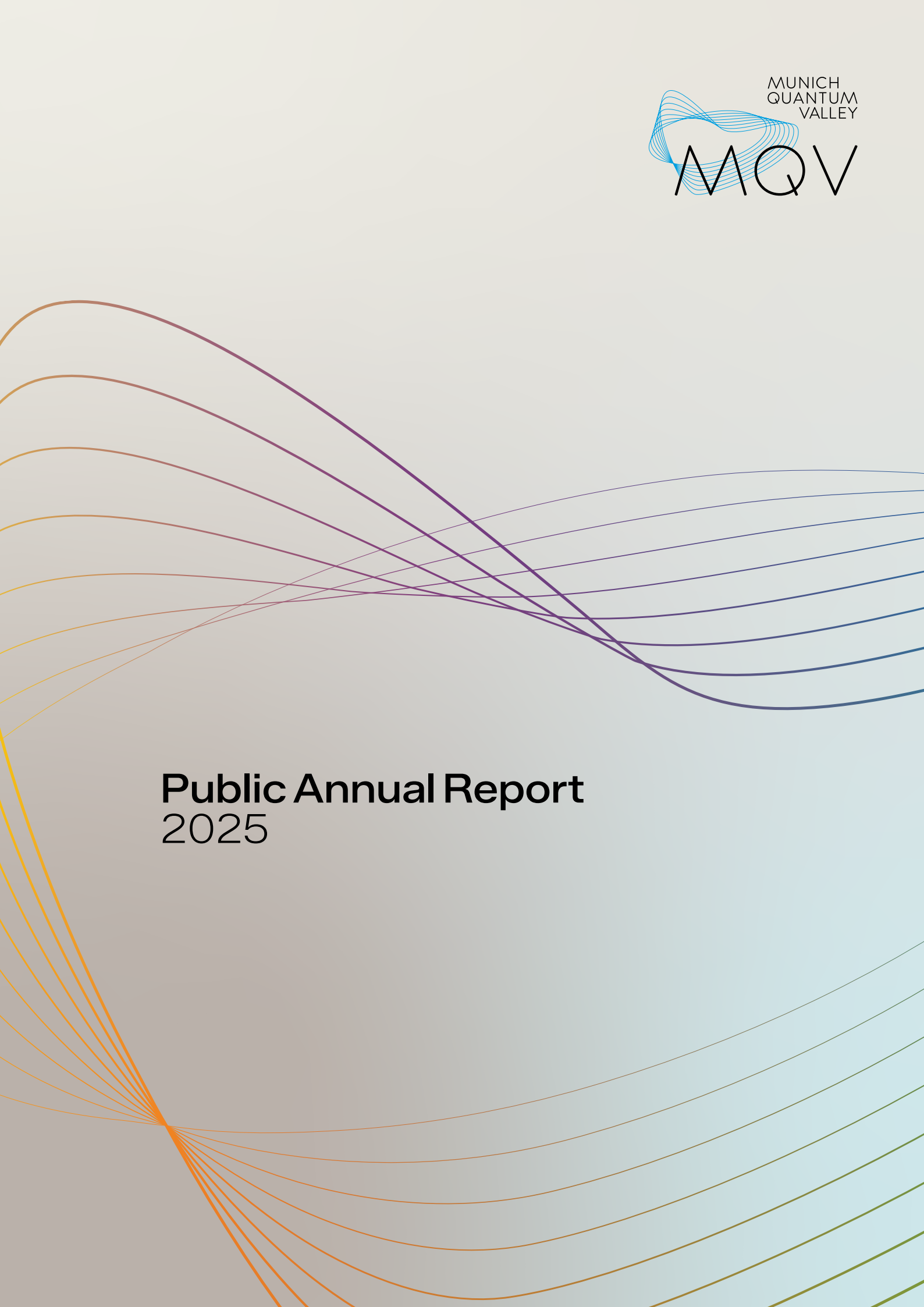


The background of the cover is a light blue gradient with several abstract, flowing lines in shades of orange, purple, and blue. These lines originate from the left side and curve across the page, creating a sense of movement and depth.

# **Public Annual Report 2025**



# Welcome address of the Bavarian State Minister for Economic Affairs, Regional Development and Energy

Hubert Aiwanger



As part of our Hightech Agenda, Bavaria continues to place great emphasis on strengthening and advancing Munich Quantum Valley (MQV) as a flagship initiative in the field of quantum technologies. The close and fruitful collaboration with companies from diverse industries and emerging start-ups remains a fundamental pillar of the success of MQV. By fostering a vibrant ecosystem that unites cutting-edge research, innovative start-ups, and industry partners, we are accelerating the transformation of quantum scientific breakthroughs into practical, market-ready solutions that drive economic growth and technological leadership.

A significant milestone in 2025 was the establishment of the MQV gGmbH, which represents an important step toward the professionalization and sustainable governance of MQV. This new entity will assume a central role in coordinating strategic development efforts, managing partnerships, and facilitating access to quantum computers for both industry and academia. With this robust organizational foundation, we are well positioned to successfully navigate a prospective second funding period, ensuring that MQV continues to prosper and enhance Bavaria's standing within the global quantum technology landscape.

I would like to extend my sincere gratitude to all partners, researchers, and companies whose dedication and innovative spirit have been instrumental in the remarkable progress achieved to date. Looking ahead, I encourage ongoing collaboration and networking across disciplines and sectors to fully unlock the potential of quantum technologies. Together, we can advance groundbreaking innovations and secure Bavaria's position as a global leader in the research, development, and industrial application of quantum technologies.

I wish Munich Quantum Valley every success in 2026 and beyond, with numerous exciting partnerships, pioneering projects, and sustained momentum on the path to shaping the future of the quantum economy.



# Welcome address of the Bavarian State Minister of Science and the Arts

Markus Blume



In 2025 we celebrated 100 years of quantum revolution. I am very proud that Bavaria has shaped the quantum miracle from the beginning. And that is why it was a great pleasure to welcome the quantum world in Munich in October 2025 for a series of events! In Bavaria, however, every year revolves around quantum technology because with Munich Quantum Valley we are at the forefront of the global race to utilize it! In recent years, we have succeeded in establishing a leading European center for quantum research and technology. I would like to express my sincere thanks to everyone who has contributed to this outstanding accomplishment.

The foundation for the success of Munich Quantum Valley was laid by the Hightech Agenda Bavaria, which now serves as a role model for the Hightech Agenda Deutschland. From the outset, leading universities, non-university research institutions, and industry partners have joined forces to develop quantum computers 'made in Bavaria' for practical use. The in-depth collaboration with industry is testament to the quality and relevance of your work at Munich Quantum Valley!

Ambitious goals require robust structures! The establishment of the MQV gGmbH in September 2025 saw Munich Quantum Valley evolve further, paving the way for innovative, agile, and powerful multi-institutional cooperation. The MQV gGmbH will serve as the coordination center and system enabler within the Bavarian quantum ecosystem, bringing together research, industry, and start-ups and providing access to infrastructure while enabling early industrial access to quantum computers. This new structure sets the course for the second funding phase of Munich Quantum Valley. I wish the MQV family a successful and insightful fifth year. My forecast, without the uncertainty principle: Bavaria will continue its success story – for the next frontier crossing and a new global quantum landscape.







# Table of contents

|          |                                                                                                            |           |
|----------|------------------------------------------------------------------------------------------------------------|-----------|
| <b>1</b> | <b>About Munich Quantum Valley</b>                                                                         | <b>11</b> |
|          | Our mission                                                                                                | 11        |
|          | Organizational structure                                                                                   | 12        |
|          | Munich Quantum Valley e.V. – The registered association                                                    | 13        |
|          | <i>Executive Board</i>                                                                                     | 14        |
|          | Scientific advisors                                                                                        | 15        |
|          | <i>Scientific Advisory Board</i>                                                                           | 15        |
|          | <i>External advisors</i>                                                                                   | 16        |
|          | MQV Office                                                                                                 | 17        |
|          | MQV in numbers                                                                                             | 19        |
| <b>2</b> | <b>Research highlights</b>                                                                                 | <b>21</b> |
|          | Neutral-atom qutrits: paving the way for novel hardware architectures                                      | 22        |
|          | Optimizing Josephson junctions: from atomic-level quantum transport to mesoscopic-scale device performance | 23        |
|          | Improving surface code: boosting quantum error correction with multi-qubit gates                           | 24        |
|          | Toward scalable and fast decoders: solving a bottleneck in quantum error correction                        | 25        |
|          | Providing access to quantum computers: AQT friendly-user pilot phase                                       | 26        |
| <b>3</b> | <b>Fostering an ecosystem</b>                                                                              | <b>29</b> |
|          | Quantum education                                                                                          | 30        |
|          | <i>Starting early: quantum physics for schools</i>                                                         | 30        |
|          | <i>Supporting Master's students: fellowships &amp; internships</i>                                         | 31        |
|          | <i>Recognizing excellence: Bavarian-wide doctoral fellowships</i>                                          | 31        |
|          | Quantum Technology Park                                                                                    | 32        |
|          | Entrepreneurship                                                                                           | 36        |
|          | Start-up voices                                                                                            | 37        |
|          | <i>Munich Quantum Software Company (MQSC)</i>                                                              | 37        |
|          | QTAS                                                                                                       | 38        |
|          | <i>Peak Quantum</i>                                                                                        | 39        |
|          | MQV Partner Network                                                                                        | 40        |
|          | MQV at fairs                                                                                               | 43        |
| <b>4</b> | <b>Public engagement</b>                                                                                   | <b>45</b> |
|          | MQV in touch                                                                                               | 46        |
|          | <i>MQV-Einblicke: a rare glimpse behind the scenes and into the laboratories</i>                           | 47        |
|          | <i>From the lab to the pub: quantum special at Pint of Science</i>                                         | 48        |
|          | <i>Girls'Day</i>                                                                                           | 49        |
|          | MQV In Persona                                                                                             | 50        |
|          | Quick Quantum Questions                                                                                    | 55        |





# About Munich Quantum Valley

## Our mission

Munich Quantum Valley (MQV) aims to create the world's foremost ecosystem for industrializing quantum technologies. It combines research, technology development, graduate training, and educational outreach in quantum science and technology (QST) by establishing a tight network of research institutions, industry, incubators, funding agencies, and the public. By uniting public and private efforts in a shared enterprise and attracting the world's best scientists and engineers, MQV aims to develop and operate competitive quantum computers and achieve breakthroughs in QST that will transform our future. It will accelerate technological disruption by promoting knowledge transfer between science

and industry to foster quantum applications and push Bavaria and Germany to the forefront in QST. MQV will build on the most promising hardware platforms and technologies developed within MQV and by European partners to realize full-stack scalable quantum computers. In the coming years, MQV will fabricate systems with up to 1,000 qubits, integrate them into the powerful Bavarian high-performance computing (HPC) infrastructure, and make them available to users via cloud access. MQV will also develop fault-tolerant quantum computers, which can solve a wide class of practical problems and hence are of broad use for both the economy and society.

# Organizational structure

In order to achieve its primary objective of developing and operating competitive quantum computers, Munich Quantum Valley (MQV) is taking a “full-stack” approach. All layers of a quantum computer, from hardware and control to software and applications, are developed by multidisciplinary consortia. In terms of hardware, MQV’s quantum-computing research covers three different platforms: superconducting qubits, neutral-atom qubits, and trapped-ion qubits. Each of these platforms has different characteristics and advantages for different use cases. The MQV approach ensures cross-fertilization between platforms when it comes to developing scalable platforms.

The Superconducting Qubit Quantum Computer (SQQC) consortium specializes in superconducting quantum systems, renowned for their design flexibility and precise controllability. Meanwhile, the Trapped Atom Quantum Computer (TAQC) consortium focuses on neutral-atom platforms, which offer strong potential for scaling qubit arrays and achieving high-fidelity entanglement operations. Trapped-ion systems have already proven their high performance and compatibility with classical computing infrastructures. Building on decades of expertise, MQV utilizes these advanced hardware platforms as testbeds to pioneer the integration of quantum computing into high-performance computing environments. This critical effort is spearheaded by the Quantum Development Environment, System Software & Integration (Q-DESSI) consortium, which is responsible for developing a complete software stack and establishing a robust programming and runtime environment tailored for quantum-classical hybrid systems. To enable scalable quantum devices, the Scalable Hardware & System Engineering (SHARE) consortium delivers essential classical control technologies, including the fabrication of scalable integrated chips – such as superconducting quantum devices for SQQC and chip-based traps for TAQC – as well as high-speed electronic control systems for both platforms. The Quantum Algorithms for Application, Cloud & Industry (QACI) consortium supports user adoption by providing training tools, services, and resources that facilitate seamless integration of quantum technologies into real-world applications and cloud environments. At the theoretical front, the Theoretical Quantum Computing (THEQUCO) consortium lays the groundwork for quantum computing with hardware-independent theoretical models, while the Hardware Adapted Theory (HAT) consortium focuses on platform-specific quantum control, error mitigation, and quantum-error-correction strategies. Together, these consortia adopt a holistic, integrated approach – where software engineering seamlessly bridges hardware development and high-level applications – ensuring a cohesive and scalable path toward practical quantum computing in high-performance computing ecosystems.

Beyond the individual mandates of each consortium, collaborative efforts span cross-sectional challenges to drive integrated progress. The SHARE consortium works closely with both the

SQQC and TAQC consortia to develop specialized platform technologies tailored to superconducting and neutral-atom quantum hardware, ensuring scalability and performance. The HAT consortium partners directly with the hardware-focused consortia on quantum-control strategies and co-design initiatives, aligning theoretical advancements with practical implementation. The Munich Quantum Software Stack (MQSS), developed mainly by the Q-DESSI consortium, is being built in close coordination with the hardware consortia to enable a seamless flow of functionality – from low-level device control to high-level user applications – ensuring end-to-end integration. On the theoretical and algorithmic front, the HAT and THEQUCO consortia collaborate with QACI to advance quantum algorithms and explore real-world use cases, bridging abstract theory with practical application. Ultimately, assessing the suitability of current and emerging quantum devices for realistic computational tasks is a collective endeavor – requiring the combined expertise and coordination of all seven research consortia, ensuring a unified, multidisciplinary approach to quantum computing advancement.

Two additional consortia complement the research and development activities by addressing other aspects of building a successful, vibrant, and skilled quantum ecosystem. The Quantum Technology Park & Entrepreneurship (QTPE) consortium establishes cutting-edge infrastructure equipped with advanced technological tools and engineering expertise. It also provides a structured entrepreneurial pathway to transform scientific breakthroughs into innovative startups, and accelerate the commercialization of quantum technologies, ensuring tangible societal impact. The Quantum Science & Technology: Education in Bavaria (QST-EB) consortium nurtures the next generation of quantum talent by providing education, training, and support to future researchers and users of quantum technologies throughout Bavaria.

Funded through the Hightech Agenda Bavaria, all MQV consortia operate with strong collaborative ties – both internally among the MQV groups and externally with projects supported by the German Federal Ministry of Research, Technology and Space (BMFTR) and the European Union. This ensures a coordinated, multidimensional advancement of quantum innovation.

# Munich Quantum Valley e.V. – The registered association

Founded on 27 January 2022, Munich Quantum Valley e.V. is a registered association that manages and coordinates MQV's efforts to develop and operate competitive quantum computers in Bavaria, as well as promote quantum technology and science. The association is also the sole stakeholder in the MQV gGmbH, a non-profit company founded in 2025 to further strengthen and support MQV's mission of developing industry-relevant quantum-computing applications with external partners.

The seven founding members of the association are listed below:



BAYERISCHE  
AKADEMIE  
DER  
WISSENSCHAFTEN

**Bavarian Academy of Sciences and Humanities (BAW)**



**Fraunhofer**

**Fraunhofer-Gesellschaft (FhG)**



Friedrich-Alexander-Universität  
Erlangen-Nürnberg

**Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)**



Deutsches Zentrum  
für Luft- und Raumfahrt

**German Aerospace Center (DLR)**



LUDWIG-  
MAXIMILIANS-  
UNIVERSITÄT  
MÜNCHEN

**Ludwig-Maximilians-Universität München (LMU)**

MAX PLANCK  
GESELLSCHAFT



**Max Planck Society (MPG)**

Technische  
Universität  
München



**Technical University of Munich (TUM)**

## Executive Board

Each of the seven founding institutions of Munich Quantum Valley e.V. appoints one representative to the Executive Board. As of 31 December 2025, the members of the Executive Board were:



**Prof. Claudia Felser, Chairwoman**  
Max Planck Society (MPG)



**Dr. Robert Axmann**  
German Aerospace  
Center (DLR)



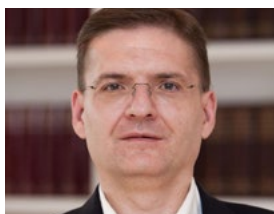
**Prof. Arndt Bode**  
Bavarian Academy of  
Sciences and Humanities  
(BAW)



**Prof. Gerhard Kramer**  
Technical University of  
Munich (TUM)



**Prof. Jürgen Schatz**  
Friedrich-Alexander-  
Universität Erlangen-  
Nürnberg (FAU)



**Dr. Sigmund Stinzing**  
Ludwig-Maximilians-  
Universität München  
(LMU)



**Dr. Hannah Venzl**  
Fraunhofer-Gesellschaft  
(FhG)

# Scientific advisors

In the pursuit of excellence, MQV actively seeks the advice and feedback of leading international experts, both through a Scientific Advisory Board and by consulting individual distinguished scientists.

## Scientific Advisory Board

The Scientific Advisory Board (SAB) of MQV consists of internationally recognized external experts. The MQV General Management, the Executive Board, and the Bavarian State Ministries use the results of the SAB meetings for strategic decisions regarding current and future MQV projects.

Independent evaluation by the SAB ensures the quality of MQV projects and public accountability for the appropriate and effective use of funds. As of 31 December 2025, the members of the SAB were:



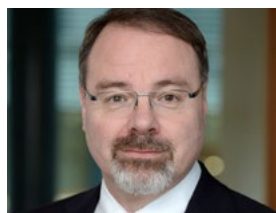
**Prof. Markus Aspelmeyer, SAB chair**  
University of Vienna



**Dr. Michael Bolle**  
Carl-Zeiss-Stiftung



**Prof. Per Delsing**  
Chalmers University of Technology



**Prof. Dietmar Harhoff**  
Max Planck Institute for Innovation and Competition



**Dr. Bettina Heim**  
NVIDIA



**Dr. Sebastian Luber**  
Infineon



**Prof. Roee Ozeri**  
Weizmann Institute of Science



**Dr. Carsten Polenz**  
SAP



**Prof. Anita Schöbel**  
Fraunhofer Institute for Industrial Mathematics ITWM



**Prof. Philipp Slusallek**  
Deutsches Forschungszentrum für Künstliche Intelligenz GmbH (DFKI)



**Prof. Stephanie Wehner**  
Delft University of Technology



**Dr. Sabine Wölk**  
German Aerospace Center (DLR)

## External advisors

In addition to the SAB, MQV is pleased to have further renowned experts in the field of quantum technologies as scientific advisors. As of 31 December 2025, these included:



**Prof. Rainer Blatt**  
University of Innsbruck



**Prof. Rudolf Gross**  
Walther Meißner Institute



**Laura Schulz**  
Argonne National Laboratory

# MQV Office

The MQV Office is the first point of contact for all internal and external inquiries from MQV members, industry partners, ministries, and funding agencies and gives Munich Quantum Valley (MQV) a unified voice in communications with the press and the general public.

The MQV Office is responsible for managing and coordinating the overall strategic direction of MQV. It supervises and directs the MQV research program, including monitoring project progress against deliverables and milestones, periodic reporting, and budgeted expenditures. Additionally, it prepares annual reports, provides recommendations to the Scientific Advisory Board and the Bavarian State Ministries involved, and offers administrative, fundraising and application support to the Executive Board and all members and partners.

It also coordinates and leads central public engagement activities to create a broad public understanding of quantum technologies and their societal benefits, and to increase national and global awareness of MQV and its research and development program. It develops educational, social media and online content, works with the media, and organizes events for a wide range of audiences.



**256**  
scientific talks



**175**  
scientific publications



**12**  
patents

**4** (+3)  
networking partners



**18**  
research institutes



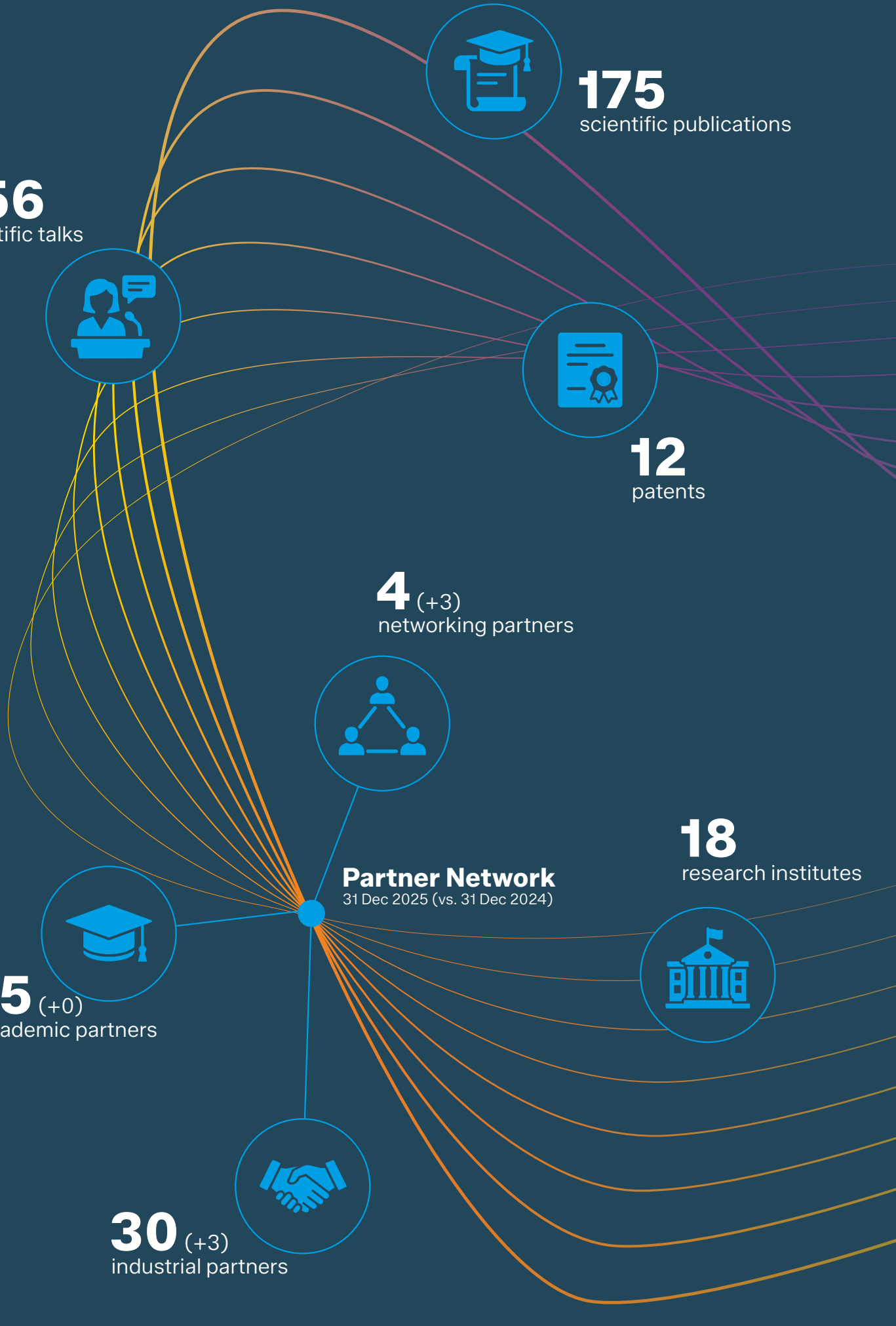
**15** (+0)  
academic partners



**30** (+3)  
industrial partners



**Partner Network**  
31 Dec 2025 (vs. 31 Dec 2024)



# MQV in numbers

**7**

MQV Colloquium talks

**~400**  
scientists**19**

public events

**209** (+68)**social media followers**  
31 Dec 2025 (vs. 31 Dec 2024)**14377** (+3821)**210** (+37)**1217** (+303)**598** (+499)



# 2 Research highlights

The field of quantum computing is advancing rapidly, with substantial progress being made in quantum-computing theory, hardware, software, and applications. This chapter outlines a selection of key research achievements in the MQV ecosystem in 2025, highlighting the innovative contributions of MQV researchers and their collaborators.

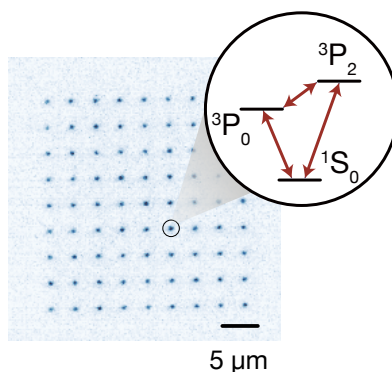
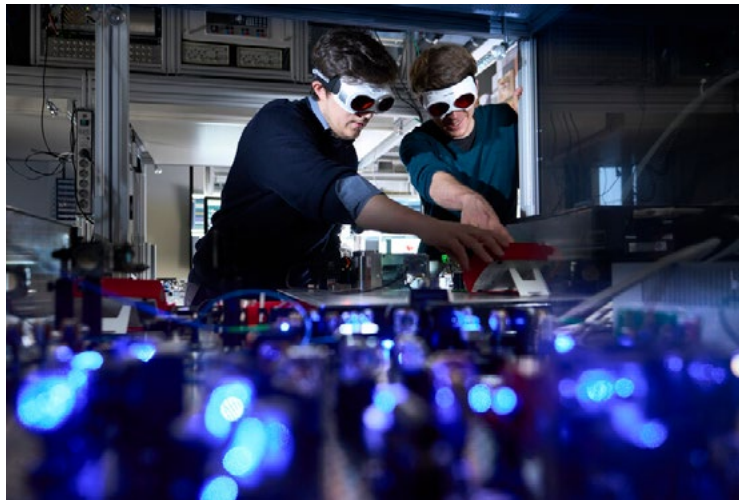
Ranging from enhancements in quantum hardware platforms and improvements in quantum error correction to first steps in making quantum computers accessible to a wider user community, these research highlights underscore the swift momentum driving this dynamic and evolving field.

# Neutral-atom qutrits: paving the way for novel hardware architectures

Most approaches to quantum computing are based on qubits, which operate using superpositions of two states that represent 0 and 1. To realize a quantum computer with neutral atoms, at least two energy states are therefore required, which can be controlled and superimposed using laser beams. However, atoms generally have far more states that could in principle be used for processing or storing quantum information, thus offering potential for new, non-binary quantum calculations. The additional control required, however, poses an experimental challenge, so that further research at the experimental and theoretical level into these novel quantum-computer architectures has so far been limited to a minimum.

Researchers from the Max Planck Institute of Quantum Optics (MPQ) and the Ludwig-Maximilians-Universität München (LMU) have now succeeded in creating a three-state system, a so-called qutrit, in a register of neutral strontium atoms and controlling it precisely with lasers. This new realization required modifying the quantum register so that it takes into account three instead of only two electronic states of the strontium atom. The special feature here is that the three-state system has excellent coherence and can be quickly manipulated using two- and three-photon couplings. In addition to the exciting prospects for quantum computers, this enables the optimal exploitation of the advantages of different qubit subgroups and provides new methods for carrying out precise measurements with atomic clocks.

This breakthrough opens up new possibilities for neutral-atom applications using three states, which has stimulated further collaboration within MQV. Follow-up projects have already successfully implemented universal gate operations, paving the way for novel quantum-computing architectures.



*Individual strontium atoms are trapped in optical tweezers and imaged using a high-resolution microscope. Each atom realizes a qutrit whose internal states can be manipulated using laser pulses.*

## REFERENCE

M. Ammenwerth et al., Realization of a Fast Triple-Magic All-Optical Qutrit in  $^{88}\text{Sr}$ .

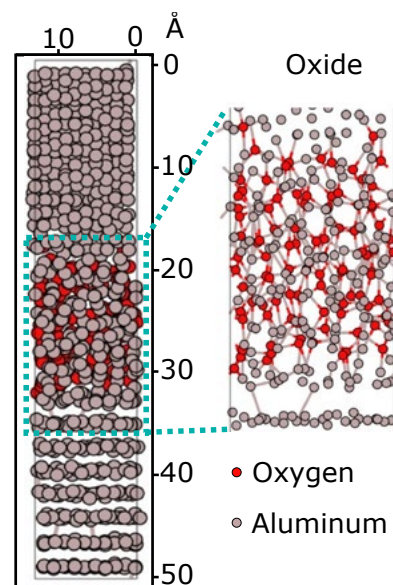
# Optimizing Josephson junctions: from atomic-level quantum transport to mesoscopic-scale device performance

Researchers at Fraunhofer IISB use simulations to study special components called Josephson junctions – the central building block of superconducting qubits – in order to better understand how final device performance depends on what happens at the atomic level.

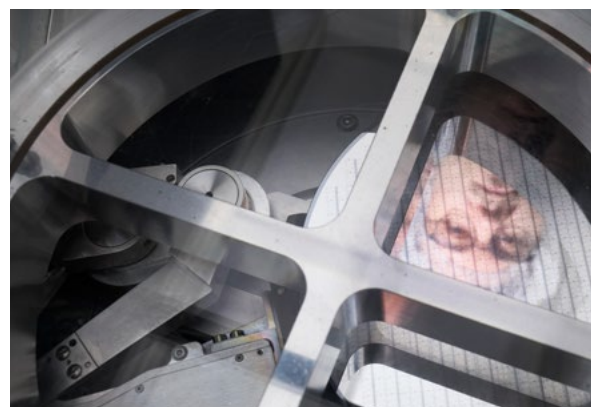
The movement of electrons through a Josephson junction is controlled by individual atoms. Even a thin oxide layer may have defects, or "traps", which can be thought of as potholes that block electron flow. These tiny problems can significantly impact the performance of the resulting qubit. To connect the atomic behavior to real device performance, it is necessary to measure quantities such as electrical resistance to determine if a qubit works well.

Computer simulations help map this connection. By testing different manufacturing conditions, such as temperature and oxygen supply, the team discovered that improved atomic organization in the aluminum oxide mitigates harmful effects. Since detailed atomic simulations are scarce, they created simpler one-dimensional models that can still predict real experimental results.

This approach connects atomic-level physics to mesoscopic-scale device performance, giving manufacturers a blueprint for building better Josephson junctions in quantum computers.

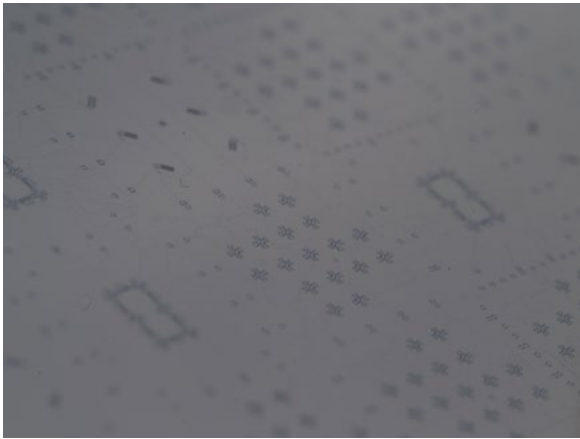


*A layer of aluminum oxides forms the necessary electrically insulating barrier in the Josephson junction.*



# Improving surface code: boosting quantum error correction with multi-qubit gates

Quantum computers still struggle with errors that occur during operation. Correcting these errors, a process known as quantum error correction (QEC), is therefore one of the most essential capabilities of any practical quantum computer. However, QEC comes at a cost. It requires substantial overhead in additional qubits and, in particular, many extra gate operations. Furthermore, the circuits used must be fault-tolerant, meaning they should not introduce too many additional errors or allow errors to spread uncontrollably.

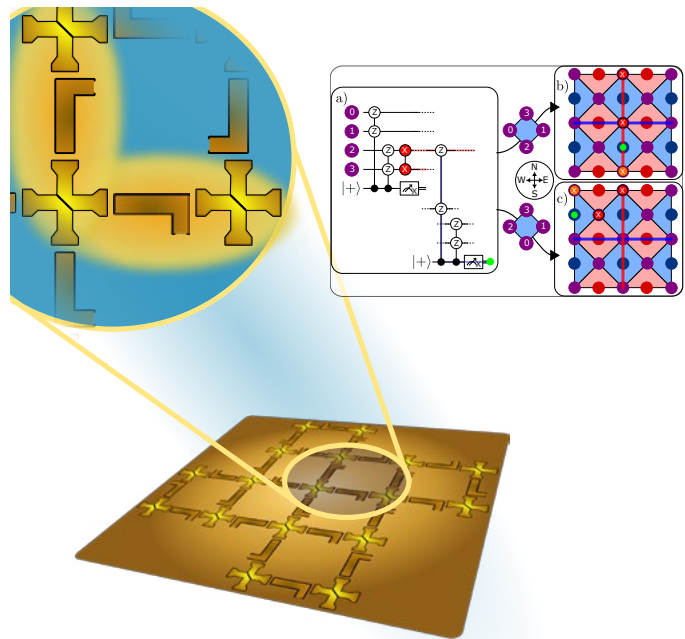


In a joint effort, MQV researchers from the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and Forschungszentrum Jülich combined their expertise in QEC and superconducting-circuit design to improve one of the most prominent QEC schemes, the surface code.

The team demonstrated fault-tolerant QEC circuits in unrotated surface codes using three-qubit gates, challenging the long-standing assumption that multi-qubit gates are unsuitable for fault-tolerant designs. Their approach reduces circuit depth and works for up to 30% higher error probabilities, offering a substantial reduction in required resources.

Even for non fault-tolerant implementations, such as the rotated surface code, the researchers showed that the performance of the three-qubit-gate circuits can be enhanced by including a new gate-optimization concept. Instead of merely minimizing the overall error rate, their method optimizes three-qubit gates to minimize the types of errors that are particularly detrimental to error correction. This strategy significantly reduces the resources needed for successful QEC in experimentally relevant regimes.

Overall, these results highlight the potential of multi-qubit gates as a powerful tool for scalable quantum computing, offering a promising alternative to existing QEC approaches.



**Schematic of a fault-tolerant surface-code quantum error-correction architecture** using three-qubit gates in superconducting circuits. The superconducting chip layout (bottom) highlights the implementation of native multi-qubit interactions, while the magnified view (left) shows a representative three-qubit gate geometry. The schematic circuits (right) compare a non-fault-tolerant with the proposed three-qubit-gate approach.

## REFERENCES

- J. Old et al., Fault-Tolerant Stabilizer Measurements in Surface Codes with Three-Qubit Gates.
- S. Tasler et al., Optimizing Superconducting Three-Qubit Gates for Surface-Code Error Correction.

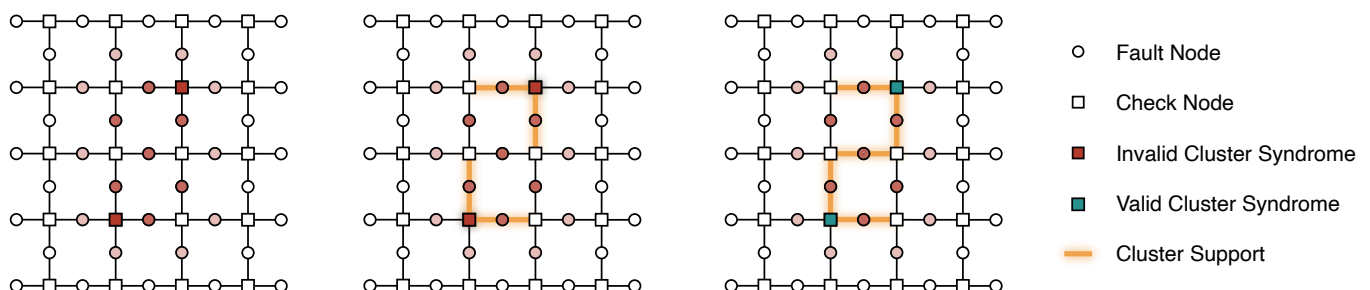
# Toward scalable and fast decoders: solving a bottleneck in quantum error correction

Reliable quantum computers require sophisticated notions of quantum error correction to be scalable. While the idea is not new, there have been enormous developments in theory and experiment in recent years. For example, new codes with attractive features, such as quantum low-density parity-check (qLDPC) codes, have been designed. Alongside these exciting developments, however, a new challenge has emerged: designing good algorithms for performing the actual correction. This is by no means a minor detail. So-called decoders must properly process measurement outcomes, make good choices, and find optimal correction strategies. This must happen in real time, as errors accumulate during an experiment. Thus, decoders have to be fast, versatile, and accurate. This capability is lacking in some of the best known codes today – the aforementioned qLDPC codes.



Close collaboration between researchers from Technical University of Munich (TUM) and Freie Universität Berlin (FUB) brought together insights from quantum error correction and software design to overcome this bottleneck and develop a scalable, fast decoder. The new method, called localized statistics decoding, makes use of the intuition that one should be able to look at errors in a local way without considering the entire system in full.

This is a substantial theoretical advance and, at the same time, one that closely interfaces with the development of Rydberg-atom quantum computers as they are being developed in MQV, as it is precisely such codes that are best suited for them.



**Schematic representation** of the principle of local errors.

## REFERENCE

T. Hillmann et al., *Localized statistics decoding for quantum low-density parity-check codes.*

# Providing access to quantum computers: AQT friendly-user pilot phase

Part of the mission of the Leibniz Supercomputing Centre (LRZ) within MQV is to provide access to quantum-computing hardware for MQV researchers as well as partners. This aligns with LRZ's long-standing experience as a technology provider of services, particularly in the HPC area, for the research communities in Munich, Bavaria, and Germany.

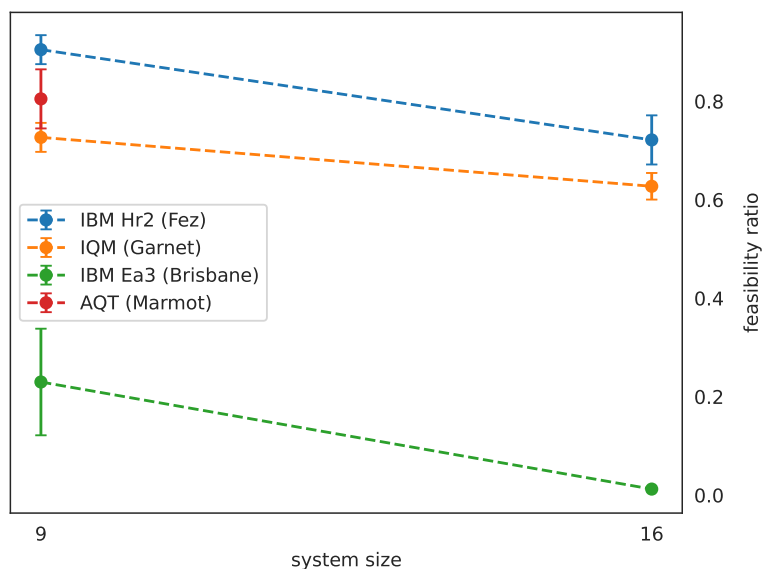


The years 2024–2025 mark a special milestone in this effort. In the second half of 2024, the LRZ has operated a first pilot phase – giving access to selected internal and external users – of the Q-Exa system, a 20-qubit superconducting quantum computer from IQM installed on-premise in the institute's compute building. From March to May of 2025, access has been opened, according to the same concept, to the Marmot system, a 16-qubit ion-trap quantum computer from AQT, installed in the LRZ Quantum Integration Centre.

During this AQT friendly-user pilot phase, eleven teams, comprising a total of thirty users, were onboarded into Marmot. These teams represented several MQV consortia, including THEQUCO, Q-DESSI, and HAT, as well as MQV Lighthouse Projects. They covered all of the main MQV institutional partners. The activities of the test users have been constantly supported by the LRZ Solution Architects, with one of them assigned to each team for consulting and troubleshooting. Both LRZ and AQT engaged in a tight feedback loop with the users, also including a kick-off and a wrap-up event, as well as frequent online “open mic” sessions where users could join and discuss their questions. The feedback collected by the Solution Architects has been used to steer and prioritize the development work of the software ecosystem and user interfaces. A final user survey has shown that, in all areas of inquiry (documentation, communication, support, among others), the user evaluation has been very positive.

Of course, the statistics on use cases are limited by the small number of test projects, but one can observe that all the main areas of investigation for quantum algorithms, such as computational chemistry, optimization, and image processing, are represented. Comparisons between different qubit modalities are of special interest and are made possible by the simultaneous availability of the Q-Exa and Marmot systems for users. In a benchmarking study of the Traveling Salesperson Problem, a prototypical optimization problem, the results highlight the importance of understanding hardware performance from an application perspective.

Since the beginning of September 2025, both Q-Exa and Marmot have been in regular user operation, building upon the collected experience and useful user feedback. Interested researchers can check the access process for the systems on LRZ's documentation server. Access to Marmot is based on institutional affiliation with an MQV member or partner institution. However, LRZ still requests that users fill out a use-case description to better understand the problems addressed in the community.



#### Feasibility ratio for the Traveling Salesperson

**Problem runs** done with different system size and on different quantum hardware. A higher value for the feasibility ratio indicates a better solution quality.

## REFERENCE

A. Bentellis et al., *Application-Driven Benchmarking of the Traveling Salesperson Problem: a Quantum Hardware Deep-Dive*.



# 3 Fostering an ecosystem

Munich Quantum Valley (MQV) continues to advance its mission of establishing the world's leading ecosystem for the industrialization of quantum technologies. Beyond its core R&D programs, MQV strengthens the quantum landscape through targeted education initiatives, advanced infrastructure, entrepreneurial support, and strategic partnerships. The Quantum Technology Park (QTP) advanced significantly in 2025, providing state-of-the-art, tailor-made infrastructure for the fabrication, testing, and scaling of quantum devices. MQV's education strategy is expanding at all levels: The PhotonLab at MPQ welcomed and

inspired national and international high-school students, young scientists in the field were again supported with a variety of fellowships and internships and the prestigious MQV doctoral fellowship program attracted a record number of applications. The annual Spring Meetings of the German Physical Society served as platforms to showcase Bavaria's quantum research landscape to prospective Ph.D. candidates. Furthermore, MQV's active participation in major international events has expanded its reach, enabling impactful dialogues with industry leaders, research institutions, and policymakers.

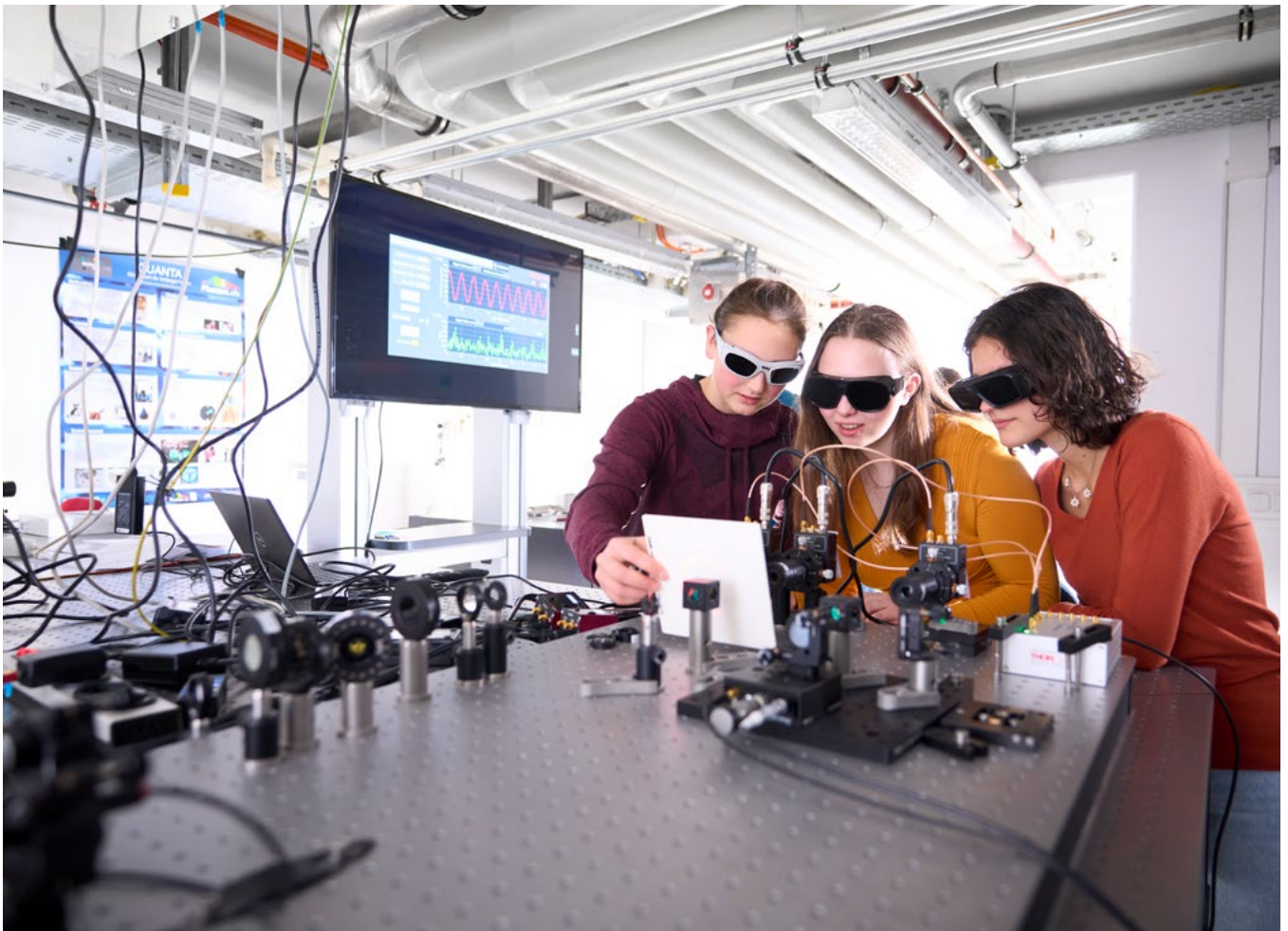
# Quantum education

A key objective of Munich Quantum Valley (MQV) is to develop and support educational programs for schools, universities, and industry partners, aiming to nurture the next generation of experts in quantum technology and quantum computing across Bavaria and beyond. These efforts are carried out through MQV's comprehensive education strategy, addressing various levels – from inspiring curiosity at a young age to supporting early-career researchers in the field.

## Starting early: quantum physics for schools

MQV provides educational support already at the high-school level, primarily through active support of the PhotonLab, a laboratory for pupils located at the Max Planck Institute of Quantum Optics (MPQ), where more than 2,000 schoolchildren experiment independently on 20 different experimental setups every year. The PhotonLab's offers extend beyond national borders, inviting international visitors from all over the world to participate in its exciting experiments. In 2025, school classes from Austria, Switzerland, the Czech Republic, Italy, Greece, the UK, and the USA took advantage of the unique program.

With quantum physics now being part of the syllabus in Bavarian high schools, MQV also broadened its offers in training teachers. Concrete examples were used to show how quantum computing can be integrated into teaching in a didactically meaningful way. The teacher training was complemented by the publication of interactive qubit and quantum books, an innovative learning resource available to all Bavarian teachers via an online platform.





## Supporting Master's students: fellowships & internships

At the university level, the Ludwig-Maximilians-Universität München and the Technical University of Munich have joined their forces to establish the interdisciplinary Master's study program "Quantum Science & Technology" (QST). MQV supports QST Master's students through targeted fellowships and internships to strengthen Bavaria's quantum ecosystem. A fellowship for outstanding women awards up to five students annually based on academic achievement, social engagement, and individual interviews. The exchange fellowship enables mobility between QST students and partner universities, supporting stays of at least four weeks. In collaboration with the Fraunhofer-Gesellschaft, MQV also offers industry internships open to students from all Bavarian universities. These placements connect learners with companies advancing quantum technologies and computing, providing hands-on experience, career insights, and opportunities to build professional networks, bridging research and industry.

## Recognizing excellence: Bavarian-wide doctoral fellowships

The excellence-focused doctoral fellowship program awards highly prestigious doctoral fellowships to outstanding young researchers. The MQV doctoral fellows, selected through an annual international competition, receive a three-year ad personam fellowship which offers them the flexibility to join research groups at any Bavarian university. Being fully funded for three years, the holders of the fellowship are welcome in many groups and can then join the graduate program of their host institution. In 2025, a new record number of applications were received, with 247 students from 47 different countries answering the call. 21 of these students participated in personal interviews. In the end, five candidates accepted the MQV doctoral fellowship while five further candidates were strongly recommended for special consideration to MQV colleagues seeking to hire doctoral students using other funds, as they also made an excellent impression.



**Simone Foderà**

MQV doctoral fellow at the Chair for Theoretical Solid State Physics (LMU)

Simone is researching a quantum-inspired algorithm called Quantics Tensor Cross Interpolation (QTCI). Using parallel computing – where a computer performs multiple tasks simultaneously with the help of different cores – and distributed computing – where many computers are interconnected to calculate a solution together – he aims to optimize and accelerate the algorithm. This benefits his colleagues who use QTCI in their research.

# Quantum Technology Park

The Quantum Technology Park (QTP) is a central element of Munich Quantum Valley (MQV), offering advanced technological infrastructure to drive research and innovation in quantum technologies. By integrating state-of-the-art facilities across multiple institutions into a unified network, the QTP aims to serve as a shared center for scientific discovery and industrial development.







The expansion of infrastructure continued to progress in 2025. The 120 m<sup>2</sup> big LMU cleanroom has been completed and the facility is now open to the research community with several key tools newly installed in 2025. In total, around ten new systems have been installed or ordered, making it possible to quickly and easily test research ideas, new quantum-device concepts, and develop initial device-fabrication processes.

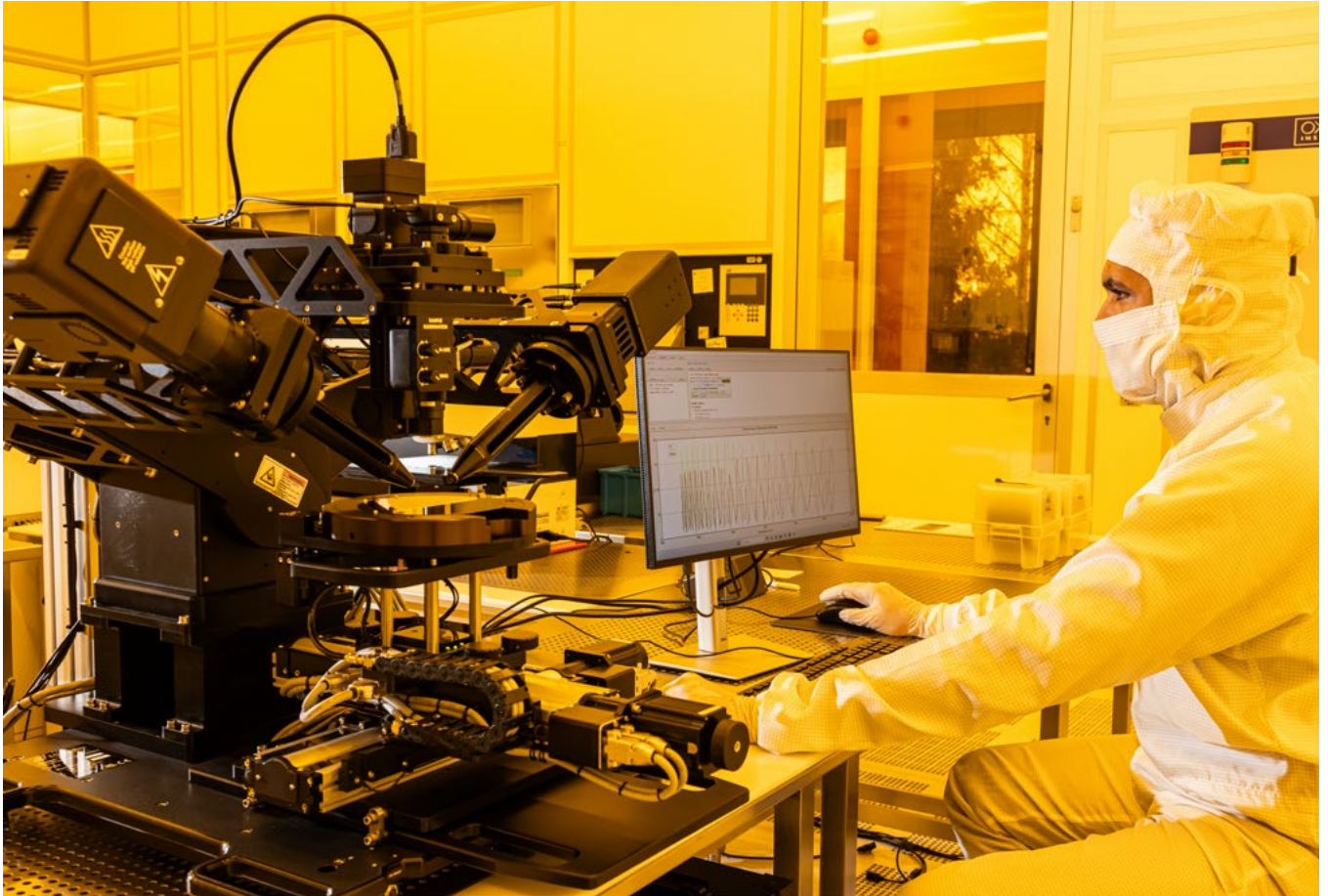
The new building of the Max Planck Semiconductor Laboratory (HLL) has also been completed and several major tools have been installed. The facility is currently being prepared for full operation, adding 1,400 m<sup>2</sup> of state-of-the-art cleanroom space to the QTP ecosystem. A collaboration agreement of the Walther Meißner Institute (WMI) with the HLL now ensures enhanced access to high-quality infrastructure for superconducting device fabrication.

In addition, planning for the new Fraunhofer EMFT facility on the Garching campus is advancing. Phase II planning – defining full cost structures and technical specifications – is now completed.

Beyond the ongoing QTP projects, two major strategic initiatives are underway that will significantly enhance and expand the MQV's mid- and long-term capabilities:

Firstly, as part of the European Chips Act, the German partners WMI, HLL, Fraunhofer FMD, IPHT Jena, Infineon, and the MQV start-up Peak Quantum have joined a Europe-wide consortium led by VTT (Finland) – a pilot line enabling high-quality, large-scale fabrication of superconducting quantum devices. The project was approved in December 2025 and will substantially expand the technical capabilities available within MQV while providing services to external academic and industrial users.

Secondly, a major infrastructure proposal has been submitted for a "Nanofabrication Center for Quantum and Semiconductor Technologies (NanoTeQLab)" on the Garching campus as part of a strategic expansion of high-tech cleanroom capacities at the site. A central element is the creation of a user facility that provides low-threshold access to cutting-edge fabrication technologies for researchers, start-ups, and industrial partners alike. The proposal is currently under consideration within the Bavarian and German Hightech Agenda frameworks.



# Entrepreneurship

Turning world-class research into economic success and establishing a globally competitive quantum-technology industry in Bavaria are central objectives of Munich Quantum Valley (MQV). Technology transfer is therefore a key priority. Entrepreneurship is essential for overcoming the bottleneck of turning scientific research into market-ready products. Within MQV, the entrepreneurial efforts are driven by the Venture Lab Quantum/Semicon (VLQS), MQV's innovation center for quantum technologies.

Since the start of MQV, and even the months before, founder teams at various maturity stages have received support from the VLQS. In 2025, Linq Photonics – a spin-off from an MQV project with Prof. Pernice at Heidelberg University that aims to build photonic integrated circuits for quantum-computing applications – joined MQV's start-up ecosystem, which currently includes Munich Quantum Instruments, the Munich Quantum Software Company, Peak Quantum, planqc, Qlibri, Qoro Quantum, QTAS, and Quantum Diamonds.

At the university level, the VLQS offers a range of educational programs at the intersection of quantum technology and entrepreneurship, designed to nurture the next generation of founders and inventors.

In 2025, the VLQS successfully concluded the first round of the Quantum Fellowship Program – a one-year entrepreneurship education program within the quantum-tech industry for ten students from a variety of backgrounds – and kicked off the second round. After undertaking an entrepreneurial project, in which the students ideate, innovate, and validate their quantum-technology-inspired projects within their chosen project team, they can intern at one of the start-ups in the MQV and TUM Venture Lab Quantum/Semicon ecosystem.

After its great success in 2023 and 2024, the VLQS ran the Idea Lab program twice with a total of 20 participants in 2025. The entrepreneurial education program tailored for Ph.D. students and postdocs in quantum-related disciplines supports researchers with identifying and evaluating commercial applications of their academic work in a two-day workshop. The format imparts holistic knowledge on how to develop a deep tech start-up, spanning from IP management to customer acquisition. Additionally, helping connecting European entrepreneurial ecosystems, the VLQS organized this year's Quantum Innovation Lab – an entrepreneurial program comparable to the Idea Lab that is open to scientists from across Europe – together with Austrian universities and research institutions as well as non-academic Austrian partners.

Furthermore, together with the student initiative Push-Quantum, the VLQS organized the sixth edition of the

Quantum Entrepreneurship Laboratory. In this program, interdisciplinary teams of technical and business students work on technology challenges, simulating the experience of launching a start-up in the quantum technologies sector.



# Start-up voices

A vibrant start-up community is one of the key components of the MQV ecosystem. The following brief interviews with three young companies from this entrepre-

neurial ecosystem highlight the innovative work being done, with each start-up tackling unique challenges and opportunities in the field.

## Munich Quantum Software Company (MQSC)



### Short introduction to MQSC

MQSC aims to create industry-grade software tools and services that provide for quantum computing what we already take for granted in conventional IT. We offer software stacks, compilers, interfaces, application demos, and benchmarking frameworks that connect users to quantum hardware and HPCQC systems.

### What was MQSC's biggest success in 2025?

We are not "burning" money! We had a profitable first year with several successful customer projects, major open-source contributions, and the launch of MQT Bench 2.0 – showcasing that professional quantum-software development can be sustainable and industry-ready.

### What challenges are coming up next?

Growing beyond small-scale operations, extending our toolchain, and securing long-term projects with our partners – all while keeping pace with fast-moving quantum hardware developments.

### What does it mean for MQSC to be part of the MQV ecosystem?

Being part of MQV gives us access to a strong ecosystem of researchers, hardware partners, and industry users. It accelerates collaboration, visibility, and innovation, and helps us position Munich as a hub for quantum software excellence.

## QTAS

### Short introduction to QTAS

At QTAS, we've built breakthrough quantum-sensing technology that enables a fundamentally new way to assess cancer treatment response directly in blood. We translate world-class quantum research into clinical reality and unlock capabilities for more effective, personalized cancer therapies.

### What was QTAS' biggest success in 2025?

In 2024, QTAS demonstrated the direct detection of individual tumor cells in human blood using our quantum MRI microscope – bypassing the limits of classical fluorescence microscopy in a world-first result.

### What challenges are coming up next?

Our next challenge is scaling this breakthrough to clinical sample throughput and deploying it with our clinical partners to establish a new standard for precision oncology.

### What does it mean for QTAS to be part of the MQV ecosystem?

MQV unites quantum hardware, theory, and engineering in a truly world-class ecosystem. This unique concentration of expertise forms an excellence hub that strengthens and accelerates our ongoing success in translating quantum technology into medical applications.



## Peak Quantum

### Short introduction to Peak Quantum

Peak Quantum is building high-quality quantum processors based on superconducting qubits. Launched in 2024 by researchers from the Walther Meißner Institute, the spin-off is pioneering a novel qubit architecture with built-in error protection, to accelerate the development of fault-tolerant and application-ready quantum computing.

### What was Peak Quantum's biggest success in 2025?

We were selected to operate the first European pilot line for superconducting quantum chips, backed by a major EU grant. It's a strong validation of our team and technology and puts us in an ideal position to push quantum-hardware development forward in Europe.

### What challenges are coming up next?

We're working toward key inflection points on our research-and-development roadmap like validating multi-qubit performance and achieving high-yield, industrial-grade fabrication. Recruiting top technical talent, especially internationally, will be key to hitting our next milestones.



### What does it mean for Peak Quantum to be part of the MQV ecosystem?

MQV gives us a setup that's rare anywhere in the world: proximity to leading research, access to advanced fabrication and test facilities, and a deep local talent pool. It's what lets a small team like ours compete with billion-dollar players.

# MQV Partner Network

The Munich Quantum Valley e.V. Partner Network unites key players from research institutions, universities, and industry, all committed to advancing quantum science and quantum technologies across Bavaria. The network drives the development and operation of quantum-computing systems, identifies and assesses potential real-world applications, facilitates effective knowledge transfer from research to industry, and fosters educational initiatives for schools, universities, and businesses.

In 2025, new industry partners as well as network partners joined the MQV Partner Network, which now includes 30 industry partners, 15 academic partners and four network partners, making it one of the leading quantum ecosystems in Europe. MQV partners gain practical benefits through access to exclusive workshops and events, including priority registration, free attendance, and opportunities to suggest topics. They can connect with top scientists and peers, stay updated on research developments, and present their work at MQV events. Partners also benefit from the network by connecting them to skilled workforce and early-career researchers. The network provides regular updates via a members-only newsletter, access to privileged exhibition space at MQV events and fairs, and the opportunity to collaborate on outreach activities. Partners can actively explore new collaborations with researchers and co-develop projects as well as training possibilities for their staff.

Dedicated events in 2025 constructively connected representatives from industry and science within the MQV ecosystem, further strengthening the quantum community. In May, the second edition of the MQV Supplier Workshop took place. Primarily aimed at the MQV Partner Network, the event created a platform for open exchange and networking, giving both industry and academia room to share latest highlights and current challenges from their respective perspectives. In June, the World of Quantum trade fair, the world's largest fair for quantum technology, took place again in Munich, now settling on a two-year cycle. MQV made a strong showing with its own stage program at its booth and an expanded ecosystem area. A selection of member institutes, industry partners, and start-ups from the MQV ecosystem were located around the MQV booth, giving the Bavarian quantum-technology landscape as a whole an extremely strong presence.

## Industry



## Academic



## Networks





# MQV at fairs

As in previous years, MQV was present at a variety of fairs, meetings, and conferences to exchange ideas with companies and highlight opportunities for scientific and industrial cooperation.

At the very well attended annual Spring Meetings of the German Physical Society (DPG), namely of the Atoms, Molecules, Quantum Optics and Photonics Section (SAMOP) and the Condensed Matter Section (SKM), MQV presented the quantum-research landscape in Bavaria as well as career opportunities within the MQV ecosystem. A special addition on the occasion of "100 Years of Quantum Physics" was the DPG Fall Meeting, where MQV was also present with a booth. As in the last two years, MQV was an exhibitor at the Hannover Messe. Already for the fourth time, MQV joined the Leibniz Supercomputing Centre at their booth at the International Conference for High Performance Computing, Networking, Storage, and Analysis (SC25), which created the ideal setting for discussing high-performance and quantum computing, as well as their integration within the Bavarian quantum ecosystem.

The World of Quantum, the world's largest trade fair for quantum technology, returned in June for its third installment with new records in both exhibitor and visitor numbers, clearly having established itself as an important industry gathering for the quantum community and industry. MQV showcased the excellent work and impressive development of the research association and network since the last trade fair, displayed exciting exhibits that vividly illustrate technological progress, and also gave interested quantum newcomers an understandable introduction to the world of quantum technologies, especially quantum computing. The booth also served as a first point of contact for all questions relating to the Bavarian quantum ecosystem and invited visitors to engage in lively discussions. A dedicated stage was regularly used for short pitches in which scientists presented their work and start-ups introduced themselves. Placed around the MQV booth was a selection of member institutes, industry partners, and start-ups from the MQV ecosystem, nicely illustrating the strength of the Bavarian quantum-technology landscape and MQV's enabling role in the quantum community. The TUM Venture Lab Quantum/Semicon booth offered the recently founded MQV start-ups in particular a platform to network within the community.

MQV's researchers also once again demonstrated an exceptionally strong presence at this year's IEEE International Conference on Quantum Computing and Engineering – also known as IEEE Quantum Week, which took place in September. Over 40 contributions covered the entire spectrum of quantum-computing research, from applications and software to the corresponding hardware. The variety of activities was extremely well received by participants of IEEE Quantum Week, sparking exciting discussions. The MQV booth in the conference exhibition area was a central point of contact for all enquiries about the project, particularly the Munich Quantum Software Stack.





# 4 Public engagement

In 2025, Munich Quantum Valley (MQV) continued to prioritize public engagement as a core mission, striving to inspire curiosity and promote informed dialogue about quantum science and technology (QST). To foster a foundational understanding of quantum technologies and their societal implications, MQV organized and participated in a diverse range of public events. These included science festivals, lab tours, public lectures, and interactive workshops, offering the public meaningful opportunities to engage directly with ongoing research and discuss the broader impact of quantum science.

The popular monthly series “MQV In Persona”, launched in 2023, was further extended in 2025 and now comprises

29 portraits, spotlighting the innovative work of early-career researchers while offering personal stories that highlight the diversity of quantum research within MQV. The video series “Quick Quantum Questions”, delivering bite-sized explanations of QST topics through short, expert-led videos, was also continued in 2025 and now features 14 questions.

Additionally, MQV remained actively involved in the federally funded projects GALaQSci and Quanten(t)räume, where it contributed to the development of innovative educational tools, including an interactive smartphone game, and other dynamic outreach formats designed to make quantum science accessible and exciting for learners of all ages.



*Overview of  
MQV outreach  
events*

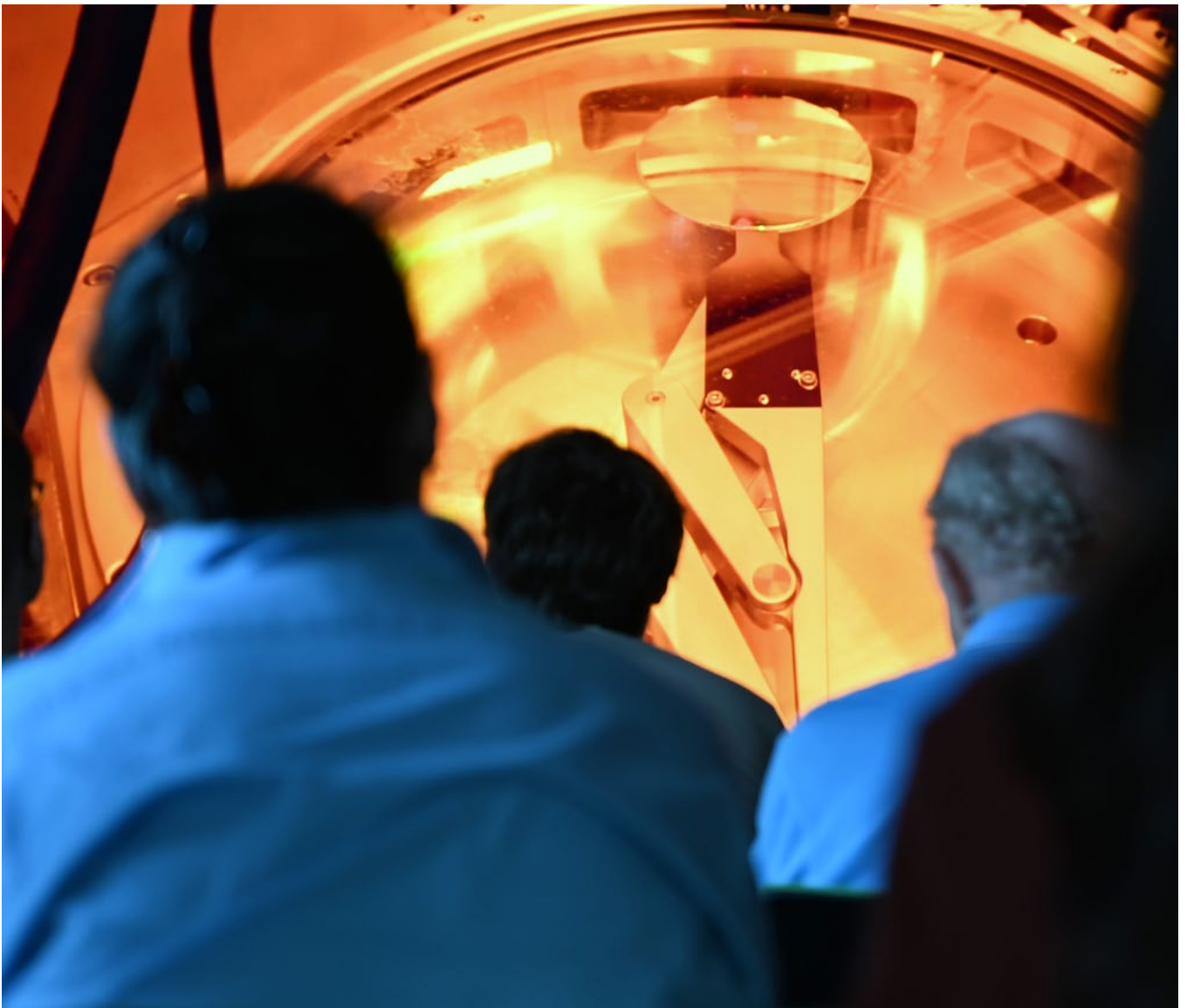


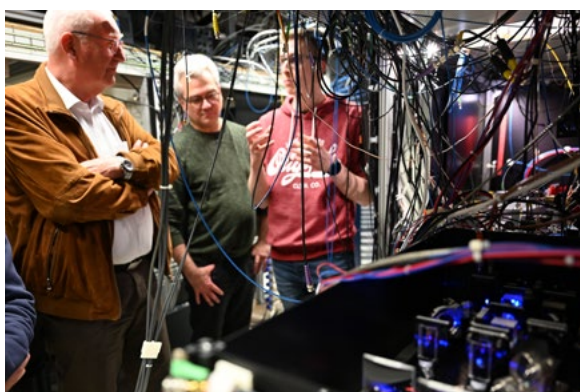
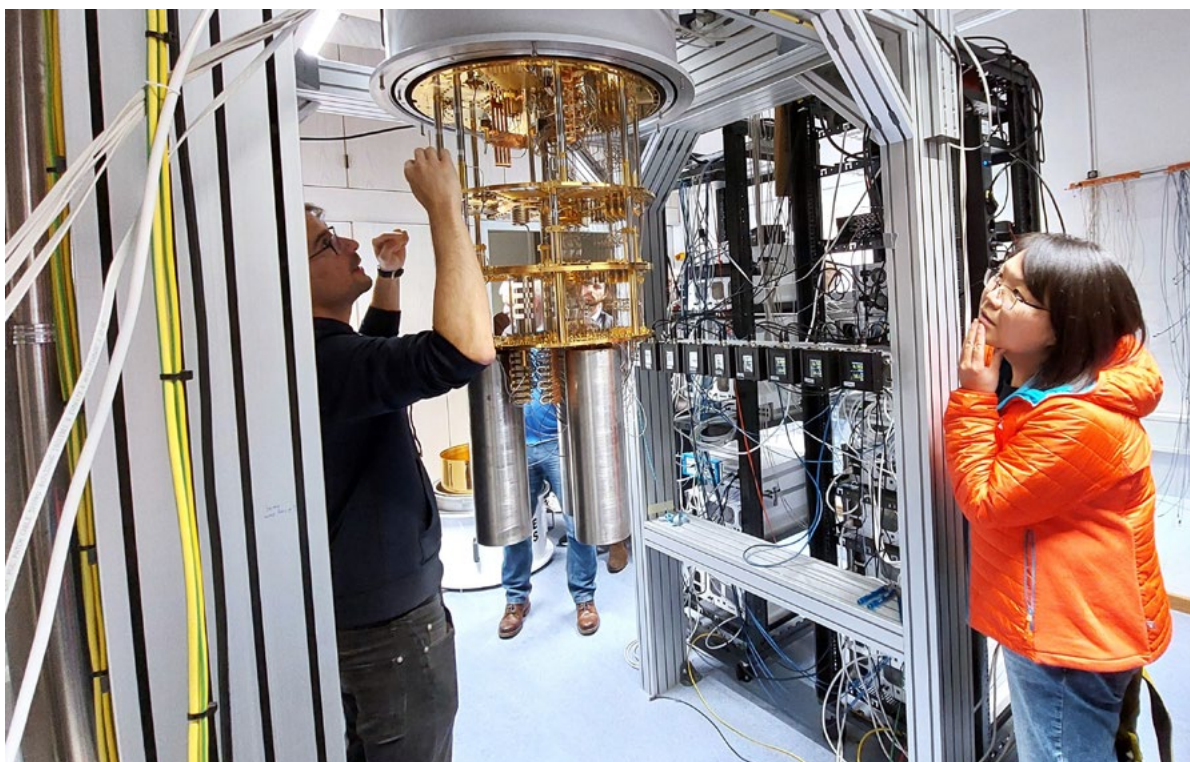
*Details on  
federally funded  
projects*

# MQV in touch

The year 2025 marked a special year for the quantum community as it was proclaimed the International Year of Quantum Science and Technology by the United Nations. Celebrating the 100th anniversary of the formulation of quantum mechanics in 1925, universities, research institutions, scientific societies, and many more around the world participated in the Quantum Year. MQV joined the festivities with numerous special activities that gave the public a glimpse into the impressive world of quantum mechanics and offered the rare opportunity to take a look behind doors that are usually closed to the outside world.

These events complemented formats such as open days and science festivals, which have become an integral part of the MQV event calendar. At the numerous public events, MQV was able to make direct and personal contact with an interested audience of all ages and answered their questions ranging from the basics of quantum physics to specific technological details and the economic or social relevance of quantum technologies, particularly quantum computing.





## MQV-Einblicke: a rare glimpse behind the scenes and into the laboratories

The MQV Quantum Year got off to a brilliant start in February with Prof. Rainer Blatt's lecture "100 Years of Quantum Physics – and That's Just the Beginning". Around 350 guests flocked to the Bavarian Academy of Sciences and Humanities (BAW) to join MQV's first Scientific Director on a whirlwind tour through the history of quantum physics. Blatt's lecture was also the first event in the series "MQV-Einblicke – 100 Jahre Quantenwissenschaften und woran wir heute forschen" (MQV Insights – 100 years of quantum science and what we are researching today), in which MQV invited the public to its member institutes to experience their current cutting-edge research on site. The evening events, most of which were completely booked out, offered guests the opportunity to learn about various aspects of quantum-technology research and take a look behind the scenes and into the laboratories. Throughout the year, visitors saw complex experimental

setups up close, learned about the control of individual atoms or light particles, stood next to superconducting quantum computers – whose hearts are among the coldest points in the Universe –, examined processors with tiny structures, and were equally impressed by huge machines and server racks.

As diverse as the facilities and topics visited were, one thing always remained the same: the unbroken interest of the visitors and a never-ending stream of questions. The "MQV-Einblicke" series will therefore continue in 2026 – after the initial spark provided by the Quantum Year.



[Overview of MQV-Einblicke events](#)



Full recap  
of the event



## From the lab to the pub: quantum special at Pint of Science

While the “MQV-Einblicke” series brought the audience into the labs, another event took the scientists out of the lab: Together with Pint of Science, MQV organized a quantum special of the popular science festival and transformed the Haderner Bräustüberl into a quantum pub. On three completely sold-out evenings, scientists from the MQV network took the audience on an exciting and informative journey through various areas of quantum science and technology. Not only the audience, but also the speakers clearly enjoyed bringing quantum technologies and

pubs together – beers were “entangled” with each other and remarkable parallels were drawn between beer brewing and the compilation of quantum algorithms.

The perfect souvenir for the event were the specially made MQV beer coasters printed with gate symbols that can be used to build quantum circuits. The coasters have been extremely popular ever since and have been used on many other occasions.

## Girls'Day

What is it like to work as a computer scientist, physicist or mathematician in a computer center and to research supercomputers and quantum computers? With its Girls'Day offer on 3 April 2025, MQV specifically addressed girls from high school to gain an insight into this career field. Eight students aged 14 to 17 took the opportunity and participated in the MQV program, which this year took place in cooperation with and at the Leibniz Supercomputing Centre (LRZ). The day started with classical computer hardware: To see with their own eyes what actually comprises the hardware of an ordinary computer, the students took apart old PCs in a "dissection lesson". They identified the "brain" (processor), "nervous system" (mainboard) and "short-term memory" (RAM) before they pulled out all kinds of cable clamps and plugs and unscrewed numerous screws to get the individual parts loose. From the ordinary PC, the program moved on to the supercomputer, which girls got to see it in its entirety on the tour of the computer building. Past humming ventilation systems and whirring server racks, they first saw the world's largest chip – used at the LRZ for AI applications –

and then the quantum computer, which has already been successfully connected to the classical supercomputer SuperMUC-NG. Back in the classroom, the girls were introduced to the basics of quantum physics and quantum computing. Finally – because they have already been eagerly asking questions about this topic during the tour. After the lecture, they took a closer look at exhibits, which gave them an idea of how different the hardware of a quantum computer can look and what the similarities and differences are compared to the PC they were allowed to take apart at the beginning of the day.



*Full recap  
of the event*

# MQV In Persona

The Munich Quantum Valley (MQV) ecosystem plays a vital role in accelerating advancements in quantum science and technology, driven in large part by the passion and dedication of a dynamic new generation of scientists, engineers, and entrepreneurs. Here are some of their activities to highlight the variety of challenges they tackle within the MQV network – ranging from basic research on fundamental quantum processes to bringing applications to the market – as well as the different aspects that inspire and motivate them in their daily work.

As a research associate at the Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT, Daniela Zahn is primarily responsible for testing various hardware components for superconducting quantum computers with the aim of making this technology scalable. One essential component that Daniela and her colleagues are testing is, of course, the qubits fabricated in-house. "There is a whole zoo of measurements that we implement to learn as much as possible about our qubits." The fact that many time-resolved measurements are required makes the analysis of qubits one of her more demanding tasks. It becomes even more complicated when qubits are not characterized individually, but instead are coupled together – as is necessary for application in quantum computing. "It's not difficult to measure any signal," Daniela explains, "but it is difficult to measure the right signal. You have to have a very good understanding of the measurement setup to ensure that you actually see what you wanted to measure." In addition to the actual research work, Daniela also played a major role in setting up the institute's cryogenic laboratory. She likes the wide range of complex tasks she encounters in her work: "I definitely seek intellectual challenges," says the scientist. "And when it comes to measurement technology, it's a bit like being a detec-

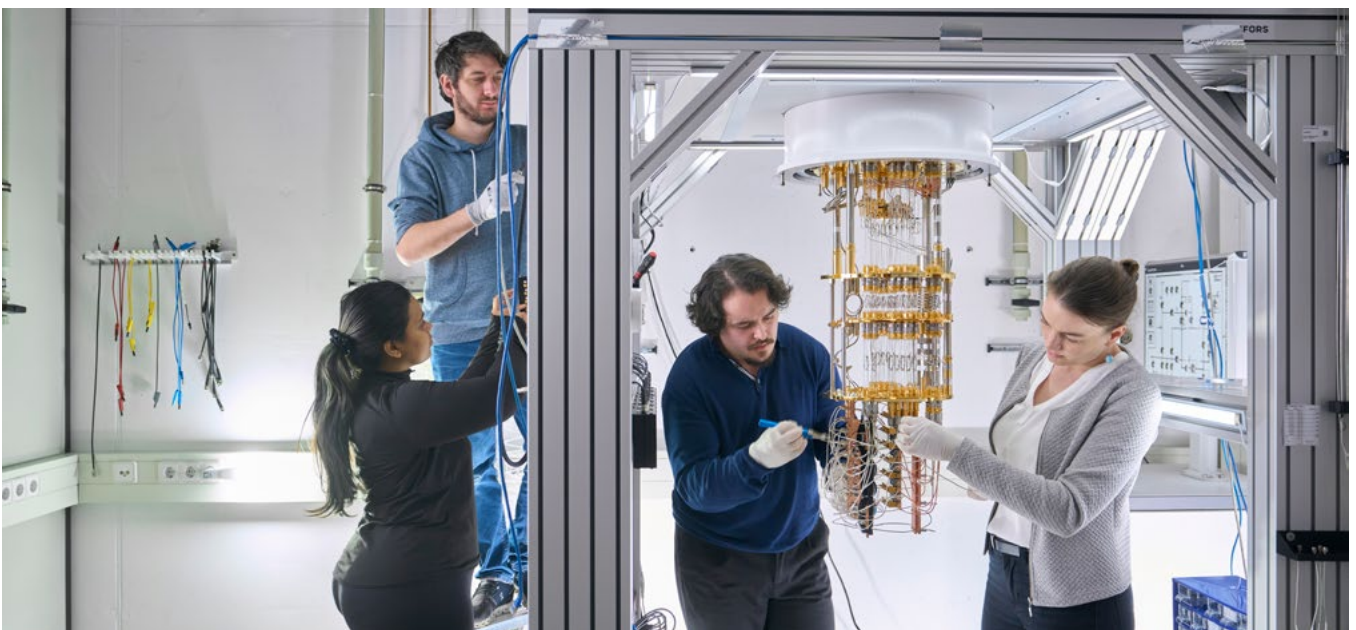


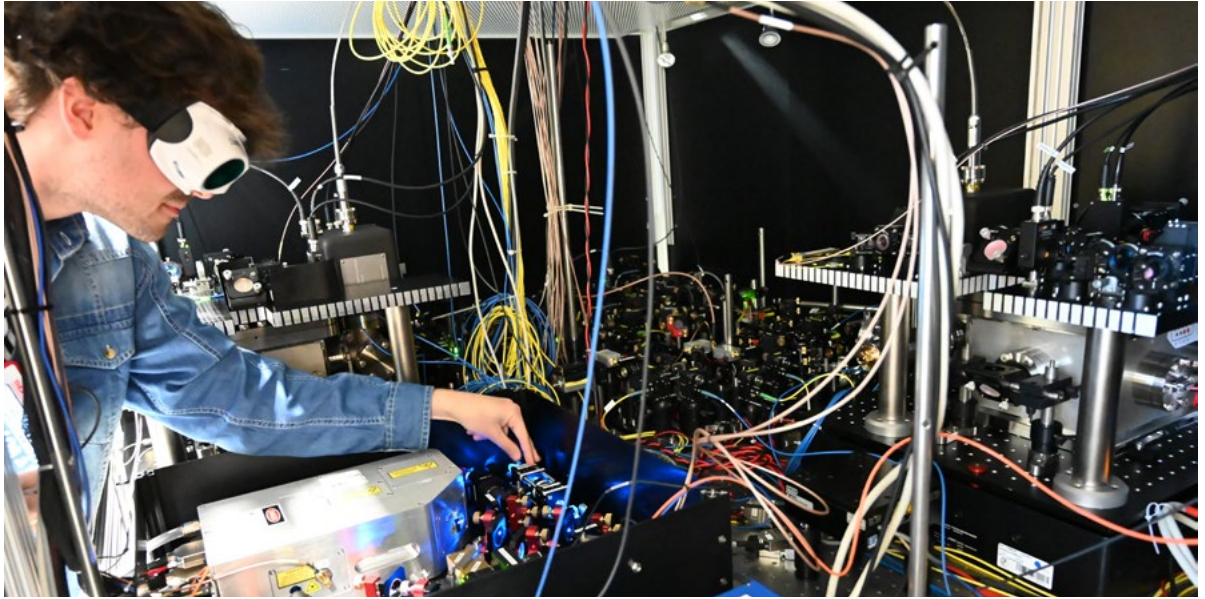
**Daniela Zahn**

Fraunhofer Institute for Electronic  
Microsystems and Solid State Technologies

*"Metrology is a bit like  
being a detective"*

Daniela tests various hardware components for superconducting quantum computers. In the cryo lab, she analyses qubits, so-called through-silicon vias (TSVs), and flexible superconducting connections at extremely low temperatures. Her analysis of quantum-computing hardware is an important step on the way to scalability.





tive. You get a few clues and then you have to understand what's going on. I just love that." She also sees her work at Fraunhofer EMFT as offering "an optimal mix" of research and proximity to application, which motivates her greatly: "Particularly in the case of application-oriented research, you are potentially doing something that will advance technology."

Unlike Daniela Zahn's work, David Gröters' research is not aimed at a specific application. As part of his doctorate at the Max Planck Institute of Quantum Optics, the MQV doctoral fellow uses ultracold atoms trapped in standing waves of light to study quantum many-body systems. "We want to understand the fundamental processes that occur when many particles interact with each other at the quantum level," David explains. Already during his Master's, the field of ultracold atoms in so-called optical lattices captured his heart and still evokes his enthusiasm: "The fact that it is possible to really see the individual atoms in our experiment as they sit in a standing wave of light is still incredibly fascinating to me. I don't know if this will become something ordinary one day – I almost hope not!" In addition, the young scientist is still fascinated by the complex experimental setup required for such research. The vacuum chamber containing the atoms is located between tons of optics and cables, which are piled up on several levels on the main table. "The main table is really, really full!" David laughs, looking with enthusiasm at what appears to outsiders as a tangle. He finds it impressive how generations of Ph.D. students have built up the experiment over the years, constantly adding new elements and upgrades. The complex setup makes it possible that whether and how the atoms move within their light cage, how they collide and interact with one another, is entirely in the hands of the experimenters. "In principle, we completely determine the rules of the game. Ultracold atoms in optical lattices are therefore a wonderfully diverse platform that can be used to research a wide variety of physical questions and theories," the young scientist enthuses.



**David Gröters**

Max Planck Institute of Quantum Optics

***"We can control the atoms in almost every respect"***

David uses ultracold atoms trapped in standing waves of light to study the fundamental processes that occur when many quantum particles interact. In their experiments, he and his colleagues take advantage of the fact that they can precisely control whether and how the atoms can move and interact within their "light cage".

Exploring quantum-mechanical interactions using an experimental platform is also what Adrian Paulus does in his doctoral studies at the Walter Schottky Institute. However, instead of individual atoms trapped in standing waves of light, Adrian works with materials so thin that they are described as two-dimensional. He produces them from natural crystals: "When people ask me what I do, I always say I work a lot with adhesive tape," the MQV doctoral fellow laughs as he sums up his work like this. Standard Tesafilm is actually an important everyday tool for him, for a process known as exfoliation. He uses the adhesive tape to peel off individual monolayers from the initial crystals and then layers them on top of each other to form the final

sample. The resulting two-dimensional materials serve as a platform for analog quantum simulation, explains the young scientist: "Analog quantum simulation means putting a quantum-mechanical model into an experimental platform. Then you can test the complexity of quantum mechanics in a real experiment or simulate it, which is not possible with computer-based models." The fascination with pushing boundaries, both in science and in himself, is what drives Adrian to this day. A field of application that he finds particularly exciting is the precise measurement of certain natural constants, for which two-dimensional materials are an ideal platform as they are very clean and defect-free. This allows the definitions of these constants to be improved. More accurate measurements are important not only for science but also for industries such as the semiconductor industry, which manufactures chips in the nanometer range. "If you can measure more accurately, it improves the world as a whole," says the physicist. "But much of it is simply pure basic research. And that's important too, even if no application comes out of it," he says. For him, it's about satisfying intellectual curiosity: "It's just exciting, for its own sake!"

In contrast to Adrian's work, Laura Herzog's doctorate at the Technical University of Munich does focus on a specific application, namely error-corrected quantum computing. From dealing with the philosophy of quantum mechanics in her bachelor's thesis to researching numerical methods in condensed matter physics during her master's – realizing how much she enjoys programming and writing scientific code – she ultimately gravitated toward quantum computing. What Laura particularly likes about her Ph.D. topic in quantum error correction is that it allows her to combine her

knowledge as a theoretical physicist with practical problems from computer science. In her current research, Laura examines how much she can move away from the details of specific quantum-error-correction codes to derive more general approaches for compiling quantum algorithms. To do this, she first has to understand how the various codes work in detail – a topic that, as the doctoral student notes, involves many fundamental concepts of quantum information theory and is very physics-heavy. However, based



**Adrian Paulus**  
Walter Schottky Institute

***"We create a model  
framework in which we can  
verify the physics"***

Adrian works with two-dimensional materials as an experimental platform for analog quantum simulation. This allows him to test quantum-mechanical interactions that cannot be simulated using computational methods due to their complexity.





on this detailed knowledge, Laura continues, one can try to abstract and formulate problems that ultimately stem from computer science. It is precisely this bridge-building that the scientist likes so much about quantum error correction: "That's what I think is so nice about the topic. It, in a sense, connects two different worlds."

Nina Stockinger, doctoral student at the Friedrich-Alexander-Universität Erlangen-Nürnberg shares Laura's enthusiasm for abstract theory. "Group theory was the coolest", she says, thinking back on her studies. Describing things mathematically and looking at them

on an abstract level is something she finds "really nice!". Unlike Laura however, Nina works in the realm of so-called noisy intermediate-scale quantum (NISQ) computers, which do not have error correction. "It will still take time before error-corrected hardware is available. That's why we are trying to develop algorithms for quantum computers that are currently available or will be available in the near future," the scientist explains. Starting with a bachelor's degree in Applied Chemistry, Nina is now pursuing her Ph.D. at the Chair for Quantum Theory: "In my group, we are working, among other things, on quantum algorithms, which we want to use to calculate the electronic structure of molecules." The electronic structure, which describes the distribution of electrons in the atoms of the molecule and thus its energy, is relevant for the development of materials, for example, or for predicting the reactivity of a chemical reaction, the chemist continues. The fact that fundamental quantum physics and application potential come together in this field inspires the young theorist: "I find it super exciting that fundamental quantum effects, such as superposition and entanglement, are used to construct algorithms." Algorithms that promise concrete applications, for example in chemistry.



**Laura Herzog**

Chair for Design Automation (TUM)

### *"It connects two different worlds"*

Laura is researching compilation methods for error-corrected quantum computers. For that, she first has to study the details of specific quantum-error-correction codes. Then, she has to abstract from these details to derive more general computer science problems.

Karl Briegel, co-founder of the start-up QTAS, also has a background in chemistry. For a long time, he thought he would ultimately end up in theoretical chemistry, until one of his professors at the Technical University of Munich sparked his interest in Nuclear Magnetic Resonance (NMR) using quantum sensors. This drew the chemist more into experimental quantum physics, and he ultimately pursued his Ph.D. in this area. Researching something with a clear practical application was a major motivation for



**Nina Stockinger**  
Chair for Quantum Theory (FAU)

***"We use fundamental quantum effects to construct algorithms"***

Nina is researching algorithms for so-called noisy intermediate-scale quantum (NISQ) computers. Specifically, she is studying algorithms for calculating the electronic structure of molecules, which, for example, plays an important role in chemical research and materials development.

Karl already during his doctoral studies. At QTAS, this is now even more the case. Together with his colleagues, he develops a new blood analysis device that will allow for faster assessment of cancer therapies. The blood analyzer is based on the technology that Karl worked on during his doctoral degree: "My research group developed a microscope that does something very similar to an MRI device in a hospital," the chemist explains, "only on a very small scale and without producing a 3D image, but rather a 2D image of a sample placed on a specially prepared, tiny diamond chip." Unlike classical NMR methods, where the sample is surrounded by a coil that detects the NMR signal by induction, the new microscope uses special quantum sensors in the diamond chip, so-called nitrogen vacancy centers, for this purpose. On the one hand, these quantum sensors can translate the NMR signals into optical signals that can be

filmed with a high-speed camera. On the other hand, they allow for a spatial resolution that is on the order of magnitude of individual cells. "We take one shot, 300 milliseconds, and have hundreds of thousands of NMR spectra. It's extremely fast, with very high spatial resolution at the same time!", Karl enthuses. With QTAS, the aim now is to turn this technology into a real application that can be used in clinics and really help people, the young founder proclaims: "We're going full steam ahead to achieve this goal of building this device!"



**Karl Briegel**

***"We're going full steam ahead"***

At the start-up QTAS, Karl and his team are developing a new blood analysis device that will enable faster detection of the effectiveness of cancer treatments. The technology builds on optical NMR microscopy, whose functioning relies on quantum sensors in diamond.



*Find all portraits of our 'In Persona' series in full length on our website! Available in English and German*

# Quick Quantum Questions

In the video series “Quick Quantum Questions”, experts from Munich Quantum Valley (MQV) answer questions on different aspects of quantum science and technologies. In short clips, they clarify core concepts such as superposition and entanglement, introduce specific technologies, explain current challenges, and provide deeper insights into the quantum landscape MQV is building. In 2025, the list of answered questions grew by five more questions.

That building quantum computers requires experts from different fields is made clear by Robert Wille from the Technical University of Munich who illustrates why the exchange between hardware and software developers is so important in making quantum

computers accessible to end users. The question posed to Matt Tovey from the Leibniz Supercomputing Centre is along similar lines. He discusses the technical challenges that arise when integrating quantum computers into data centers, through which the technology can be made accessible to a wider user community. Jan von Delft from the Ludwig-Maximilians-Universität München answers a specific question about the MQV ecosystem, guiding viewers on how to identify and connect with quantum research groups across Bavaria. Returning to fundamental challenges, Esther Cruz from the Max Planck Institute of Quantum Optics explains the unavoidable issue of decoherence, and how researchers meet this challenge in terms of error correction. Meanwhile, Amit Devra from the Technical University of Munich sheds light on the more specific task of achieving optimal control of quantum computers by exploiting theoretical models, demonstrating how theoretical physicist contribute to controlling qubits on experimental platforms as precisely as possible.



*Find all video clips of our 'Quick Quantum Questions' series on YouTube! Available in English and German*

# Imprint

## Munich Quantum Valley Public Annual Report 2026

### PUBLISHER

Munich Quantum Valley  
Walther-von-Dyck-Straße 6  
85748 Garching  
Germany  
+49 89 99727430  
info@munich-quantum-valley.de  
www.munich-quantum-valley.de

### DESIGN + LAYOUT

www.mattweis.de

### IMAGE CREDITS

**page 3** — © StMWi | R. Dier — **page 5** — © StMWK | Böttcher — **page 6/7** — © MQV | Flavio Cury — **page 14** — Claudia Felser © MPI CPfS — Robert Axmann © DLR — Arndt Bode © TUM | Andreas Heddergott — Gerhard Kramer © TUM | Andreas Heddergott — Jürgen Schatz © FAU | Gerd Grimm — Sigmund Stintzing © LMU — Hannah Venzl © Fraunhofer — **page 15** — Markus Aspelmeyer © Mateusz Kotyrba — Michael Bolle © Carl Zeiss AG — Per Delsing © Peter Widing — Dietmar Harhoff © David Ausserhofer — Bettina Heim © Bettina Heim — Sebastian Luber © QUTAC — Roee Ozeri © Weizmann Institute of Science — Carsten Polenz © Carsten Polenz — Anita Schöbel © Fraunhofer ITWM — Philipp Slusallek © DFKI | Jürgen Mai — Stephanie Wehner © TU Delft — Sabine Wölk © Roger Riede — **page 16** — Rainer Blatt © MQV | Mikka Stampa — Rudolf Gross © MQV | Mikka Stampa — Laura Schulz © Laura Schulz — **page 17** — © MQV | Flavio Cury — **page 22** — © MQV | Jan Greune — **page 23** — © MQV | Jan Greune — **page 24** — © MQV | Mikka Stampa — **page 25** — © MQV | Jan Greune — **page 26** — © MQV | Jan Greune — **page 30** — © MQV | Jan Greune — **page 31** — © MQV | Jan Greune — Adelina Bärligea © MQV | Veronika Früh — Simone Foderà © MQV | Veronika Früh — **page 32/33** — © MQV | Silvia Steinbach — **page 34** — © MQV | Silvia Steinbach — **page 35** — © MQV | Silvia Steinbach — **page 36** — © Bert Willer — © VLQS — **page 37** — MQSC © MQSC — **page 38** — QTAS © QTAS — **page 39** — Peak Quantum © Peak Quantum — **page 42/43** — © MQV | Flavio Cury — **page 46** — © MQV | Veronika Früh — **page 47** — © MQV | Maria Poxleitner — © MQV | Sascha Mehlhase — © MQV | Veronika Früh — **page 48** — © MQV | Veronika Früh — **page 49** — © MQV | Mikka Stampa — **page 50** — Daniela Zahn © MQV | Veronika Früh — © MQV | Jan Greune — **page 51** — © MQV | Maria Poxleitner — **page 52** — © MQV | Veronika Früh — **page 53** — © MQV | Maria Poxleitner — **page 54** — © MQV | Maria Poxleitner