti - Chalmers University, Sweden
Towards Verified Quantum Speedup in a Bosonic Quantum Processor*

*09:25 – 09:50 Claudio Gatti - INFN Laboratori Nazionali di Frascati, Italy
Superconducting Qubits for sensing and computing*

*09:50 – 10:15 Katia Gallo – KTH, Sweden
Nonlinear and Quantum Photonic Materials and Devices*

Coffee break

Fourth session Chair: Thilo Bauch - Chalmers University, Sweden

*10:45-11:10 Giovanna Tancredi Sammarco -Chalmers University, Sweden
Building a large quantum processor*

*11:10 – 11:35 Alberto Bortone - INFN Torino, Italy
Engineering of solid-state qubits for sensing and quantum information processing*

*11:35 – 12:00 Fabio Lingua - KTH, Sweden
Continuous-variable two-dimensional cluster states in a microwave frequency comb*

Concluding remarks

Abstracts

Thilo Bauch



Biography

Thilo Bauch earned his physics degree (Diploma) from the University of Tübingen in 1995 and completed his PhD at the University of Cologne in 2000. His primary research focuses on investigating the mechanisms behind superconductivity in High Critical Temperature Superconductors (HTS) using quantum nanodevices, as well as exploring topological superconductivity in emerging 2D materials. He has made pioneering contributions to Macroscopic Quantum Tunnelling phenomena in HTS Josephson junctions. Since 2011, he has served as an associate professor at the Department of Microtechnology and Nanoscience at Chalmers University of Technology in Gothenburg, Sweden.

NANOSCALE YBCO DEVICES FOR QUANTUM SENSORS AND DETECTORS

Thilo Bauch^{a*}, Alessia Garibaldi^a, Núria Alcalde Herraiz^a, Edoardo Trabaldo^a, Alexei Kalaboukhov^a, Riccardo Arpaia^a, Dag Winkler^a, Floriana Lombardi^a, Justin F. Schneiderman^b

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Recent advances in nano-patterning of high critical-temperature (high-T_c) superconductors have enabled simpler, more versatile, and highly sensitive quantum devices, such as SQUID magnetometers, THz mixers, and single photon detectors. Conventional approaches using bicrystal and step-edge Josephson junctions, developed in the 1980s and 1990s, rely on complex epitaxy and multilayer structures that limit performance and design flexibility. Our nanoscale Dayem bridges [1] and novel grooved Dayem-bridge [2] process addresses these limitations, offering an effective alternative. We present SQUID magnetometers based on GDBs that match or exceed the low-noise performance of conventional SQUIDs at moderate temperatures (~77 K). This enables applications like magnetoencephalography (MEG) with sensor placement within 1 mm of the scalp, capturing stronger neuromagnetic signals and improving imaging resolution [3].

Additionally, we demonstrate THz harmonic frequency mixing using a YBCO nanobridge with cross section 70 × 50 nm² integrated with a spiral broadband antenna. At 1.2 THz (×12 mixing), with ~1 μW input and operating at 77 K and 60 K, the device achieved a 20 dB SNR at 1 Hz bandwidth. These results highlight the suitability of nanowire-based devices for high-frequency detection.

Finally, we report dark count observation in ultra-thin (10 nm) YBCO nanowire single photon detectors below 20K [4]. The high critical current density leads to hysteretic current voltage characteristics (IVCs), enabling bistable switching and revealing fluctuation induced dark pulses. This marks a milestone toward developing YBCO based quantum detectors for high temperature operation.

References

- [1] Nawaz S., et al., *Microwave Response of Superconducting YBa₂Cu₃O₇ Nanowire Bridges Sustaining the Critical Depairing Current: Evidence of Josephson-like Behavior*, Phys. Rev. Lett. **110**, 167004 (2013)
<https://doi.org/10.1103/physrevlett.110.167004>
- [2] Trbaldo E., et al., *Grooved Dayem Nanobridges as Building Blocks of High-Performance YBa₂Cu₃O_{7-δ} SQUID Magnetometers*, Nano letters **19**, 1902 (2019)
doi.org/10.1021/acs.nanolett.8b04991
- [3] Pfeiffer C., et al., *A 7-Channel High-Tc SQUID-Based On-Scalp MEG System*, IEEE Transactions on Biomedical Engineering **67**, 1483 (2020)
doi.org/10.1109/TBME.2019.2938688
- [4] Ejrnaes M., et al., *Observation of dark pulses in 10nm thick YBCO nanostrips presenting hysteretic current voltage characteristics*, Supercond. Sci. Technol. **30**, 12LT02 (2017). doi.org/10.1088/1361-6668/aa94b9

Alberto Bortone



Biography

My scientific career started with the development of the CGEM gas detector for the BESIII experiment, where I contributed to both off-detector and on-detector electronics and developed the corresponding acquisition and control software. In recent years, I have applied my expertise in electronics and radiation detectors to the field of quantum technologies within the Italian National Institute for Quantum Science and Technologies (NQSTI), focusing on the fabrication of color centers via ion implantation, beam diagnostics, device characterization, and the development of new technologies for quantum optics experiments.

Engineering of solid-state qubits for sensing and quantum information processing

Alberto Bortone^{a*}, Emilio Corte^{ba}, Manuel Dionisio Da Rocha Rolo^a, Jacopo Forneris^{ba}, Paolo Olivero^{ba}, Sviatoslav Ditalia Tchernij^{ba}, Ettore Vittone^{ba}

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Defects in wide-bandgap materials, such as diamond and silicon, provide a highly promising platform for quantum technologies. Optically active crystal defects, commonly known as color centers can act as stable single-photon sources [1], which are key enablers for quantum photonics protocols, nanoscale measurements (including potential applications in biological systems) as well as qubits for quantum computation, quantum memories and quantum repeaters, depending on the opto-physical properties of the specific emitter under consideration. The controlled introduction of point defects into crystal lattices represents a fundamental step toward the realization of quantum devices and is typically performed via ion implantation [2], which offers high versatility and scalability compared to alternative methods.

The Laboratory for Ion Implantation at the University of Turin (LIUTo), whose equipment is shared with INFN, addresses these challenges with a state-of-the-art multi-elemental ion implanter [3]. The facility is equipped with a Source of Negative Ions by Cesium Sputtering (NEC SNICS II), chosen for its versatility in generating a wide range of ion species, a fundamental requirement for the controlled creation of color centers in semiconductors and insulators. The apparatus operates at terminal potentials up to 100 kV and can deliver ion beams of various species, with currents ranging from 10^{-12} to 10^{-6} A and typical spot sizes of about 1 cm². The system features a cleanroom-integrated irradiation chamber and two beamlines. The facility instrumentation, including room temperature and cryogenic single-photon fluorescence confocal microscopes has enabled the INFN Sect. of Torino to demonstrate and assess novel classes of solid-state quantum emitters in diamond [4,5,6], aluminum nitride [7] and silicon [8] for quantum information processing and quantum sensing of weak electromagnetic field and temperature gradients [9, 10].

LIUTo also supports a broad range of applications, spanning from materials modification and semiconductor doping to Ion Beam Induced Charge (IBIC) studies and, most notably, applications for quantum technologies. In this latter domain, the facility enables controlled implantation down to the single-ion level, paving the way for the deterministic

engineering of optically active defects in wide-bandgap materials for advanced quantum devices. A precise control of these processes relies on the accurate characterization of the ion beam intensity and spatial distribution, which is particularly demanding at low implantation energies and ion fluxes.

At LIUTo, Ion Beam Induced Charge (IBIC) is employed both as a powerful technique for the functional characterization of semiconductor devices (owing to the high sensitivity of low-energy ion probes to surface conditions, contamination, and charge-carrier dynamics) and as a beam monitoring tool, enabling single ion level characterization of the beam, including its energy distribution, prior to implantation.

Within this framework, we explored the potential of monolithic CMOS sensors as position-sensitive detectors for ion-beam characterization in the context of quantum technologies. Specifically, we employed the ARCADIA-MD3 ASIC [11], developed by the INFN ARCADIA collaboration for high-energy physics applications. The chip integrates a 512×512 pixel matrix with 25 μm pitch on a $1.28 \times 1.28 \text{ cm}^2$ active area, operates at low power (10 mW cm^{-2}), and supports a scalable readout architecture. Tests at the LIUTo facility, using proton beams with energies down to 17 keV, demonstrated that MD3 can visualize the beam profile through patterned masks of different sizes and geometries, while simultaneously enabling real-time monitoring of particle rates at the single-ion level. Despite not being specifically optimized for this application, MD3 has shown strong potential for beam diagnostics relevant to defect engineering in quantum materials.

Future perspectives include the development of monolithic CMOS sensors with energy-resolving capability, integrating active pixel arrays with column-level ADCs and on-chip digitization for fully digital output. In parallel, efforts are directed toward the development of CMOS modelling and process design kits optimized for cryogenic operation, with parameter extraction performed at temperatures down to 4 K using the AttoDry800 cryostat. These advancements will enable the design of cold-IP for quantum sensing and qubit control, thereby extending the role of CMOS technology in next-generation quantum devices.

References

- [1] M. Ruf *et al.*, (2021), “Quantum networks based on color centers in diamond,” *J Appl Phys*, (vol. 130, no. 7, Feb. 2021). <https://doi.org/10.1063/5.0056534>
- [2] J.L. Pacheco *et al.*, (2017), Ion implantation for deterministic single atom devices, *Rev. Sci. Instrum.* (88). <https://doi.org/10.1063/1.5001520>
- [3] E. Corte, A. Bortone, *et al.*, (2025), The development of IBIC microscopy at the 100 kV ion implanter of the University of Torino (LIUTo) and the application for the assessment of the radiation hardness of a silicon photodiode. *Eur. Phys. J. Plus* (140, 609). <https://doi.org/10.1140/epjp/s13360-025-06528-1>
- [4] V. Pugliese *et al.*, (2025), Photoactivation of Color Centers Induced by CW Laser Irradiation in Ion-Implanted Diamond, *ACS Photonics* 2025 12 (7), 3803-3814. <https://doi.org/10.1021/acsp Photonics.5c00826>
- [5] V. Pugliese *et al.*, (2025), Formation yield of germanium-vacancy centers in diamond upon keV ion nano-implantation and thermal annealing, *J. Appl. Phys.* 138, 044401. <https://doi.org/10.1063/5.0258262>
- [6] S. Ditalia Tchernij *et al.*, (2017), Single-Photon-Emitting Optical Centers in Diamond Fabricated upon Sn Implantation, *ACS Photonics* 2017 4 (10), 2580-2586. <https://doi.org/10.1021/acsp Photonics.7b00904>

- [7] E. Nieto Hernández *et al.*, (2024), Fabrication of quantum emitters in aluminum nitride by Al-ion implantation and thermal annealing, *Appl. Phys. Lett.* 18 March 2024; 124 (12): 124003. <https://doi.org/10.1063/5.0185534>
- [8] G. Andrini *et al.* (2024), Activation of telecom emitters in silicon upon ion implantation and ns pulsed laser annealing. *Commun Mater* **5**, 47 (2024). <https://doi.org/10.1038/s43246-024-00486-4>
- [9] G. Petrini *et al.*, (2022), Nanodiamond–Quantum Sensors Reveal Temperature Variation Associated to Hippocampal Neurons Firing, *Adv. Sci.* 2022, 9, 2202014. <https://doi.org/10.1002/advs.202202014>
- [10] G. Zanelli *et al.*, (2025), Interplay between dressed and strong-axial-field states in Nitrogen-Vacancy centers for quantum sensing and computation, *In preparation*, <https://doi.org/10.48550/arXiv.2412.17608>
- [11] M. Da Rocha Rolo *et al.*, (2025), ARCADIA fully depleted CMOS MAPS development with LFoundry 110 nm CIS *Frontiers in Sensors*, (Volume 6). <https://doi.org/10.3389/fsens.2025.1603755>

Caterina Braggio



Biography

Caterina Braggio is currently Associate Professor at the Physics and Astronomy Department of the University of Padova. She is Co-Lead for the “Physics and Sensing” area in the Superconducting Quantum Materials and System (SQMS) US Quantum Information Center, and the Scientific Coordinator for the National Institute of Nuclear Physics (INFN) in the center. She served as Co-convenor in the Task Force 5 “Quantum and Emerging Technologies” of the ECFA Detector R&D roadmap, and is currently a member of the Technical Expert Group of the CERN Quantum Initiative. Caterina Braggio’s research interests center around the development of quantum sensors and new technologies towards discoveries of new physics in the context of dark matter searches.

Superconducting circuits in axion dark matter search: microwave photon counting with transmon qubits

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Devices and methods of quantum information science can bring significant upgrades to current and future particle physics detectors. In particular, I will briefly introduce experiments testing the hypothesis that dark matter is composed of very light particles, detectable as an effective field with a specific frequency set by their mass. As the signal to noise ratio is very poor in these experiments, new technologies need to be developed and tested, including superconducting circuits like Josephson parametric amplifiers and microwave single photon detectors (SMPD). With SMPDs, the speed at which most detectors probe the open parameter space at relevant sensitivity can largely be enhanced, and I will report about recent results obtained by applying a transmon-based microwave photon counter to the readout of a cavity haloscope [1].

Later, I will discuss the next steps to take in this field, which aim to expand the “dynamic” bandwidth of new sensors. Currently, the range they can cover is limited to about 200 MHz, whereas their use becomes truly valuable when applicable for much broader ranges. I will then present some superconducting circuit designs for mixer implementation that show promise in achieving this goal.

Reference

[1] C. Braggio, L. Balembois, R. Di Vora, Z. Wang, J. Travesedo, L. Pallegoix, G. Carugno, A. Ortolan, G. Ruoso, U. Gambardella, D. D’Agostino, P. Bertet, and E. Flurin, Quantum-Enhanced Sensing of Axion Dark Matter with a Transmon-Based Single Microwave Photon Counter. *Phys. Rev. X* (15), 021031, 2015
<https://doi.org/10.1103/PhysRevX.15.021031>

Laura Cardani



Biography

Laura Cardani is a senior researcher at the Italian National Institute for Nuclear Physics (INFN). She received her PhD in Physics in 2014 from Sapienza University of Rome. Her early research focused on the development of cryogenic particle detectors for the study of rare nuclear events. During her postdoctoral work, she contributed to a project aimed at applying superconducting microwave resonators to particle physics. She later proposed a project investigating the impact of particles produced by ambient radioactivity on superconducting qubits, demonstrating that these devices are sensitive to ionizing radiation. She is currently exploring the potential of superconducting qubits as particle detectors.

IMPACT OF AMBIENT RADIOACTIVITY ON TRANSMONS QUBITS

Laura Cardani ^{a*}

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Transmon qubits, the building blocks of superconducting quantum computers, have been shown to be sensitive to sudden energy deposits caused by ambient radiation [Vepsäläinen2020]. Prior studies suggested that such events may induce time- and space-correlated errors in superconducting circuits [Wilen2020, McEwen2021]. Furthermore, operating the device in a low-radioactivity environment significantly improved the performance of superconducting microwave resonators [Cardani2021], the locking of fluxonium qubits at their sweet spot [Gusenкова2022], and the mitigation of correlated errors in a small array of qubits [Bratrud2024].

A significant effort to mitigate such effects is ongoing. The R&D activities include, but are not limited to, the design of new circuits with gap engineering [McEwen2024], the design of new chips in which qubits are entangled across separate silicon dies [Gold2021] or equipped with phonon traps [Henriques2019, Martinis2021, Iaia2022], and the development of radiopure materials and screening techniques (including operation in deep underground laboratories) for qubit operation [Cardani2023].

Here we propose a different approach, aiming to answer a fundamental question: can this sensitivity to radiation become an advantage for particle detection? Particles impinging on a qubit chip create thousands of electron–hole pairs by ionization, which in turn recombine into phonons. Phonons can spread throughout the chip and be absorbed by qubits, creating a stream of “errors.” This stream of errors is what we consider to be the signal.

Preliminary Monte Carlo simulations of the generation, transport, and absorption of phonons [Linehan2025] predicted excellent sensitivity of transmon qubits for detection, provided that (at least) some major changes are made: (i) the ground plane, which competes with qubits for phonon absorption, must be removed, and (ii) the active part of the qubit, where the quasiparticle signal is produced via phonon interaction, must be enlarged [Fink2024]. In [DeDominicis2025] we started from a qubit chip hosting 8 transmon qubits with long lifetime ($T_1 \sim 0.1$ millisecond) and characterized its response to a controlled source of gamma rays, showing that the stronger the source activity, the higher the rate of errors in single transmons. We operated the device in two different setups: the deep underground Gran Sasso laboratories (L’Aquila, Italy) and the Quantum Garage of the SQMS Center (Fermilab, US). We proved that the event rate increases

above ground, in agreement with Monte Carlo predictions. Both measurements point to a detection efficiency of about 10%. We discuss the limits of these measurements and how they can be overcome for particle detection.

References

- Bratrud G. et al. (2024). First measurement of correlated charge noise in superconducting qubits at an underground facility. [arXiv:2405.04642](https://arxiv.org/abs/2405.04642).
- Cardani L. et al. (2021). Reducing the impact of radioactivity on superconducting quantum circuits in a deep underground facility, *Nature Communications* 12 (2733). <https://doi.org/10.1038/s41467-021-23032-z>.
- Cardani L. et al. (2023). Disentangling the sources of ionizing radiation in superconducting qubits. *The European Physics Journal C* 83, 94. <https://doi.org/10.1140/epjc/s10052-023-11199-2>.
- De Dominicis F. et al. (2025). Evaluating radiation impact on transmon qubits in above and underground facilities. [arXiv:2405.18355v3](https://arxiv.org/abs/2405.18355v3).
- Fink C. et al. (2024). Superconducting quasiparticle-amplifying transmon: A qubit-based sensor for mev-scale phonons and single terahertz photons. *Physical Review Applied* 22, 054009. <https://doi.org/10.1103/PhysRevApplied.22.054009>.
- Gold A. et al. (2021). Entanglement across separate silicon dies in a modular superconducting qubit device. <https://doi.org/10.48550/arXiv.2102.13293>.
- Gusenкова D. et al. (2022). Operating in a deep underground facility improves the locking of gradiometric fluxonium qubits at the sweet spots. *Applied Physics Letters* 120, 054001. <https://doi.org/10.1063/5.0075909>.
- Henriques F. et al. (2019). Phonon traps reduce the quasiparticle density in superconducting circuits. *Applied Physics Letters* 115, 212601. <https://doi.org/10.1063/1.5124967>.
- Iaia V. et al. (2022). Phonon downconversion to suppress correlated errors in superconducting qubits. *Nature Communications* 13, 6425 (2022). <https://doi.org/10.1038/s41467-022-33997-0>.
- Linehan R. et al. (2025) Estimating the energy threshold of phonon-mediated superconducting qubit detectors operated in an energy-relaxation sensing scheme. *Physical Review D* 111, 6, 063047. <https://doi.org/10.1103/PhysRevD.111.063047>.
- Martinis J. (2021). Saving superconducting quantum processors from decay and correlated errors generated by gamma and cosmic rays. *npj Quantum Information* 7, 90. <https://doi.org/10.1038/s41534-021-00431-0>.
- McEwen M. et al., (2021). Resolving catastrophic error bursts from cosmic rays in large arrays of superconducting qubits. *Nature Physics*, 18 (107). <https://doi.org/10.1038/s41567-021-01432-8>.
- McEwen M. et al. (2024). Resisting high-energy impact events through gap engineering in superconducting qubit arrays. *Phys. Rev. Lett.* 133 24060. <https://doi.org/10.1103/PhysRevLett.133.240601>.
- Vepsäläinen A.P. et al., (2020). Impact of ionizing radiation on superconducting qubits. *Nature*, 584, 551. <https://doi.org/10.1038/s41586-020-2754-2>.
- Wilén C. et al., (2020). Correlated charge noise and relaxation errors in superconducting qubits. *Nature*, 594, 369. <https://doi.org/10.1038/s41586-021-03557-5>.

Saroj Dash



Biography

Prof. Saroj Dash is leading the Spin and Quantum Devices group at Chalmers University of Technology. He holds a PhD degree in Physics from the Max Planck Institute (2007, Stuttgart, Germany) and postdocs at Uni. of Twente and Uni. of Groningen in the Netherlands. He has made pioneering contributions to Spintronic devices using 2D Quantum Materials, particularly focusing on spin transport and interactions in graphene, semiconductors, magnets, topological quantum materials and their hybrid structures. He received Wallmarkska Prize 2023 by the Royal Swedish Academy of Sciences for "groundbreaking research on spintronic devices using 2D quantum materials." He has delivered over 100 plenary, semi-plenary and invited talks at international conferences, colloquia, workshops, and schools.

SPIN ON 2D QUANTUM MATTER

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Exploring spin, orbital, and topological properties of two-dimensional (2D) quantum materials represents a new platform for realizing novel quantum and spin-based phenomena and device applications. We showed that the unique band structure and lower crystal symmetries of WTe_2 and TaIrTe_4 can provide an unconventional spin-polarized current [1] and out-of-plane spin-orbit torque [2] needed for field-free magnetization switching. On the other hand, 2D magnets are promising owing to their tunable magnetic properties. We reported above room temperature 2D magnet-based spin-valve devices in heterostructure with graphene [3,4]. We further utilized such 2D magnets with co-existence of ferromagnetic and anti-ferromagnetic orders with intrinsic exchange bias in the system, giving rise to a canted magnetism [5]. Such canted magnetism of 2D magnets helps in achieving field-free magnetization switching with conventional spin-orbit materials such as Pt [5,6].

Combining such 2D quantum materials in van der Waals heterostructures can offer a promising platform for efficient control of magnetization dynamics for non-volatile spin-based memory. Recently, we demonstrated energy-efficient field-free spin-orbit torque (SOT) switching and tunable magnetization dynamics in 2D heterostructure comprising out-of-plane magnet Fe_3GaTe_2 and topological Weyl semimetal TaIrTe_4 [7]. In $\text{TaIrTe}_4/\text{Fe}_3\text{GaTe}_2$ devices, an energy-efficient and deterministic field-free SOT magnetization switching is achieved at room temperature with a very low current density (see Fig. 1) [7]. These results establish that 2D heterostructures provide a promising route to energy-efficient, field-free, and tunable SOT-based spintronic memory devices.

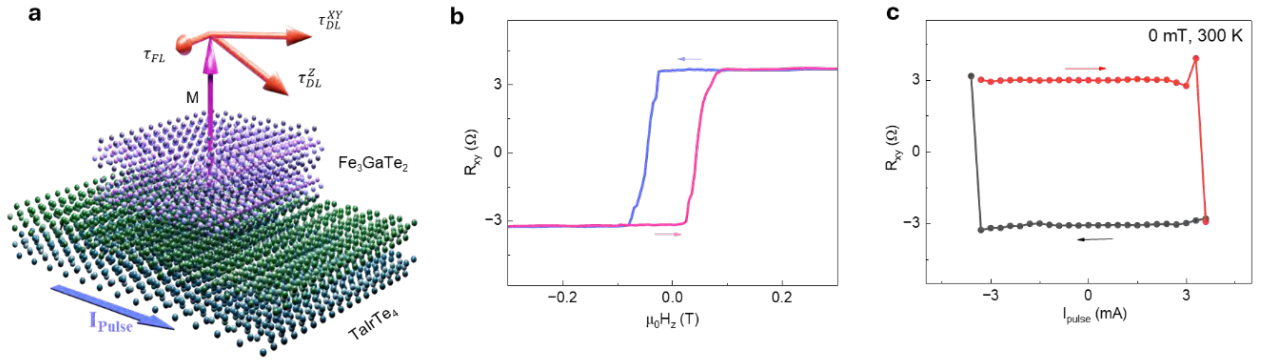


Figure 1: **a.** Spin-orbit torque in the TaIrTe₄/Fe₃GaTe₂ heterostructure [7]. **b.** Anomalous Hall effect of the TaIrTe₄/Fe₃GaTe₂ heterostructure with magnetic field sweep at 300 K. **c.** Field-free and deterministic switching is achieved without an external magnetic field at 300 K when current is applied along the symmetric a -axis of TaIrTe₄ [7].

References

- [1] B. Zhao et al, Saroj Dash, Advanced Materials 32, 2000818 (2020).
- [2] L. Binasal et al, Saroj Dash, Nature Communications 15 (1), 4649 (2024).
- [3] B. Zhao et al, Saroj Dash, Advanced Materials, 2209113 (2023).
- [4] R. Ngaloy et al, Saroj Dash, ACS Nano 2024, 18, 7, 5240 (2024).
- [5] B. Zhao et al, Saroj Dash, Advanced Materials (2025)
<https://doi.org/10.1002/adma.202502822>
- [6] B. Zhao et al, Saroj Dash, ACS Nano 2025,
<https://doi.org/10.1021/acsnano.4c16826>
- [7] L. Pandey et al, Saroj Dash, Accepted in Nature Communications,
<https://doi.org/10.48550/arXiv.2408.13095>

Katia Gallo



Biography

Professor at KTH, Katia Gallo leads the *Nonlinear and Quantum Photonics* group at the Dept of Physics. She holds a M.Sc. and a Ph.D. degree in Electronic Engineering from Italy and a Ph.D. in Physics from France. She received the 1996 IEEE Student Award in Electronic Engineering, and Fellowships from the EU (twice Marie Curie), the Leverhulme Trust, the London Technology Network and the Swedish Research Council. Prior to joining KTH in 2007, she led a research line on integrated photonic devices at Southampton University. In Sweden she has led the VR research center for Optical Quantum Sensing. She currently leads the quantum communications pillar of WACQT as well as the national quantum communication infrastructure. Her research interests span theory, technology and experiments in nanostructured ferroelectrics and integrated photonic devices for all-optical signal processing, biosensing and quantum applications. She has authored 195 journal and conference contributions and given > 50 invited talks at conferences and symposia in the fields of nonlinear optics, polar dielectric materials, integrated photonics and telecommunications.

Nonlinear and Quantum Photonic Materials and Devices

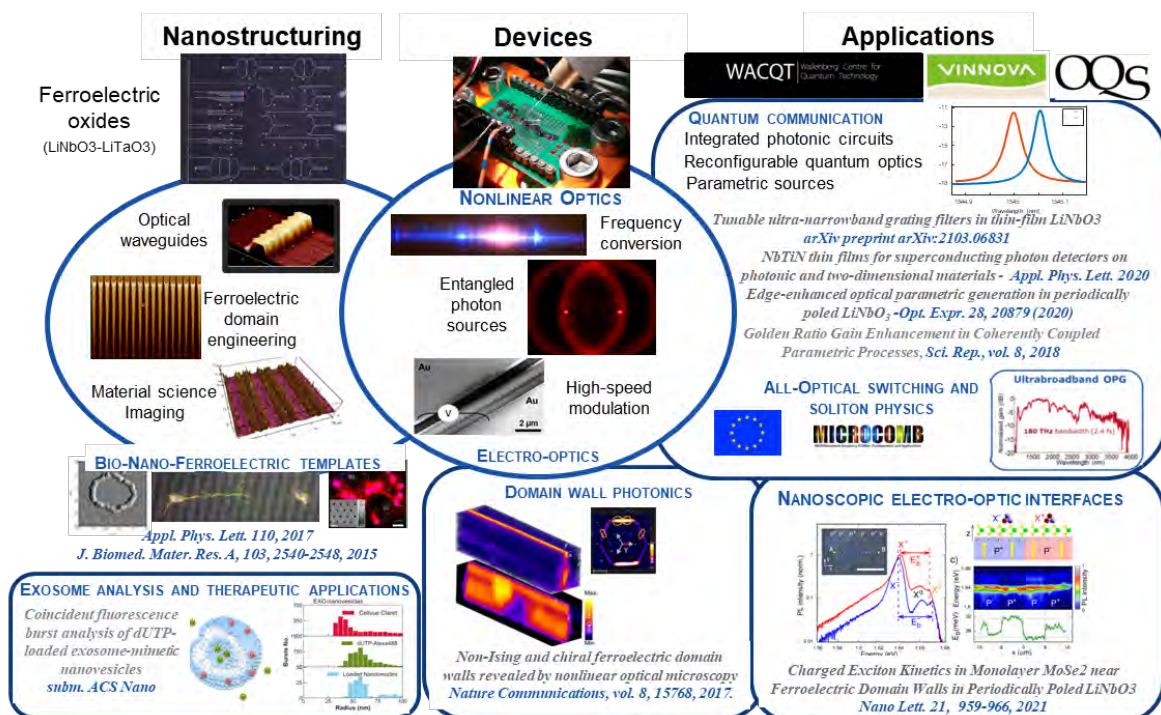
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The activities of the Nonlinear and Quantum Photonics group at KTH span the full spectrum from fundamental material investigations and nanotechnology to photonic devices and systems for optical communication and sensing in classical and quantum regimes, as illustrated by the diagram here below.



At the technology level we focus in particular on nanostructuring nonlinear and ferroelectric materials such as lithium niobate and lithium tantalate in bulk and thin film formats, to realize state of the art photonic integrated circuits (PICs) for advanced electrooptic and nonlinear applications. In the quantum domain, this includes photon transducers from e.g. the telecom band to the visible and infrared ranges as well as a variety of engineered entangled photon sources based on spontaneous parametric downconversion (SPDC), as well as phase-sensitive optical parametric amplifiers. The talk shall present recent highlights of the work on our in-house thin film lithium niobate (TFLN) PIC platform, encompassing the selective incorporation of rare-earth ions for the perspective on chip realization of integrated single photon sources and quantum memories at telecom wavelengths,¹ as well as the hybrid integration of superconducting detectors on photonic wire waveguides.² It shall also address more foundational studies on short-period ferroelectric domain patterning,³ enabling novel parametric optical devices such as counterpropagating SPDC sources,⁴ as well as more exotic investigations on the physics of ferroelectric domain walls and their interplay with excitons in 2D materials.⁵

References

1. Adshead, M., Sanaee, M., Blight, D., Prencipe, A., Curry, R. J. & Gallo, K. (2023). [Erbium implantation in thin film Lithium Niobate](#). *Proceed. Conference on Lasers and Electro-Optics Europe – CLEO Europe (Optica Publishing Group)*, Paper CE9.4.
2. Prencipe, A., Gyger, S., Baghban, M. A., Zichi, J., Zeuner, K. D., Lettner, T., Schweickert, L., Steinhauer, S., Elshaari, A. W., Gallo, K., & Zwiller, V. (2023). [Wavelength-sensitive superconducting single-photon detectors on thin film lithium niobate waveguides](#), *Nano Letters* **23**, 9748.
3. Fergestad, H.R., Fu, D., Li, T., & Gallo, K. (2025). [High-Resolution Electron-Beam Poling of X-Cut Lithium Niobate Thin Films](#). *Adv. Optical Mater.* e01126
4. Fergestad, H. R., Fu, D., Adya, V.B., & Gallo, K. (2025). Counterpropagating non-degenerate frequency up-conversion in X-cut Periodically Poled LiNbO₃ nanophotonic wires. *Proc. CLEO Europe 2025*, Paper CD-1.5.
5. Soubelet, P., Tong, Y., Astaburuaga Hernandez, A., Ji, P., Gallo, K. Stier, A.V., & Finley, J.J. (2025) [Strong Quantum Confinement of 2D Excitons in an Engineered 1D Potential Induced by Proximal Ferroelectric Domain Walls](#). *Nano Letters* 25 (34), 12842-12850.

Simone Gasparinetti



Biography

Simone Gasparinetti is an Associate Professor at Chalmers University of Technology, Sweden. His research group, the 202Q-lab, studies superconducting circuits for quantum technologies. He is a member of the management team at the Wallenberg Centre for Quantum Technology (WACQT), a 12-year national initiative driving the development of quantum technologies in Sweden. Simone is also a co-founder of Sweden Quantum AB, a startup specializing in infrared-blocking filters for cryogenic quantum applications. His research focuses on quantum computing with bosonic modes, quantum thermodynamics, and enabling technologies for next-generation quantum systems.

TOWARDS VERIFIED QUANTUM SPEEDUP IN A BOSONIC QUANTUM PROCESSOR

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We are developing a superconducting platform for boson sampling, aiming to demonstrate quantum speedup in a verifiable manner. Achieving this goal requires the deterministic preparation of nonclassical states in bosonic modes with high local dimensionality, the realization of high-fidelity beam-splitting interactions with all-to-all connectivity, and the ability to perform both homodyne/heterodyne detection and photon-counting measurements with high efficiency. In this presentation, I will discuss our experimental progress in developing these critical building blocks. Specifically, I will highlight results on fast state preparation achieved through combined charge and flux drives, as well as a novel protocol for homodyne and heterodyne detection on stationary bosonic modes, enabled by an ancillary qubit. Finally, I will outline our strategy for implementing quantum verification on this platform and achieving verified quantum speedup.

References

Kudra, Marina, Mikael Kervinen, Ingrid Strandberg, et al. "Robust Preparation of Wigner-Negative States with Optimized SNAP-Displacement Sequences." *PRX Quantum* 3, no. 3 (2022): 030301. <https://doi.org/10.1103/PRXQuantum.3.030301>.

Eriksson, Axel M., Théo S  pulcre, Mikael Kervinen, et al. "Universal Control of a Bosonic Mode via Drive-Activated Native Cubic Interactions." *Nature Communications* 15, no. 1 (2024): 2512. <https://doi.org/10.1038/s41467-024-46507-1>.

Strandberg, Ingrid, Axel M. Eriksson, Baptiste Royer, Mikael Kervinen, and Simone Gasparinetti. "Digital Homodyne and Heterodyne Detection for Stationary Bosonic Modes." *Physical Review Letters* 133, no. 6 (2024): 063601. <https://doi.org/10.1103/PhysRevLett.133.063601>.

Claudio Gatti



Biography

Research Director at Laboratori Nazionali di Frascati (LNF) of INFN the Italian Institute of Nuclear Physics. Over the years he has coordinated several projects on quantum sensing and light dark matter research. In 2024, Claudio Gatti received the ERC Synergy Grant with M. Schott, D. Budker and D. Blas for the project GravNet a global network for the search for high-frequency gravitational waves.

SUPERCONDUCTING QUBITS FOR SENSING AND COMPUTING

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Quantum technologies are having a transformative impact on fundamental physics, enabling unprecedented measurement sensitivities and simulations of quantum phenomena otherwise inaccessible to experimental investigation. Quantum sensing with superconducting qubits leverages on entanglement, quantum error correction, and high-photon-number Fock states to significantly boost the sensitivity for detecting weak coherent states. Quantum analog simulations use superconducting circuits to mimic the behavior of other quantum systems, allowing researchers to study complex many-body phenomena that are too difficult for classical computers to handle. In recent years, INFN has funded several projects aimed at the development of superconducting devices for sensing and computing. We will briefly review the results and the prospects for the future.

Andrea Giachero



Biography

Andrea Giachero is an Associate Professor at the University of Milano-Bicocca and an affiliated researcher with the Italian National Institute for Nuclear Physics (INFN). Over the years, he has coordinated several national and international projects on quantum technologies for sensing and computing applications. From 2021 to 2023, he was a Marie Skłodowska-Curie Actions Fellow, visiting faculty at the University of Colorado Boulder, and research associate in the Quantum Sensors Division at the National Institute of Standards and Technology (NIST), Boulder. He is internationally recognized as an expert in quantum-limited amplifiers.

Broadband Quantum-Limited Traveling-Wave Microwave Parametric Amplification for Quantum Sensing and Computing

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Ultra-sensitive detection schemes at microwave frequencies play a central role in many advanced applications, including quantum sensing, quantum computing, and fundamental physics searches. In many of these applications, the necessity of reading a large array of devices (e.g., detectors, cavities, qubits) calls for large-bandwidth amplifiers with the lowest possible noise [1, 2, 3]. Broadband, quantum-limited amplification is fundamental for quantum technology applications, as it enables high-fidelity readout, efficient scaling, and improved sensitivity across multiple platforms [4]. Solid-state amplifiers offer exceptional gain but fall short of the quantum noise limit. Traveling-Wave Parametric Amplifiers (TWPAs), especially Kinetic Inductance TWPAs (KI-TWPAs), present a compelling solution. KI-TWPAs are simpler to fabricate than traditional TWPAs based on Josephson junctions, boast a high dynamic range, exhibit magnetic-field resilience, and offer the potential for operation at higher temperatures (4 K).

National and international research groups, such as the Italian National Institute for Nuclear Physics (INFN) [2], the U.S. National Institute of Standards and Technology (NIST) [1, 3, 4], and Chalmers University of Technology in Sweden, are working to enhance the performance of KI-TWPA amplifiers. Their goal is to improve readout fidelity while, at the same time, simplifying the readout scheme and increasing sensitivity in fundamental physics experiments. In this presentation, we will review the current status of KI-TWPA development, outlining the design solutions implemented to improve amplifier performance, the results obtained, and possible future directions for further enhancing readout sensitivity.

References

1. L. Howe, A. Giachero *et al.*, Kinetic Inductance Traveling Wave Parametric Amplifiers Near the Quantum Limit: Methodology and Characterization, <https://doi.org/10.48550/arXiv.2507.07706>;

2. A. Giachero *et al.* Detector Array Readout with Traveling Wave Amplifiers, *J. Low Temp. Phys.* 209 (2022) 3-4, 658-666, <https://doi.org/10.1007/s10909-022-02809-6>;
3. L. Howe, A. Giachero *et al.*, Compact Superconducting Kinetic Inductance Traveling Wave Parametric Amplifiers with On-chip rf Components, *IEEE Trans. Appl. Supercond.* 35 (2025) 5, 1701107, <https://doi.org/10.1109/TASC.2025.3553466>;
4. M. A. Castellanos-Beltran, L. Howe, A. Giachero *et al.*, *IEEE Trans. Appl. Supercond.* 35 (2025) 5, 1500305, <https://doi.org/10.1109/TASC.2024.3525451>

Sergey Kubatkin



Biography

Sergey Kubatkin earned his Ph.D. (1982–1988) at the P. L. Kapitza Institute in Moscow, where he continued as a scientist until 1997. Since 1996, he has been affiliated with Chalmers University of Technology, becoming full Professor in 2016. His research is centered on quantum device physics, spanning from molecular electronics to qubits and two-dimensional materials and sensors. He was appointed InstituteQ Chair of Excellence in Finland for 2024–2026, where he leads investigations into superconducting decoherence and quantum transport and sensing in low-dimensional structures. Sergey contributed to establishing epitaxial graphene on silicon carbide (SiC) as a platform for quantum Hall resistance standards and also made important advances in molecular electronics, demonstrating single-electron transistors based on a single organic molecule with accessible redox states, opening new directions for studying charge transport at the molecular scale.

TOWARDS QUANTUM-LIMITED SENSING OF MICROWAVE PHOTONS WITH SCALABLE EPITAXIAL GRAPHENE BOLOMETERS

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Quantum interference of charge carriers in epitaxial graphene grown on silicon carbide provides a built-in resistive thermometer not found in other types of graphene. Along with a tunable and well-controlled heat sink for the electronic system to the substrate and leads, epitaxial graphene offers a robust platform for a wide range of bolometers designed for low temperature operation. Low carrier density ($|n| < 10^{10} \text{ cm}^{-2}$) contributes to both low heat conductivity and electron heat capacity, enhancing epitaxial graphene's performance as a bolometer/calorimeter. These unique properties enabled the creation of an ultrasensitive spectrometer for astronomy in the THz range [1]. Similar ideas for detection of photons in the GHz range were explored through collaboration between Aalto and Chalmers groups, showing promising prospects for calorimetry [2]. The heat capacity in our device was approximately k_B and noise equivalent power (NEP) of 50 zeptowatt/ $\sqrt{\text{Hz}}$ at $T=40 \text{ mK}$, owing to the steep dependence of heat conductance from the graphene electronic system to the substrate phonons, $G_{\text{th}} \sim T^4$ for $T < 100 \text{ mK}$. The projected energy resolution of these devices in calorimetric mode is 0.7 yJ, corresponding to the energy of a single 1 GHz photon. Our results pave the way for scalable, compact, and low-back-action bolometric readout in quantum processors, potentially enabling fundamental studies in quantum thermodynamics.

References

- [1] S. Lara-Avila (2019). Towards quantum-limited coherent detection of terahertz waves in charge-neutral graphene, *Nat. Astron.* 3, 983
- [2] Yu-Cheng Chang et al., (2025), Quantum-Ready Microwave Detection with Scalable Graphene Bolometers in the Strong Localization Regime, *arXiv:2505.24564*

Fabio Lingua



Biography

Fabio Lingua earned his PhD in Physics from Politecnico di Torino in 2017, where his research focused on phase separation and temperature effects in ultracold atomic mixtures. Following his doctorate, he pursued postdoctoral research in the United States, first at Clark University and later at Dartmouth College, studying entanglement and quantum correlations in strongly correlated many-body systems through Path-Integral Quantum Monte Carlo methods. Since 2023 he has been a postdoc at KTH Royal Institute of Technology in Stockholm, where he works on superconducting quantum circuits and microwave photonics. His team achieved the world's first large-scale continuous-variable cluster state in the microwave domain across 94 frequency modes, a milestone toward scalable quantum computation technology.

CONTINUOUS-VARIABLE TWO-DIMENSIONAL CLUSTER STATES IN A MICROWAVE FREQUENCY COMB

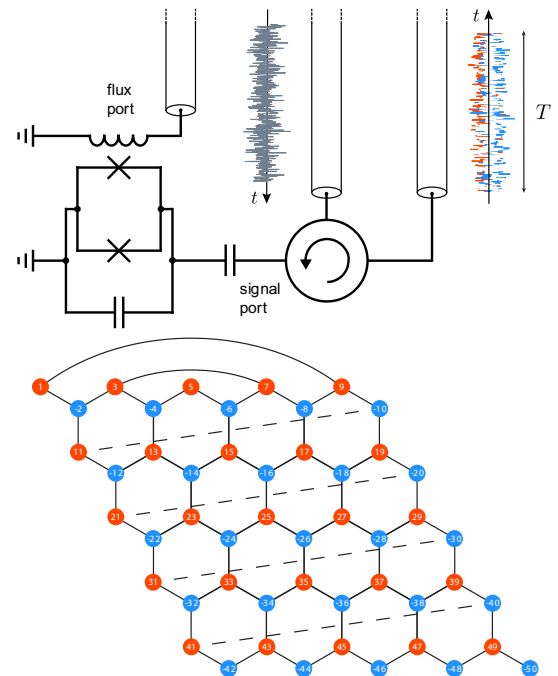
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We demonstrate the experimental realization of two-dimensional, continuous variable (CV) cluster states between $\sim 10^2$ modes of a microwave frequency comb. This result is obtained by injecting vacuum fluctuations properly thermalized at 10 mK into a Josephson Parametric Amplifier parametrically pumped by a sum of coherent signals around double the center-comb frequency. This enables frequency mixing and two-mode squeezing between different frequency modes. By carefully tuning pump frequencies, amplitudes, and phases we can engineer the interference between mixing products and realize square-ladder, honeycomb and square lattice CV cluster states with three and four pump tones respectively. We prove the presence of a cluster state with a suitable nullifier test, reaching up to 1 dB of squeezing of the cluster state's nullifiers.



References

¹Lingua, F., Rivera Hernández, J. C., Cortinovis, M., & Haviland, D. B. (2025). Continuous-variable square-ladder cluster states in a microwave frequency comb. *Phys. Rev. Lett.*, 134, 183602. <https://doi.org/10.1103/PhysRevLett.134.183602>

²Bock, C. L., Rivera Hernández, J. C., Lingua, F., & Haviland, D. B. (2025). Nonreciprocal scattering in a microwave frequency comb. *Phys. Rev. Applied*, 24, 014027.

<https://doi.org/10.1103/kz53-dryz>

³Rivera Hernández, J. C., Lingua, F., Jolin, S. W., & Haviland, D. B. (2024). Control of multi-modal scattering in a microwave frequency comb. *APL Quantum* 1, 036101.

<https://doi.org/10.1063/5.0203426>

Stefano Lupi



Biography

Stefano Lupi is full professor in Condensed Matter Physics at the Department of Physics of Sapienza University of Rome, Italy. He is involved in research activities on terahertz and infrared photonics and spectroscopy, quantum materials and photonic sensoristic applications in Life Science and Chemistry.

(<https://sites.google.com/uniroma1.it/sapienza-terahertz/home>).

QUANTUM TOPOLOGICAL MATERIALS AND THEIR APPLICATIONS IN TERAHERTZ PHOTONICS

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Topological materials are at the forefront of modern materials science, offering unique opportunities for quantum technologies^{1,2}. Their distinctive feature lies in the presence of low-energy excitations that dictate their quantum behavior. Beyond conventional single-particle responses (*Drude*-like conduction), these systems support collective excitations, such as Surface Plasmon Polaritons, which create a remarkably rich electrodynamic landscape where linear and nonlinear optical effects intertwine. In this talk, I will highlight the nature of these quantum excitations in topological materials, with particular emphasis on their exotic optical responses. I will also present recent advances in quantum devices exploiting these phenomena, ranging from enhanced infrared and terahertz detectors to next-generation platforms for quantum photonics and quantum information technologies^{3,4,5,6}.

References

- [1] Giustino F. et al., (2021), The 2021 Quantum Materials Roadmap, J. Phys. Mater. 3 042006. <https://doi.org/10.1088/2515-7639/abb74e>;
- [2] Lupi S., and Molle A., (2020), Emerging Dirac Materials for Terahertz Plasmonics, Applied Materials Today, 20, 100732. <https://doi.org/10.1016/j.apmt.2020.100732>;
- [3] Di Pietro P., et al., (2013), Observation of Dirac plasmons in a topological insulator, Nature Nanotechnology 8, 556. <https://doi.org/10.1038/nnano.2013.134>
- [4] Giorgianni F., et al., (2016), Strong nonlinear terahertz response induced by Dirac surface states in Bi₂Se₃ topological insulator, Nature Communications 7, 11421. <https://doi.org/10.1038/ncomms11421>
- [5] Macis S., et al., (2024), Terahertz and Infrared Plasmon Polaritons in PtTe₂ Type-II Dirac Topological Semimetal, Advanced Materials 36, 2400554. <https://doi.org/10.1002/adma.202400554>
- [6] Tomarchio L., et al., (2024), Optical Conductivity and Photo-Induced Polaronic Formation in Co₂MnGa Topological Semimetal, Advanced Science 11, 2400247. <https://doi.org/10.1002/advs.202400247>

Francesco Tafuri



Biography

Francesco Tafuri is Full Professor at the University of Napoli Federico II. PhD in Physics, University of Napoli Federico II, visiting student at Lawrence Berkeley Laboratory and New York State University at Stony Brook. Visiting Scientist at IBM T.J. Watson Research Center, NY, USA in 2001. FT was awarded a Fulbright grant, Ugo Fano prize in 2024 and Capo d'Orlando prize in 2025. His scientific interests fall in the field of Superconductivity and Quantum Technologies with a special focus on Josephson junction, superconducting qubits, macroscopic quantum phenomena, mesoscopic and nanoscale systems. He is leading the Superconducting Quantum Computation Team in Napoli. He is author of more than 220 publications and has given more than 100 invited talks at international conferences and research Centers.

THE 25 -> 64 QUBITS SUPERCONDUCTING QUANTUM COMPUTER OF THE HPC NATIONAL CENTER @UNINA: PHYSICS, IMPLEMENTATION, OPERATION & HARDWARE EVOLUTION

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Superconducting circuits have been up to now the most successful platform to build a quantum computer, being developed and used by major international companies since early stages. Napoli has a long-standing experience on superconducting electronics and on its key device i.e. the Josephson junction, and has assembled the first quantum computer in Italy "Partenope" based on a 25-qubits processor produced by Quantware aiming at a QPU with 64-qubits in the close future. Partenope has been the platform where to create a solid expertise for the characterization, calibration, benchmarking and implementation of subregisters of QPUs and to focus on all hardware aspects including control and read out. A full control of Partenope also due to a comprehensive handling of the physics behind including its noise issues, such as decoherence, error in the gate implementation, readout error, has allowed the run of various algorithms, paving the way more and more towards an open-source quantum computing platform. A profound understating of all the physics of the hardware has promoted progress in developing independent pathways with innovative solutions for novel quantum components. These range from a new type of qubit based on ferromagnetic Josephson junctions and a novel tunable qubits coupler to qubit readout based on Josephson digital phase detectors and to novel schemes of microwave demultiplexer. The path from the physics of the hardware to operation of a quantum computer will be the main focus of the contribution.

Giovanna Sammarco Tancredi



Biography

Giovanna graduated with a master's degree in physics from the Università degli Studi di Palermo. She received her PhD in Physics from Royal Holloway, University of London, in 2010, where she subsequently worked as a postdoctoral fellow until 2014. From 2014 to 2018, she was a postdoctoral fellow at University of Oxford. She then joined Chalmers University of Technology as a permanent researcher. Today, she is a senior researcher and the leader of the Quantum Computing group. Since June 2025, she is also serving as co-director of WACQT.

Building a large-scale quantum processor

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Superconducting circuits are among the leading platforms for building scalable quantum computers, offering a promising path toward practical quantum information processing. In my talk, I will discuss the building blocks of a superconducting-based quantum computer and present recent results and performances of the 25-qubit processor, currently in operation at Chalmers.

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