ICDK OUTLOOK: THE EMERGING QUANTUM ECOSYSTEM IN SOUTHERN GERMANY

INNOVATION
CENTRE
DENMARK

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EMERGING QUANTUM ECOSYSTEMS IN SOUTHERN GERMANY

Quantum Technology is an emerging technology area with great potential for society and industry.

Denmark and Southern Germany are at the forefront of quantum research through strong universities and research institutions. The development of quantum ecosystems has been accelerated by recent breakthroughs as public and private stakeholders band together to push the boundaries of quantum technology.

Southern Germany is characterised by strong universities and research institutions on the one side and industrial corporates with an appetite for innovations to adapt to the future on the other side. At the same time, governments are increasing investments in research and innovation, thus providing a glue to tie research institutes and private stakeholders together to ensure ongoing interaction. This is particularly true for quantum technology, which is still in an emerging phase and where commercial opportunities are highly dependent on scientific developments now and in the near future.

The quantum innovation value chain in Southern Germany starts already at universities and research institutions supporting entrepreneurs and startups, thereby creating a bridge to the industry through initiatives such as the TUM Venture Labs Quantum and Munich Quantum Valley.

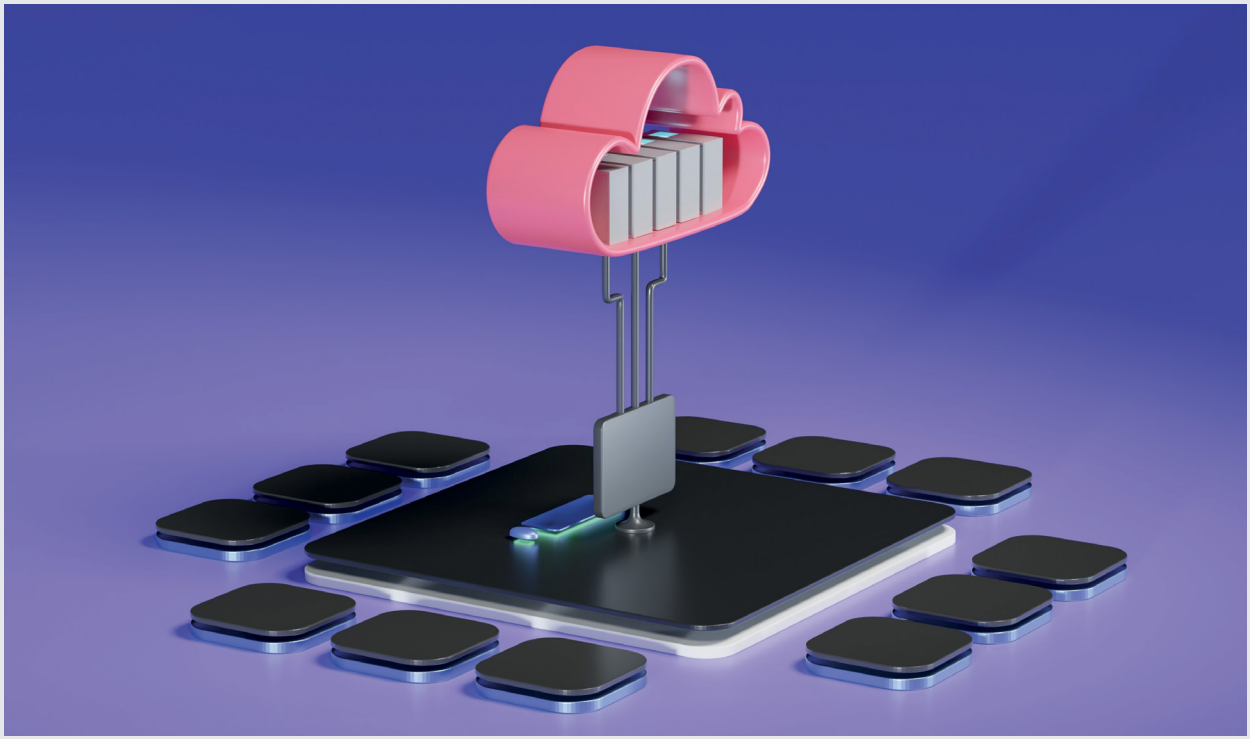
In recent years, significant public investments have been made in Germany and Southern Germany to further quantum research and innovation. At the same time, new quantum startups emerge, while already established industry players in Southern Germany are stepping up. Both in terms of their financial commitments and ways of working strategically with quantum technology. One such example is the Quantum Technology & Application Consortium, QUTAC – a community of German corporates that aim to advance research and development in the field of quantum technologies.

An ecosystems approach to innovation partnerships

Innovation Centre Denmark aims to strengthen the ties between the Danish quantum ecosystem and key research and innovation stakeholders in regional hotspots such as Silicon Valley, Tel Aviv and Munich, in which we are based.

Through deep dives, dialogues, and events, we bring Danish researchers and companies together with strong players in our ecosystems with the ambition to foster new collaborations and partnerships.

On top of online Innovation Talks on the topic, ICDK Munich has held a high-level roundtable between quantum experts from German and Danish research and industry chaired by the Danish Minister of Foreign Affairs. Furthermore, ICDK Silicon Valley, Tel Aviv and Munich brought international quantum experts to Denmark and organised a joint side event at the IQT Nordics quantum conference in Copenhagen held in June 2023.



With this ICDK outlook, we aim to bring insights into the following:

- How key stakeholders in Southern Germany from research, industry, and public networks are approaching quantum technology.
- How the stakeholders in the quantum innovation ecosystem work and interact.
- Concrete use cases to showcase how quantum technology develops and how players in the ecosystem can apply it.

At Innovation Centre Denmark in Munich, we work to connect you with excellent players from research, industry and public organisations. We do this to connect Denmark with one of the world's leading innovation ecosystems.

We wish you happy reading and look forward to hearing from you.

Innovation Centre Denmark

SOUTHERN GERMANY: SHAPING THE FUTURE OF QUANTUM TECHNOLOGY

Global tech corporations, universities, and research organisations have taken note of Southern Germany's quantum technology capabilities – making it one of the world's leading ecosystems and accelerators.

Soon, large-scale industrial use of quantum computing will be within reach, and Southern Germany is leading the field. Bavaria and Baden-Württemberg are home to major industrial companies with a strong focus on applied quantum technologies – due to the significant investments in research, education, and innovation in these areas. They aim to future-proof the most prominent industries and grow the technology required to impact global production, trade and investments.

In 2021, Germany's government announced their support for developing the first quantum computers and related technologies, with an investment of € 2 billion. More recently – in November 2022 – the government pledged to invest € 740 million in quantum computing over three years, including building the country's first quantum business cloud. Their goal is to optimise domestic business conditions and attract international companies.

Several quantum-ready companies have realised the need for cross-functional collaborations to solve their challenges. As a result, they are heavily investing in the field and building "innovation teams" in parallel with supplying resources to external researchers.

Fit for the Future

Developing quantum technology requires collaboration between researchers, industry experts, policymakers, investors, and end-users to foster innovation in this ever-evolving industry. Through collaboration and knowledge-sharing, stakeholders can leverage their strengths to accelerate research, development, and commercialisation.

Of course, the most important stakeholders in this ecosystem are:

Research institutions and clusters that conduct fundamental research to develop new quantum technologies, explore their potential applications, and identify new use cases. The most successful partnerships are well-funded and supported by a collaborative ecosystem.

For instance, the Ludwig Maximilian University of Munich and the Technical University of Munich have

joined forces in the cluster of excellence Munich Centre for Quantum Science and Technology. Separately, in cooperation with IBM Germany, Fraunhofer-Gesellschaft has established a national competence network to research quantum computing.

TUM Venture Lab Quantum is a vital initiative that fosters entrepreneurship in the quantum industry. The initiative's focus on research spinouts is particularly important, given the high potential of quantum technology to create new products and services.

Industry experts often work with researchers to develop scalable quantum technology solutions, commercialise products, and identify market opportunities.

In addition to investing in quantum technologies targeted at mobility, the BMW Group has promoted innovation programmes with external partners and invested in an endowed professorship at the Technical University of Munich.

QUTAC specialises in offering high-quality and innovative industrial automation and control systems solutions. They provide engineering services, software development, and system integration for various industries such as automotive, pharmaceutical, and food production.

Policymakers enable the development of quantum technology insofar as they support funding and research initiatives, develop regulatory frameworks and foster collaborations between industry and academia.

In Baden-Württemberg, quantum technology is key in the state's innovation strategy and a core area for research funding. Similarly, Bavaria's Hightech Agenda Bayern has led to the creation of the Munich Quantum Valley, which was launched in February 2022.

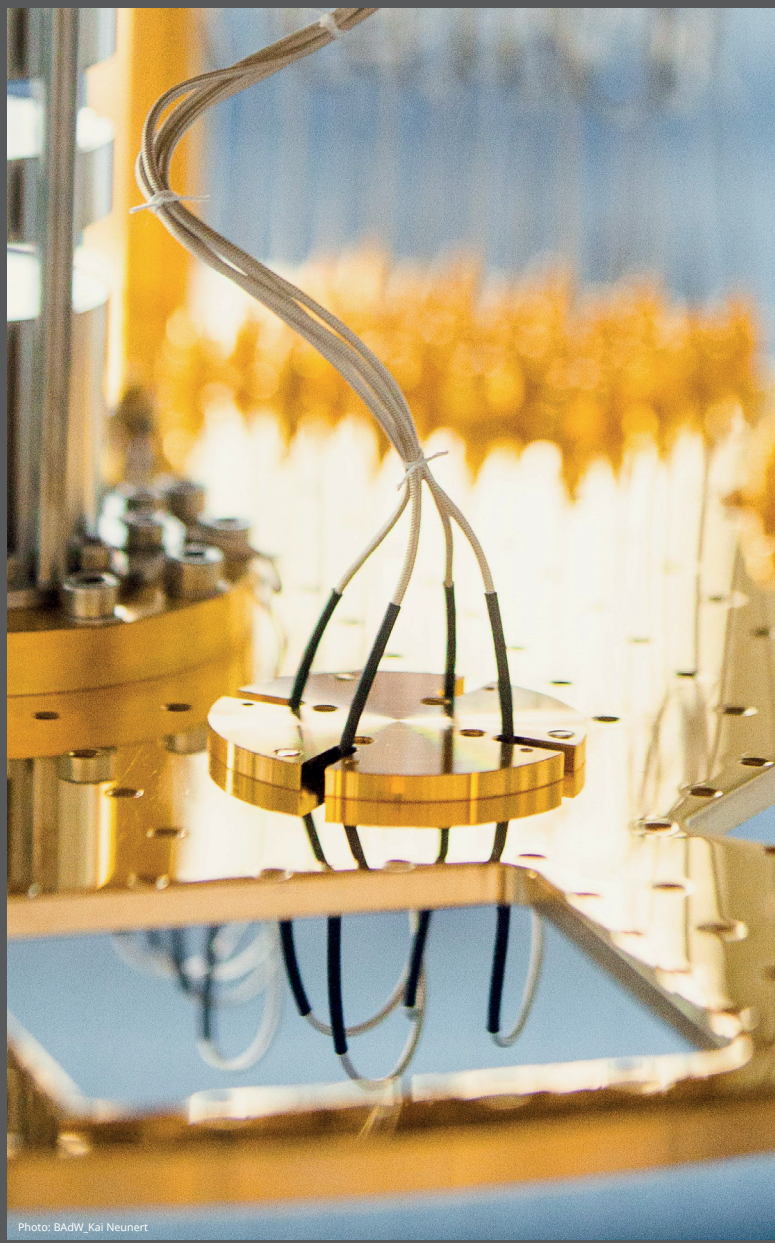


Photo: BAdW_Kai Neunert

Investors financially support startups and early-stage companies so that they can develop and commercialise quantum products.

Public funding is available for quantum-based research and innovation projects at the federal and state levels (both in Bavaria and Baden-Württemberg). In addition, in 2022, several of the region's startups secured venture funding from local and international investors.

Because end-users, SMEs and large corporations, are the ultimate beneficiaries of quantum technology solutions, they provide invaluable feedback to developers, drive demand, and help identify new use cases.

The German government is investing tens of millions in a consortium to help businesses benefit from the latest supercomputer technology through the quantum business cloud. As a result, small and medium-sized enterprises can apply the technology to their business models. And it is expected that this will be steered by end-users who understand and see the opportunity to apply the technology.

A well-nurtured ecosystem requires a **skilled workforce** that includes researchers, engineers, and technicians. Developing talent and building their capacity can strengthen the workforce, ultimately driving innovation and commercialisation.

An ecosystem that brings together researchers, industry experts, policymakers, investors, and end-users is essential to leverage their respective strengths, accelerate innovations, and create a vibrant quantum technology industry.

Granted, quantum computing is still in its infancy – even in Southern Germany – and the available computers have stringent requirements for their hardware and environmental conditions (including temperature). Still, the last five years have seen tremendous maturation. Through this lens, we will explore how the key stakeholders outlined above are working to transform business, research institutions, and the entire region into a quantum powerhouse, one that can lead the way towards the quantum future.

The quest to solve complex problems

Quantum technology is a multidisciplinary field that spans computer science, physics, and mathematics. Drawing on the principles of quantum mechanics, it solves complex problems faster than traditional computing thanks to its data processing capabilities. Instead of implementing strictly binary logic, it uses quantum mechanical objects and qubits and gains a potentially exponential calculation speed-up using quantum mechanical effects.

It is poised to solve challenges that are currently impossible for even the most powerful supercomputers, including fine-tuning machine learning algorithms, accelerating simulations in chemical processes and atomic interactions, outperforming time-sensitive financial transactions, improving the accuracy of weather predictions, providing real-time data on traffic congestion, and streamlining the development of lithium batteries. In short, it can simulate and analyse all kinds of datasets in minutes – a process that would have taken centuries with traditional computing.

QUANTUM TECHNOLOGIES

TOP RESEARCH ORGANIZATION MAPPING – SOUTHERN GERMANY

PatentPlus The Technology Transfer Platform — The following data is provided by PatentPlus, an analytics platform for technology transfer that provides insights and access to available technologies, inventors, and startups from research organizations worldwide.

University of Stuttgart · Universität Heidelberg Zukunft seit 1386 · Uni Freiburg · Universität Konstanz · KIT Karlsruher Institut für Technologie · universität ulm · Eberhard Karls Universität Tübingen

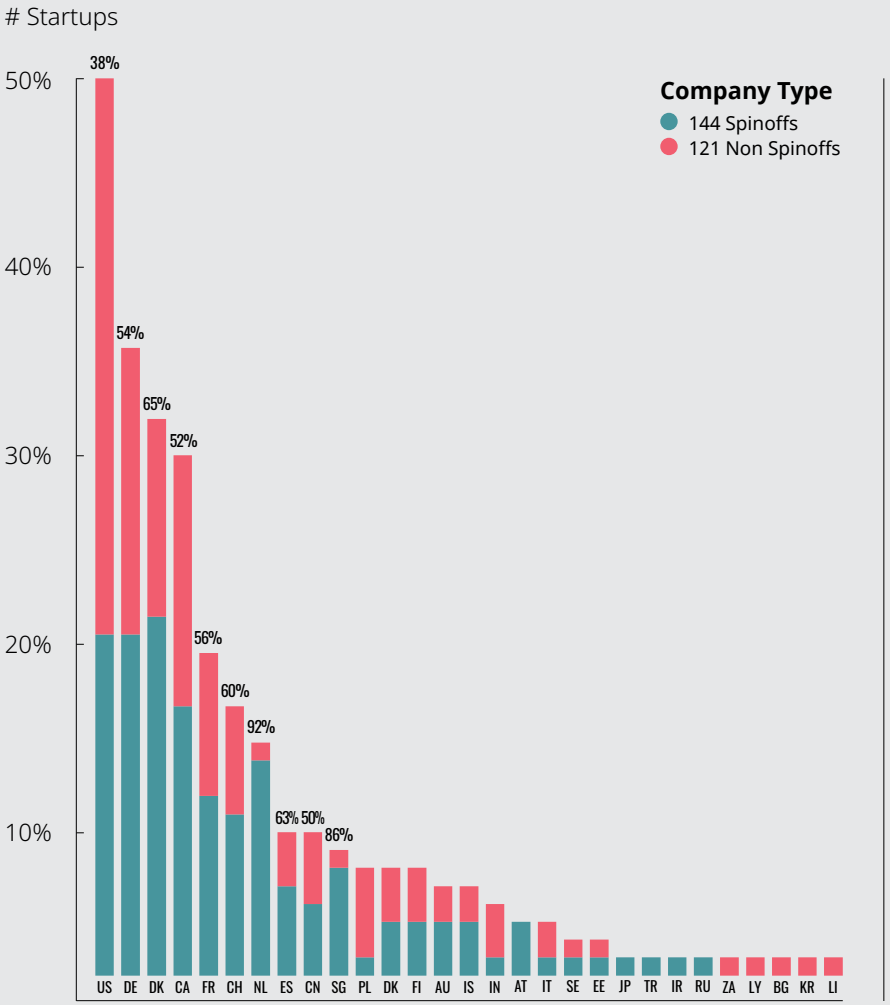
TUM · Julius-Maximilians-Universität Würzburg · LMU Ludwig-Maximilians-Universität München · Universität Bayreuth · Max Planck Gesellschaft · lrz Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften · DIT Deggendorf Institute of Technology · FAU Friedrich-Alexander Universität Erlangen-Nürnberg · Universität Passau · Fraunhofer · UNIBW der Bundeswehr München · WMI

Notes: Overview might not be exhaustive. For more information, please check the provided underlying data. # Research Organizations: 7 13

GLOBAL INSIGHTS

265 QUANTUM STARTUPS

PatentPlus The Technology Transfer Platform — The following data is provided by PatentPlus, an analytics platform for technology transfer that provides insights and access to available technologies, inventors, and startups from research organizations worldwide.



Top Spinoff Research Organization

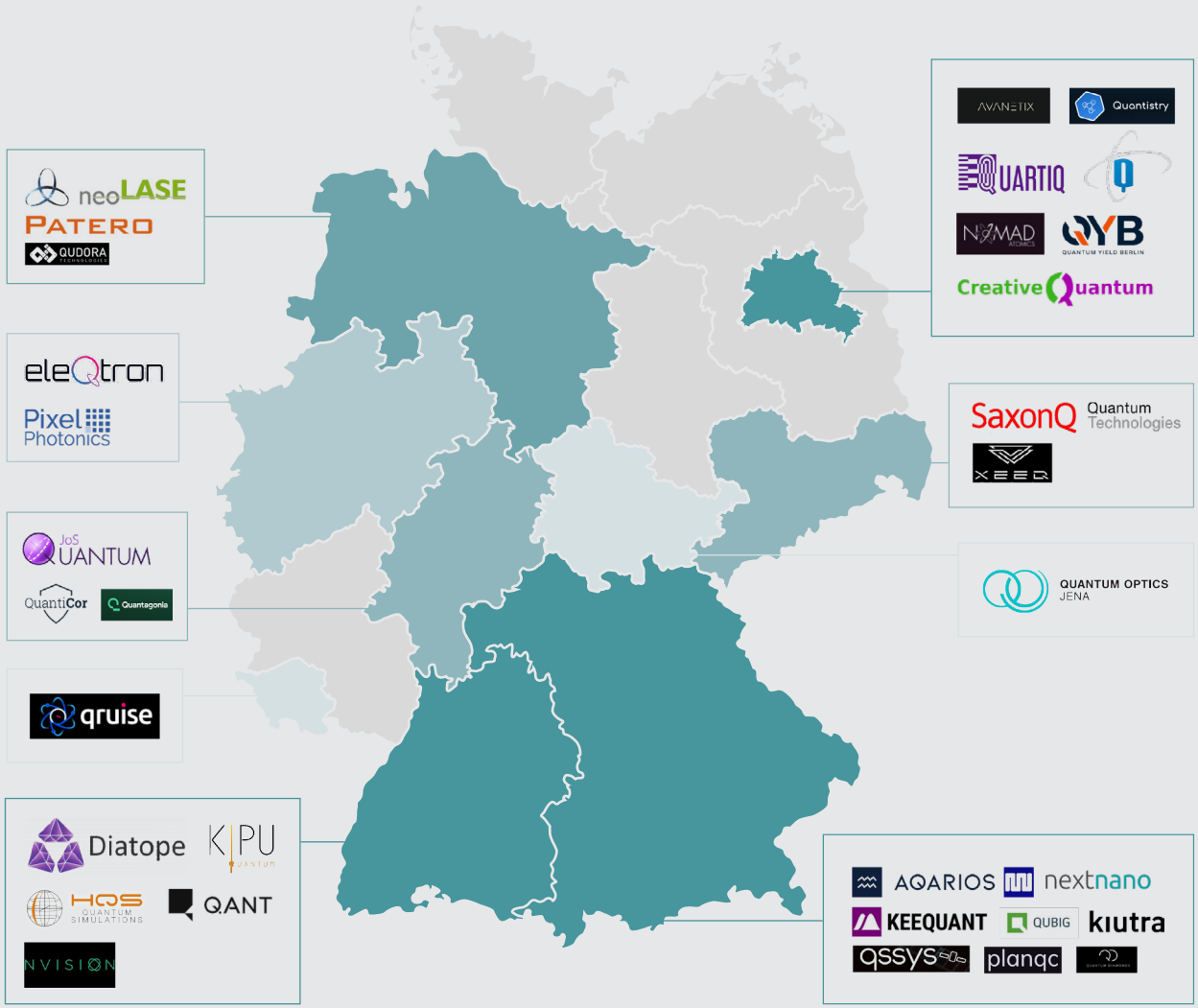
Rank[1]	Research Organization	#Spinoffs
1	TU Delft	9
2	University of Toronto	7
3	University of Oxford	6
4	NUS National University of Singapore	6
5	University of Bristol	5
6	ETH	5
7	University of Cambridge	4
8	Massachusetts Institute of Technology	4
9	University of Maryland	3
10	TUM	3

Notes: Overview might not be exhaustive. 1) Based on identified spin-offs within Quantum Technologies; % = spinoff to startup ratio; for more information, please access the PatentPlus platform

QUANTUM TECHNOLOGIES

TOP QUANTUM STARTUPS IN GERMANY

PatentPlus The Technology Transfer Platform — The following data is provided by PatentPlus, an analytics platform for technology transfer that provides insights and access to available technologies, inventors, and startups from research organizations worldwide.



Notes: Overview might not be exhaustive. For more information, please check the provided underlying data. # Startups: 0 1 2 3 4 5+

QUANTUM TECHNOLOGIES

TOP STARTUP MAPPING – SOUTHERN GERMANY

PatentPlus The Technology Transfer Platform

The following data is provided by PatentPlus, an analytics platform for technology transfer that provides insights and access to available technologies, inventors, and startups from research organizations worldwide.

Diatope

HQS QUANTUM SIMULATIONS

KIPU QUANTUM

QANT

NVISION

AQARIOS

kiutra

planqc

KEEQUANT

QUBIG

QUANTUM DIAMONDS

qssys

nextnano

Notes: Overview might not be exhaustive. For more information, please check the provided underlying data. # Startups: 5 - 60% Spinoffs 9 - 56% Spinoffs

QUANTUM TECHNOLOGIES

INITIATIVE MAPPING – SOUTHERN GERMANY

PatentPlus The Technology Transfer Platform — The following data is provided by PatentPlus, an analytics platform for technology transfer that provides insights and access to available technologies, inventors, and startups from research organizations worldwide.

Notes: Overview might not be exhaustive. For more information, please check the provided underlying data. # Initiatives: 7 13

QUANTUM TECHNOLOGIES

TOP CORPORATION MAPPING – SOUTHERN GERMANY

PatentPlus The Technology Transfer Platform

The following data is provided by PatentPlus, an analytics platform for technology transfer that provides insights and access to available technologies, inventors, and startups from research organizations worldwide.

Notes: Corporations with origin Germany; Based on top 40 in Germany. Overview might not be exhaustive. For more information, please check the provided underlying data. # Corporations: 4

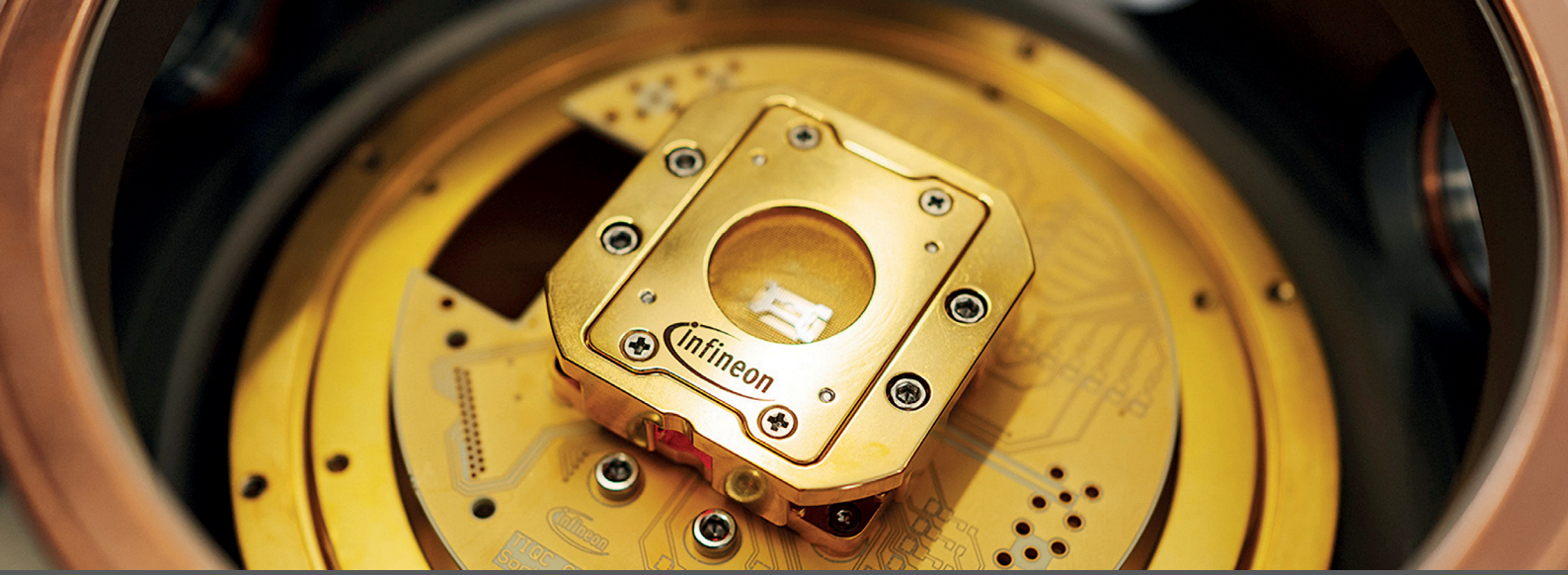


Photo: Infineon

QUANTUM IS A BET ON THE FUTURE WE MUST MAKE

Companies that invest in quantum technology can gain a significant advantage over their competitors in the future. But global challenges are straining supply chains, and investments must be made if Germany and Europe want to lead the quantum revolution on a global scale.

Germany is the largest economy in Europe, accounting for 24,7 per cent of the European Unions GDP. But the manufacturing powerhouse is challenged by climate change, the energy crisis, and geopolitical tensions impacting supply chains in all industries. To withstand this pressure, governments and companies must invest heavily in innovation in a bet to lead the quantum revolution to provide significant advantages for their companies in the future.

Because quantum technology is widely recognised as an important technology that can reshape industries in the future, it is also facing export controls. Thus, the industry will see an increased regionalisation of supply chains.

"It is crucial for both Germany and Europe as a region that we can develop and manufacture the critical components for quantum computers and are actively shaping this trend. We may depend on other regions to access this future technology without this ability. However, in the long run, this would harm our competitiveness and thus our industrial base.," says Sebastian Luber, senior director of technology and innovation at Infineon Technologies.

Sebastian Luber is coordinating quantum technologies activities at Infineon Technologies, the largest supplier of semiconductors in Europe and is actively engaged in developing and commercialising quantum technologies. The company's quantum technology research focuses on two areas: quantum computing and quantum sensing.

For more than five years, the company has been developing new hardware components that can be used in quantum computers, such as quantum processors, amplifiers and electronics for a use in cryogenic environments:

"These components are designed to be compatible with existing semiconductor manufacturing processes, which will help to accelerate the development of quantum computers and make them more performant and accessible," Luber says.

Infineon Technologies is also a pioneer in developing and implementing post-quantum cryptography (PQC). These cryptographic mechanisms can withstand the processing powers even of quantum computers. A smooth transition from currently used security protocols to post-quantum cryptography enables robust and future-proof security solutions.

Ecosystems are key

The initial ramp-up phase and 2 billion Euro investments from the German government has established strong foundations for the country to build its globally competitive quantum ecosystem of SMEs, corporations, investors, and leading researchers.

In addition to its research efforts, Infineon Technologies has also formed partnerships with other companies and academic institutions to advance the development of quantum technologies. For example, Infineon Technologies is a partner and founding member in the application consortium QUTAC, that brings together academic and industrial partners to advance research and development in the field of quantum technologies.

Sebastian Luber
Senior director of technology and innovation at Infineon Technologies

"Building an ecosystem is rather a marathon than a sprint, and when investing in a field that still lacks structures and maturity, you must allow for failures. But the investments have created a new momentum in the industry. With QUTAC, we want to foster collaboration between partners from various disciplines and drive the transfer of knowledge and technologies between academia and industry to avoid too many setbacks – or at least make sure that we learn from the ones we make fast and that we continue to strive for more knowledge that can be translated into commercially successful products," Luber added.

The potential for significant advancements, growing global competition, strong quantum research, access to funding, and potential for new products and services all make quantum technology an attractive investment opportunity for Germany's companies, according to Luber.

"It is very important for companies to have a certain number of innovative projects that promise enormous growth potential. For me, quantum computing is one of them. It comes with development risks and could fail to meet its promises. But if it succeeds, it has huge potential. It's a bet on the future we must make for the company and the region's competitiveness.

Missing the revenue

While quantum computing promises significant potential benefits, several major challenges must be overcome to realise its potential fully. The development and, to some

Photo: Infineon


Photo: Infineon

extent, operation of quantum computers is very resource intensive. The associated costs are substantial, which can hinder the required technology advancements.

"I don't think quantum computing will generate significant revenue in the next three to five years. Thus, it can be challenging to justify investments in the technology within a company. But if you're willing to take risks and think long-term, then a significant return can await you," Luber says.

With the technology being in the early stages of development, the technical complexity of building and maintaining quantum devices is a major challenge. In addition, quantum systems are extremely sensitive to external interference and require specialised treatment and infrastructure. This also results in another challenge, limitations of scaling.

"Developers that might successfully build a quantum computer face the same challenge. They have too few qubits with too little performance to make anything useful out of it. They need more and better qubits. We need industrial approaches to improve the performance of devices and integrated circuits to achieve just that," Luber concludes.

About QUTAC

QUTAC members include leading companies in important application sectors from across Germany, with a wide range of expertise in physics, computer science, and engineering fields. Through its collaborative research and development, QUTAC aims to bring quantum computing to the level of practical application and contribute to developing a thriving quantum technology industry in Germany and beyond.

See more: **www.qutac.de**

DEUTSCHE BAHN TO GAIN COMPETITIVE EDGE WITH QUANTUM COMPUTING

Deutsche Bahn is investing in quantum computing to revolutionise how it operates and help optimise routes, reduce costs, and improve efficiency.

Deutsche Bahn's investment in quantum computing technology is driven by a desire to gain a competitive advantage in the highly competitive and rapidly changing transportation industry. With the potential to revolutionise the way logistics are optimised, quantum computing could help Deutsche Bahn streamline its operations, improve its customer experience, and ultimately increase profitability.

According to Manfred Rieck, who is responsible for managing quantum technology at Deutsche Bahn, the technology can significantly improve the accuracy and speed of calculations, enabling the company to make better decisions, faster. Logistics optimisation is one area where quantum computing could make a significant impact, allowing the company to find more efficient routes, optimise train schedules, and reduce energy consumption.

"Quantum computing could enable Deutsche Bahn to get one step closer to the optimal route calculation for our assets, the rails, the trains, our people and last but not least the energy consumption," says Rieck, Head of Quantum Tech at DB Systel, the IT and technology subsidiary of Deutsche Bahn.

But it's not just about gaining a competitive edge. Investing in quantum computing technology is also about keeping up with the latest technological advances and staying ahead of the curve. With the transportation industry undergoing rapid changes due to the rise of digital technologies, including artificial intelligence, machine learning, and the internet of things, companies like Deutsche Bahn must stay on the cutting edge of innovation.

"Quantum computing could be seen as a mathematical co-processor for the IoT, AI, Data, and HPC stack, which will be the technical landscape for digital twin for rail," says Rieck and continues:

"We want to be leaders in the transportation industry, demonstrating our commitment to innovation and willingness to explore new technologies. We now lay the groundwork for future success by investing in today's technology."

Will change Deutsche Bahn

Deutsche Bahn's investment in quantum computing is part of its larger strategy to become a digital driven company. By leveraging the latest technologies, the company hopes to improve its services and quantum computing could play a significant role in this strategy.

"On the digital level the technology will change the industry completely and make a significant difference on many

parameters. By using quantum computing to calculate the best routes there is also a great potential to help optimise its maintenance schedules, allowing it to perform repairs and upgrades more efficiently," says Rieck.

Quantum technology will have a broad impact

While Deutsche Bahn is one example of a company investing in quantum computing, many other industries could benefit from the technology.

It can be used to calculate new materials, which could lead to developing new and innovative products that will impact the manufacturing industry. Finally, the energy industry and telecommunications industry could benefit from quantum computing.

Manfred Rieck
Quantum technology manager, Deutsche Bahn

"The technology can optimise physical networks, making them more efficient and reliable. It can also be used to develop new materials for energy storage, helping to improve the efficiency of batteries," Rieck says.

And quantum is not only for large incumbents. Rieck acknowledges that SMEs do not have the same resources and skills as larger companies, such as Deutsche Bahn, to invest in quantum technology.

"SMEs need to focus on understanding how quantum technology can be used in their business operations, and how it can improve their processes. SMEs need to educate their employees on the potential of quantum technology from a business perspective, rather than deep technical skills – you could argue that this is the same approach SMEs engaged with AI technology in the past," says Rieck.

Government investment in quantum technology is crucial to ensure that Europe does not fall behind in the race for quantum advantage. Germany and France have already invested significant money into building quantum computers and software.

However, Rieck believes that Europe needs to bring solutions to a concrete platform to enable developers to work on quantum technology and create European versions of Amazon's Braket and IBM Q Experience; as an example, the PlanQK platform could be mentioned.

QUANTUM COLLABORATION BOOSTS TECH ADVANCEMENTS

Bayern Innovativ works to empower industries and production companies in the Bavaria region by connecting technology experts and academia with industrial champions to accelerate innovation within quantum technologies.

In 1996, Bayern Innovativ was established by the Bavarian ministry of economic affairs to bring innovations faster to the market. The organisation brings research institutions and small and medium-sized enterprises, and larger companies in the Bavaria region closer together, generating economic turnover with innovations.

"Traditionally, Bavaria is the home to many powerful global industry champions within automotive, aerospace, textile and production, life sciences and engineering. The goal is to empower companies in these industries to apply cutting-edge technologies and foster true innovation in close collaboration from research institutions to remain global leaders," explains Dr Andreas Boehm, head of quantum technologies at Bayern Innovativ.

According to Dr Boehm, quantum technology has the potential to transform the economy by enabling new applications and industries that were previously impossible or impractical. Thanks to its strong research institutions, innovative companies, and supportive government policies, Bavaria is well-positioned to take advantage of this emerging technology.

"Bavarian companies are known for being early adopters and innovators regarding new technologies. This makes Bavaria an attractive location for companies that want to develop and commercialise new technologies and helps to explain why the region has been so successful in driving innovation and economic growth," says Dr Boehm.

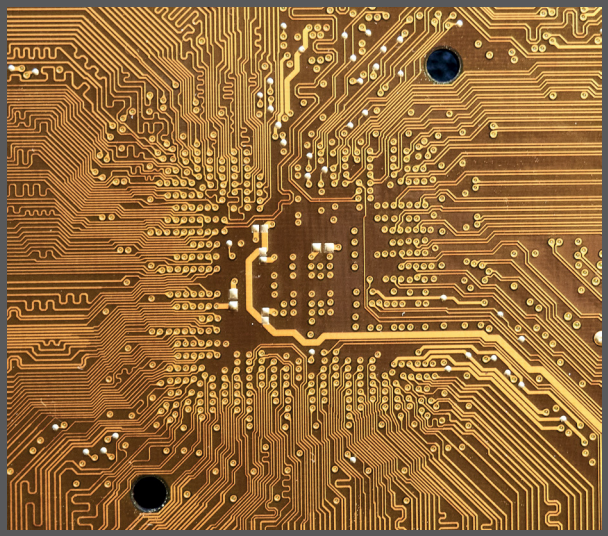


Photo: Unsplash

Which door to knock on?

Today, Bayern Innovativ have more than 30,000 companies in its network. And bringing quantum technologies to the market requires researchers to connect with companies, but often, they don't know which door to knock on. This is where Bayern Innovativ comes in, as it serves as a bridge between researchers and companies.

Dr Andreas Boehm
Head of quantum technologies at Bayern Innovativ

"In Bavaria, there are many large companies in the automotive industry with thousands of workers, but they are often not visible in the media and difficult to spot for researchers. Through our network, we identify these companies to make them aware of the potential of quantum technologies. And the automotive industry here is representative of other sectors," explains Dr Boehm.

To address one aspect of quantum technologies (which covers the attributes of computing, sensing, communication and software), industrial companies as users of quantum computing can already address industry-specific problems today.

All these companies take a practical approach, focusing on solving companies' problems rather than discussing technical concepts like qubits and low temperature. Bayern Innovativ serves as a translator, explaining how quantum technologies can be used to solve industry-specific problems.

"Focusing on solving companies' problems, rather than technical jargon, we help companies understand the potential quantum advantage. We clarify what kind of problems can be solved with a handful of qubits and what percentage of a problem can be solved in five years as hardware improves," explains Dr Boehm.

The team at Bayern Innovativ is pushing the topic through B2B-meetings, to find out the exact needs on the company side as well as the know-how on the research side. International inquiries are mostly made via the local trade attaches or inquiries made via Munich Quantum Valley – the quantum research organisation.

"By positioning us as a leader in the field of quantum technology and promoting services through events and media channels, we can attract international clients and establish partnerships with businesses looking to integrate this emerging technology into their operations."

Different branches, different use cases

According to Dr Andreas Boehm, there are three main areas in which quantum computing can be applied to companies' current agenda: optimisation, artificial intelligence/machine learning, and simulation.

Optimisation can be applied to any industry, such as optimising logistics for ports or airports. In addition, quantum computing can help reduce the time and cost of processes.

Machine learning is another area where quantum computing can be highly effective. Complex algorithms for artificial intelligence can take weeks and cost a lot of money to find the proper parameters when using cloud computing. However, with quantum machine learning, companies can start with highly optimised parameters and significantly reduce the time and cost of the process.

Simulation is also an important area where quantum technologies can be applied. For example, car manufacturers can use quantum simulation to test and optimise materials for batteries, anodes, cathodes, and other components. This can lead to the developing of more efficient and cost-effective materials for electric vehicles.

"By leveraging the power of quantum computing, companies can significantly reduce the time and cost of these processes, leading to greater efficiency, cost savings, and innovation," Dr Boehm concludes.

ACCELERATING QUANTUM TECHNOLOGIES THROUGH STARTUP INNOVATION

Munich Quantum Valley (MQV) is a regional initiative to facilitate the commercialisation of quantum research and foster a thriving startup ecosystem in Southern Germany for a new generation of quantum startups.

Despite the enormous potential, quantum technologies are still in their infancy, and their development requires significant research, infrastructure, and talent investments. That is why the German and Bavarian governments, companies, and universities have been investing in quantum research and development. Through MQV, Southern Germany has emerged as a hotbed of quantum innovation.

"You need facilities and people that allow building quantum computers, sensors and simulators to foster an ecosystem. But one key item is the definition of clear-cut goals. Concrete specifications and demands from various stakeholders need to be fleshed out to allow for an ecosystem – including science sites, startups, established companies, investors, incubators and high-tech companies – to be formed around them," says the head of media relations & public engagement at MQV Dr Sascha Mehlhase.

With the foundation of MQV, these goals were set – at least in quantum computing – and MQV aims to be the seed, if not the driving entity, of a local quantum ecosystem beyond the state of Bavaria.

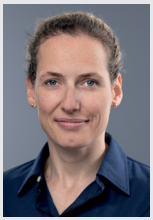
"A very close collaboration with the industry is required. In the end, the quantum computer/system that best serves the needs of the industry will be successful. Therefore, collaboration must be set up right in forming an ecosystem," says the general manager of external affairs at MQV, Julia Rucha.

Startups are facing obstacles

The MQV was officially launched in 2021, and since then, the organisation has made significant progress in fostering startup innovation and commercialising academic research.

"For decades, Germany has been very strong in basic research in quantum science and quantum technologies. But a quantum ecosystem is still in the making. It's being established and has undergone massive development over the last five years," says Rucha.

The development of the ecosystem took up pace after a flagship initiative of the EU and more so when the German government assigned 2B



Julia Rucha
General manager of external affairs at MQV

Dr Sascha Mehlhase
Head of media relations & public engagement at MQV

Euros for quantum computing in Germany for five years in 2021. It was further accelerated when some German Bundesländer (federal states) provided additional funding creating local centres such as the MQV in Bavaria.

"While the research is considered to be of a very high standard, an actual quantum ecosystem still has to grow more. The number of startups is small, and key industrial players are missing or rather concentrating on possible applications, except in enabling technologies. In the latter area, there have been for a while and still are some outstanding players like Infineon Technologies, Toptica Photonics and Menlo Systems. Also, initiatives like QUTAC and companies active in European initiatives foster the ecosystem and contribute to a dynamic environment in Germany," says Mehlhase.

According to Mehlhase, many spinouts have difficulties negotiating the rights for intellectual property (IP) when separating from universities or research institutes. In addition, there is a general lack of startup support from governmental sources. Also, there are disadvantageous conditions posed by funding agencies that limit the investment capital available, and German investors are not as risk-willing on long-term investments as in the US or UK.

"With the entrepreneurship activities within and around MQV, we try to support startups as best as we can to take the initial steps and settle or relocate to Munich and Bavaria as a whole," says Rucha.

Instant impact

The influence of the MQV on the quantum ecosystem in Southern Germany has been significant. For example, in a short time, the quantum computing startup 'plancq' experienced the impact of MQV in creating new opportunities for collaboration between academia, industry, and investors.

"With the strong financial support for MQV, the government sends an important signal to stakeholders. It tells people that we are serious and not playing around. So I can say that we would not be incorporated without the Munich Quantum Valley," says Sebastian Blatt, CTO and co-founder of planqc.

The company spun out of the Max Planck Institute of Quantum Optics in April last year and secured a funding round shortly after. planqc is the first spinout after the inauguration of the MQV, and the effects have been clear to the founding team.

"We've been able to start big projects on the academic side, and we receive a lot of inquiries on potential collaboration from interested parties from international institutions and companies – also from Denmark. We also see that many companies are trying to move into Munich now because they see the impact from the MQV and governments investments," says Blatt.

According to Blatt, MQV has created a real ecosystem around job creation and talent attraction for quantum companies:

"Now, there is a critical mass of quantum physicists, scientists and young people looking for quantum jobs and having proper education in Munich. We have yet to have any job advertisements, but our jobs email is full. People associate us with the MQV, and they want to be part of planqc."

Clear and honest communication

It is still the early days for MQV, and at this time, no quantum computer can outperform a classical computer. Therefore, explains Mehlhase, it is difficult to predict a clear quantum advantage.

"The current efforts focus on providing advanced hardware as more qubits, more gate operations, implementation of quantum error correction and scalability. Also, the software required to achieve a quantum advantage is still very limited. Thus, quantum algorithms need to be further developed and tested," he says.

Quantum computers will most likely make an early impact when used as quantum simulators in scientific problems. One thing is clear, though a level of expectation management is needed:

"We need a lot more basic research and technology development before we can answer that question of where and what to expect. The potential of quantum computers is vast; however, it can only be unleashed when we master the hardware and the quantum control at large scales - meaning three to four orders of magnitude more than currently available.

Unfortunately, nowadays, expectations are often too high due to misleading communication and false promises," he says.

Besides addressing the scientific challenges and evaluating the potential use cases and pitfalls, MQV also works on clear and honest communication and education about quantum technology and its potential applications and benefits for society.

Photo: BAdW, Kai Neunert

A SPINOUT FROM MAX PLANCK CREATING HOPES FOR GERMAN QUANTUM BET

The Munich-based quantum startup planqc develop a highly scalable room-temperature quantum computer. The company is the first spinout from Munich Quantum Valley and experiences great interest in their journey from academia to commercialisation.

The quantum startup planqc was founded in 2022 and is built on decades of groundbreaking research and technology development from Munich's Max Planck Institute of Quantum Optics (MPQ) and is the first of many startups to be spun out of the Munich Quantum Valley. The technology is based on atoms trapped in optical lattices and based on research at the MPQ and Ludwig-Maximilians-University Munich.

planqc uses ultracold-atom technology where individual atoms are isolated and trapped using laser beams to serve as qubits for quantum computing.

"Our quantum computers are built on the precision of the world's best atomic clocks, which are a candidate for replacing the current standard of frequency and time," explains Sebastian Blatt, CTO and co-founder at plancq.

With the three co-founders Alexander Glätzle, Johannes Zeiher, and Lukas Reichsöllner, Sebastian Blatt officially spun out the company from MPQ and raised 4.6 million Euro in a first funding round.

"planqc's status as the first spinout to emerge from the Munich Quantum Valley and coming from Max Planck is significant for several reasons. First, it demonstrates MPQ's commitment to supporting innovation and entrepreneurship in quantum technology. Second, it shows that the spinout process can successfully transfer knowledge and expertise from research institutions to the private sector," says Alexander Glätzle, CEO at planqc.

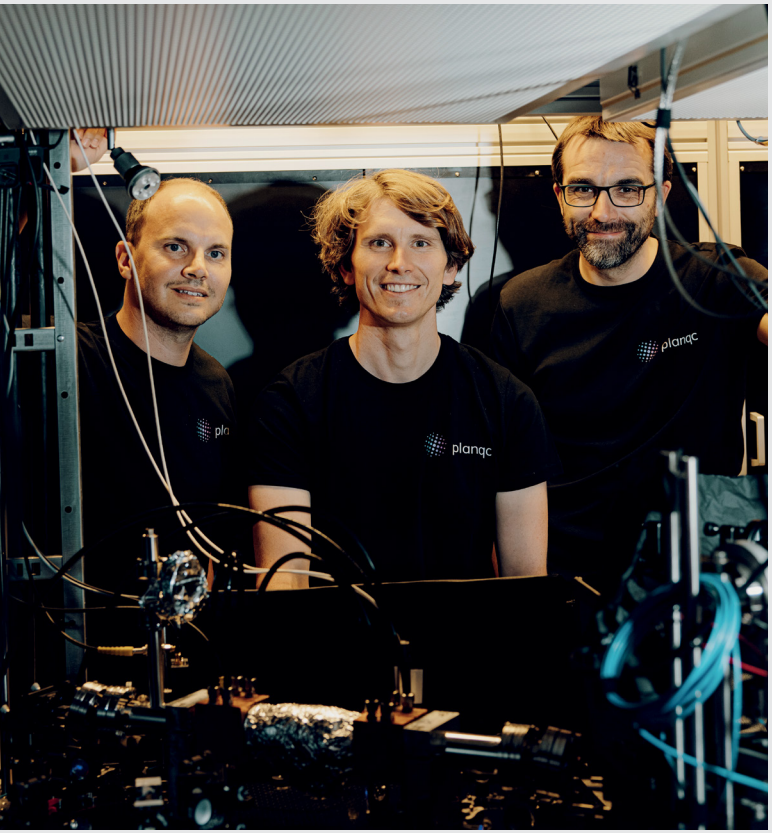
Alexander Glätzle
CEO at planqc

Sebastian Blatt
CTO and co-founder at plancq

The key to successful quantum startups

planqc has secured an exclusive license agreement with MPQ that owns the intellectual property (IP) rights. This allows the company to continue developing and commercialising the technology while the university retains IP ownership.

"The IP cannot belong to planqc if the technology is invented at MPQ. At the same time, it is impossible for a startup to invent new technologies for quantum computers if you don't have access to the right lab facilities. Our exclusive license agreement



(From left to right): Alexander Glätzle (planqc co-founder & CEO), Johannes Zeiher (planqc co-founder, Principal Scientist), Sebastian Blatt (planqc co-founder & CTO)

Photo: Dirk Bruniecki

with MPQ is very important to the investors and played an instrumental role in securing the funding round," says Glätzle.

The founders experience a lot of interest for their approach and process of spinning out a startup. It demonstrates the potential for cutting-edge research to be translated into commercially viable products. This is important in the context of the emerging quantum industry, where companies compete to develop practical applications and establish themselves as leaders in the field. But that's something that requires support from all sides.

"There is no way a startup can start from scratch and just be expected to do the same things as a research institution such as Max-Planck with the amount of money a typical startup can have. So it requires support from the research institutions. It requires political support, and it requires support and understanding from the investor side because it's not standard," Sebastian Blatt says and continues:

"It would foster more startups and innovation if the government or an institution would develop templates for boilerplate IP contracts and a clear understanding of how to transfer IP from an institute to a startup. This would make life so much easier because even if an institute like MPQ is fully motivated to make this happen, they still lack the experience and the precedence cases. We need to make it easier to transfer the knowledge to industry."

Facts

Spinouts are companies spun out of a university or research institute based on technology or intellectual property developed there. Spinouts are often created by academics who want to take their research out of the lab and into the market or entrepreneurs who see a commercial opportunity in the technology. Spinouts can be an important source of innovation and economic growth, as they create new jobs, products, and services that benefit society.

STARTUP WANTS TO PROVIDE INDUSTRIAL QUANTUM ADVANTAGE SOONER THAN COMPETITORS

With a special proprietary compression technology, KIPU Quantum (KIPU) aims to democratise quantum technology and deliver solutions to end users many years earlier than the classical standard quantum computing solutions.

KIPU is a young startup company founded in 2021 that specialises in algorithm development for quantum computers. The company recently raised 3 million euros to accelerate the future growth of their novel algorithmic compression methods along with efforts to co-design hardware that will reduce the number of qubits needed for commercially useful solutions.

Daniel Volz
CEO and co-founder of KIPU

"Our approach allows to solve industry-relevant problems while slashing required physical qubit numbers down by several orders of magnitude using proprietary compression technology. Furthermore, our tech is compatible with all leading quantum hardware technologies and platforms, enabling us to deliver solutions to end-users many years earlier than classical standard quantum computing solutions," explains Daniel Volz, CEO and co-founder of KIPU.

An agnostic approach

The startup aims to solve complex problems across a range of use cases, including financial portfolio optimisation, protein folding, molecular modelling, combinatorial optimisation, and factorisation using relatively few qubits, or quantum bits.

KIPU's technology works with multiple types of quantum hardware and can be used by clients regardless of the specific hardware they are using, providing more flexibility and choice in the quantum computing landscape. For example, imagine a car designed from the ground up to work perfectly with a specific fuel type. That's what KIPU does with quantum computing:

"Our software will be created harmoniously with the hardware it runs on. This approach helps our clients get value from quantum computing much faster than other companies, who are still struggling to make their software work well with different types of hardware," explains Volz.

A strong market

Volz has a material science and organic chemistry background, having completed his PhD at Karlsruhe Institute of Technology. He co-founded KIPU with Enrique Solano, a physicist with two decades of academic career. Solano's research forms the underlying secret sauce of KIPU's algorithmic compression technology.

The company aims to fix the resource constraints pre-

Photo: Anders Heddergott

venting early adopters of quantum computing, such as BASF, where Volz worked before founding KIPU, from realising its full potential.

"The German market has many users in quantum computing, particularly among large corporates investing heavily. Compared to the US, German companies are spending more on quantum computing, but the country underperforms when it comes to venture capital investment in quantum technology," Volz says.

According to him, the German academic ecosystem must focus on instilling a risk-taking mentality among postdocs and PhD students.

"We are slowly seeing an ecosystem on the rise with more focus on commercialising research but need to see those successful cases to inspire the talented engineers, physicists and chemists in Germany that want to make a real difference."

TUM VENTURE LAB QUANTUM: FOSTERING ENTREPRENEURSHIP IN THE QUANTUM INDUSTRY

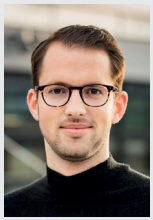
TUM Venture Lab Quantum is a vital initiative that fosters entrepreneurship in the quantum industry.

The initiative's focus on research spinouts is particularly important, given the high potential of quantum technology to create new products and services. In addition, with its educational programs, infrastructure support, and connection to investors and customers, TUM Venture Lab Quantum is a valuable resource for anyone interested in building a quantum startup.

TUM Venture Lab Quantum is a joined initiative of the Technical University of Munich (TUM) and UnternehmerTUM, Europe's largest centre for business creation. It is managed by Christopher Trummer, who has a background in both physics and business. TUM is a world-renowned research institution with a long history of entrepreneurship and innovation. The team work closely with the university's chairs and institutes and the Munich Quantum Valley, a large research initiative in the quantum field.

"We provide educational workshops and programs to help researchers understand the potential of entrepreneurship and to develop the skills they need to create successful startups," explains Trummer and continues:

"One of the most significant challenges for quantum startups is the high infrastructure cost, including clean rooms and expensive machinery. TUM Venture Lab Quantum aims to enable startups to access this infrastructure by providing office space and prototyping labs and connecting them with pilot customers and investors."



Christopher Trummer
TUM Venture Lab Quantum

TUM Venture Lab Quantum's team includes two professors who help integrate the initiative into the university and the Munich Quantum Valley. Additionally, two venture directors provide expertise in startup business development and quantum technology.

"TUM Venture Lab Quantum is open to anyone who wants to build a startup in the quantum field, and the initiative works with other venture labs in AI, robotics, chemistry, and other fields to provide support to those who do not fit exactly within their specialisation," says Trummer.

The hype is real

Trummer is looking at the ecosystem in Southern Germany with great optimism. The region is home to two great universities and leading institutes. He also mentions the Munich Quantum Valley and Munich Center for Quantum Science and Technology cluster, which have successfully brought together researchers and experts in the field.

Trummer also highlights the importance of the investor landscape in Munich, especially for early-stage deep tech teams:

"Local investors are willing to look at quantum tech teams doing hardware and building quantum computers or sensors, a crucial element for the ecosystem. Thanks to the work of several organisations that aim to commercialise academic research, there is now a critical mass of startups and relevant cases for institutional investors. Now we just need to see them become global players," says Trummer.

Moreover, Trummer emphasises the advantage of having many large companies around Munich, which helps startups in the quantum ecosystem address specific market needs. For example, many B2B businesses require specific products, and having a handful of companies from a particular field to pilot the products is helpful.

"We are experiencing a great interest around quantum from many different stakeholders, and more people, especially physicists, are thinking about starting something or spinning off. The sum of all this is to highlight the importance of collaboration and keeping an open-door policy in driving the ecosystem," concludes Trummer.

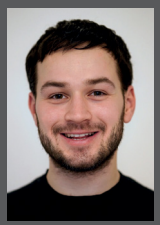
IN-HOUSE STEM COMPETENCIES MAKE BETTER INVESTMENT DECISIONS FOR DEEP TECH STARTUPS

Better materials are shaping future societies; we call it Stone Age or Iron Age. Dr. Benjamin Wolba, an investor at Lunar Ventures, believes that quantum technologies are poised to build a better society by improving material properties, e.g. for higher energy density batteries and more efficient solar cell materials, and solving hard optimisation problems more efficiently.

"The technology could accelerate the transition towards solving more Sustainable Development Goals (SDGs) faster and more efficiently. Additionally, quantum computing could help to find better medications for diseases like Alzheimer's or cancer, and solve hard optimisation problems in logistics and supply chains, unlocking billions in market value that would otherwise be wasted," says Wolba.

Lunar Ventures made their first quantum investment in March this year in the Finnish hardware company, SemiQon. And Wolba, a theoretical physicist by training, sees quantum as a scalable, long-term solution that can significantly impact solving global problems. However, quantum can be tricky to invest in due to the focus on hardware development as the fundamental layer, which requires significant investment and resources.

Overall, the difficulty in investing in quantum lies in the significant investment required for hardware development and the necessity of the hardware for the software layer to become relevant. That's why most venture capital has addressed quantum computing hardware. "Hardware is a required first step, but as hardware gets closer to reality, many more layers can be built, such as quantum developer tools and education programs," says Wolba.



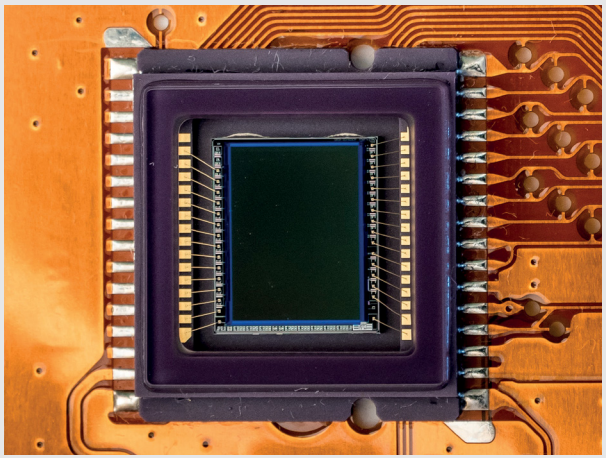
Dr. Benjamin Wolba
Investor at
Lunar Ventures

According to Dr. Wolba, Lunar Ventures stands out to other investors as they have the STEM competencies in-house to lead investments in quantum and deep tech themselves. In addition, they have gathered a team with diverse backgrounds and computer science, physics, and chemistry expertise. This allows them to understand better the technologies they are investing in, unlocking investments in different startups than other investors.

"In-house STEM competencies help us identify potential red flags or areas of concern, such as an innovation's technological feasibility or differentiation. By leveraging in-house STEM competencies, we can conduct a more comprehensive and informed due diligence process, which ultimately helps us make better investment decisions," explains Wolba.

„ENGINEERS AT HEART, INVESTORS BY CHOICE“

First Momentum was founded in 2017 by two students at Karlsruhe Institute of Technology, making it the first student-run venture fund in the DACH region. They have raised two funds for 35 million euros and made 27 investments, including Kipu Quantum.



First Momentum Ventures aims to connect university ecosystems, engineering-driven ecosystems, and the industrial base in the DACH area. They focus on pre-seed investments and support founders working on challenging industrial applications that often require significant capital.

“Our focus on B2B is a good fit for what is happening in the DACH region or for companies based in that area. They are driven by a technical perspective, including IP university spinouts, sector experience, and building technical products. In addition, we target startups where we can support their founders, who are often engineering-driven and may not have a business or consulting background,” explains Andreas Fischer, managing director and co-founder of First Momentum Ventures.

Andreas Fischer
Managing director and co-founder of First Momentum Ventures

Fischer describes the philosophy behind First Momentum as’ engineers at heart, investors by choice,’ meaning that the team primarily focuses on the technology and engineering aspects of the companies they invest in. However, they deeply understand and appreciate the technology and its potential to solve interesting problems in the physical world.

“At the same time, we recognise that they need commercial support and a network to bring these technologies to market and make a real impact. So, we are passionate about seeing companies grow and help the technology spread to make a bigger impact into the world,” says Fischer.

In addition to the financial due diligence, First Momentum has a wide network of experts in the fields that help evaluate the technology and its potential applications and ensure that the team has the necessary skills and experience to execute their plans.

HORIZON EUROPE: TRANSLATING RESEARCH INTO COMMERCIALISATION

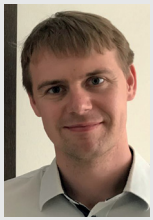
Significant research and development efforts are needed to realise quantum technologies' potential fully. This is where Horizon Europe, the EU's extensive research and innovation program, can play a crucial role.

Quantum technologies are emerging as a new frontier of innovation, potentially revolutionising how we live, work, and communicate. As a result, these technologies are expected to impact a wide range of industries and value chains significantly.

Denmark and Southern Germany are at the forefront of the quantum technology race, and they're not slowing down. With powerful research institutions and flourishing innovation ecosystems, they're ideal partners for collaboration in this field. By teaming up through EU-funded projects under Horizon Europe, they can combine their strengths and know-how to supercharge the development of quantum technologies. Together, they can create a quantum ecosystem that can take on the world's top players.

According to Ulrik Kjølsen Olsen, Research & Innovation Attaché at the Innovation Centre Denmark in Munich, Horizon Europe is the perfect chance for Danish-German and global researchers and companies to collaborate.

"The first rounds of the program prove that they're seizing this opportunity. Many of the selected projects in quantum technology have already brought together players from Denmark and Southern Germany. It's an exciting time for innovation, and both regions play an important role in making Europe a global quantum powerhouse."



Ulrik Kjølsen Olsen
Science & innovation attaché at the Innovation Center Denmark in Munich

Denmark has been at the forefront of the quantum revolution, strongly focusing on quantum communication and cryptography. On the other hand, Southern Germany, in addition to strong quantum research, has a long history of innovation in fields such as engineering and production, which can be leveraged to develop new quantum technologies.

Add to that the vibrant high-tech industry, with companies such as Siemens, Bosch, BMW Group, and Infineon Technologies leading the way in developing quantum hardware and software. By working with European partners, they can leverage their strengths and create a comprehensive quantum ecosystem covering the entire value chain, from fundamental research to commercialisation.

By participating in Horizon Europe projects, researchers and innovators from Denmark and Southern Germany can access funding, expertise, and networks that can help them advance their work and accelerate the development of quantum technologies. In 2022, organisations, institutions and companies from Denmark and Southern Germany (Bavaria and Baden-Württemberg) partnered up in several Horizon Europe projects, some of which are listed here:

QIA (Quantum Internet Alliance)
The Quantum Internet project represents a significant effort to advance the field of quantum communication and pave the way for developing a new era of secure and reliable communication networks.

Danish partners: University of Copenhagen

Southern German partners: Max Planck Institute of Quantum Optics; SWABIAN INSTRUMENTS GMBH, Toptica, Uni Stuttgart

CLUSTEC (Scalable Continuous Variable Cluster State Quantum Technologies)
The project aims to advance the development of continuous variable cluster state quantum technologies, a particular class of quantum states that can be used to implement quantum computation and quantum communication protocols. The project focuses on developing methods for generating, manipulating, and detecting these states and exploring their potential applications in various domains.

Danish partners: Technical University of Denmark, University of Southern Denmark

Southern German partners: Ruprecht Karl University of Heidelberg, Q.ANT GMBH

CARIOQA-PMP (Cold Atom Rubidium Interferometer in Orbit for Quantum Accelerometry – Pathfinder Mission Preparation)
The project aims to develop, within a European industrial framework, the engineering model of the accelerometer, which will equip the CARIOQA demonstration space mission. This significant contribution aims to place Europe at the forefront of developing quantum technologies for space.

Danish partners: DTU

Southern German partners: Technical University of Munich, Airbus Defence & Space GmbH

By collaborating through Horizon Europe, the partners can harness the potential for knowledge transfer and cross-fertilisation of ideas. Researchers and innovators from Denmark, Southern Germany, and the rest of Europe bring different perspectives and approaches to developing quantum technologies. By working together, they can learn from each other and identify new research directions and opportunities. This can lead to breakthrough discoveries and innovations that may not have been possible otherwise.

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