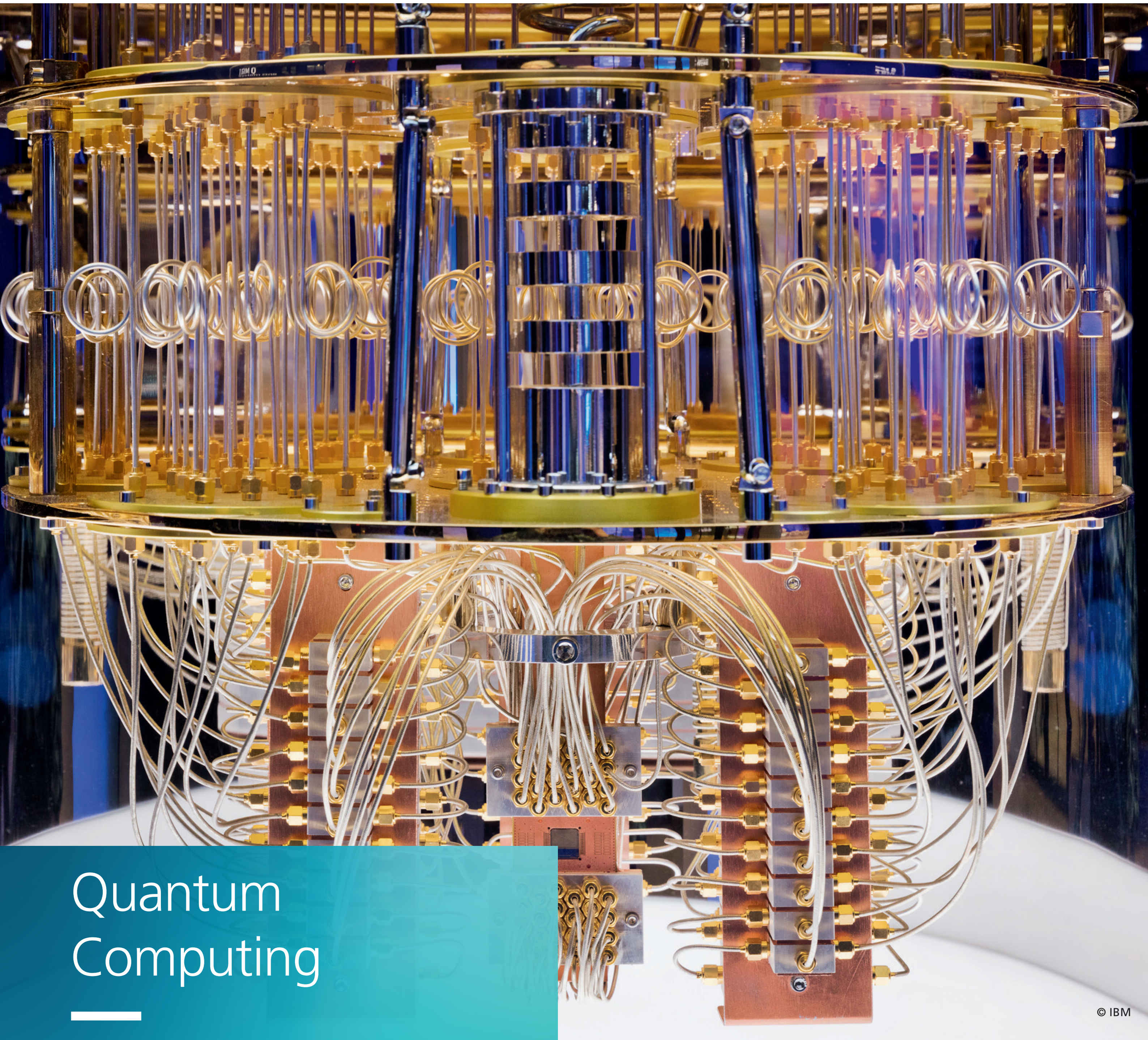

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Quantum Computing

The Fraunhofer Competence Network Quantum Computing is the first point of contact for anyone who wants to conduct research on and with quantum computing. Regional competence centers in seven German states, each with its own research focus and in turn made up of Fraunhofer institutes, have joined forces in this network. The common goal is to research and develop new technological solutions in the field of quantum computing.

Rhineland-Palatinate Promotes Competence Center for Quantum Computing

The Competence Center Quantum Computing at the Fraunhofer ITWM has already been 2020 from the baptism. It is one of meanwhile eight centers which together form the Fraunhofer Competence Network Quantum Computing. Its expansion is supported by the state of Rhineland-Palatinate with further funding. Clemens Hoch presented the director of the institute, Prof. Dr. Anita Schöbel, with a notice of funding in the amount of 1.2 million euros.

Prof. Dr. Anita Schöbel, Director of the Fraunhofer ITWM, and Minister of Science Clemens Hoch. In the background, the quantum computer System One from IBM, which is being operated by Fraunhofer near Stuttgart.

Prof. Dr. Anita Schöbel is working with Prof. Dr. Manfred Hauswirth (Director at the Fraunhofer Institute for Open Communication Systems FOKUS) responsible for the topic "Quantum Computing" within the Fraunhofer-Gesellschaft. Central research questions are, for example: Which application scenarios are suitable for computation with a quantum computer? How can algorithms be developed for this and translated into applications?

The focus of the competence center is quantum HPC (High Performance Computing). Compared to classical computing, quantum computing promises both an acceleration of certain algorithms as well as and the possibility to compute extremely complex problems in the first place.

Future Technology With Potential

The "Quantum High Performance Computing" competence center now brings together numerous projects with a wide variety of from quantum chemistry to financial mathematics, projects with financial mathematics, projects with an energy focus or material simulation to quantum image processing or quantum machine learning. The overriding goal of the diverse activities is always: the development of quantum-based computing strategies for industrial applications.

Minister of Science Clemens Hoch Hands Over Funding Notification

"You have made good use of the start-up funding," emphasized Science Minister Hoch at the handover ceremony. In the second funding phase, the researchers will deepen the work packages. This includes identifying further applications – a strategy also endorsed by the Industrial Advisory Board. It consists of representatives of BASF, Debeka, Deutsche Bahn and Schaeffler. The state of Rhineland-Palatinate will continue to support the expansion of the center of excellence in quantum computing in the future: Up to five million euros will be made available over the next three years, so that quantum computing can be used to solve problems of social, scientific and economically relevant problems supported.

www.itwm.fraunhofer.de/quantum-technology-professional-en

QCStack: Between Classical Clusters and Quantum Computing

Quantum computing is still a big promise, but at the latest since the first quantum computer went into operation in Germany in June 2021, the future technology has moved a bit into the present. Dr. Valeria Bartsch heads the "Next Generation Computing – Quantum Computing" team and talks in this interview about the current state of research.

What is the state of research In Quantum Computing?

Compared to classical computing, quantum computing is still at the beginning of its development. In principle, we are at the same stage as the first classical computers in the 1950s. We lack an invention similar to that of the transistor, which revolutionized computers and provided a hardware platform on which all further developments are based. We put a lot of work into research and testing. Therefore, we expect a rapid improvement of the hardware, the algorithms and the software stack to deliver on the promise of quantum computing. We want German industry to be ready as soon as the benefits of quantum computing can be implemented in reality. Coming from high-performance computing, we are looking in particular at the software stack and the integration between classical clusters and quantum computers. We are building an abstraction layer-an interface between the hardware and the application-that every quantum computer needs. As yet, this interface must be implemented individually for each quantum technology and variant. We would like to generalize this step. We are financially supported by the German Federal Ministry of Education and Research (BMBF). The ministry has set up a special funding program for quantum technology. We are leading the project QCStack project and, together with our partners build a suitable middleware.

What does that mean exactly?

The middleware ensures the exchange of data between application programs that work under different operating systems or in heterogeneous networks. In our case these are software stacks, i.e. software packages that build on each other software packages with the task of supporting the execution of a common application. To understand this, it is helpful to compare with an orchestra: The instruments must be tuned, i.e. calibrated, in order for the interaction to work. The music is arranged according to the composition of the orchestra. Likewise, the algorithms are calibrated to run on a particular quantum system. In the orchestra, the conductor gives the instruments the cue, the qubits get their "go" from a scheduler.

This sounds like a big task. Is the Fraunhofer ITWM working alone on QCStack?

The project is a joint effort – we focus on the compiler that translates quantum algorithms to real quantum systems. The "Dahlem Center for Complex Quantum Systems" at Freie Universität Berlin is developing methods for the optimal control of quantum systems and working on their application. Qruise GmbH, a spin-off of Forschungszentrum Jülich, then deals with the commissioning of the software and (re)calibration. At the end of the project – probably in January 2025 – we want to present the first functional iteration of the software; both the core software and the algorithms it contains must then have achieved MVP (Minimal Viable Product) status. This means that our product must be so good that it is of interesting for companies.

Qubits are the smallest computing units in quantum computing.

Fraunhofer operates "IBM Quantum System One"

Since June 2021 quantum computing is possible in Europe: Together with IBM Fraunhofer operates the quantum computer "IBM Quantum System One" under EU data protection guidelines. It is available to companies and research organizations to develop and test application-related quantum algorithms and build up know-how.

www.itwm.fraunhofer.de/QCStack_en

Contact

Dr. Valeria Bartsch
Speaker Division Management
"High Performance Computing"
Phone +49 631 31600-4741
valeria.bartsch@itwm.fraunhofer.de

Quantum Leaps in Science and Career

Dr. Jonas Koppe is research coordinator on the topic of "Quantum Computing" in the the department of "Financial Mathematics". With a team of seven, he is working the most diverse projects of the new technology in this position. What this means in practice and for him as a person, he reveals in the portrait.

Since September 2021 Jonas Koppe has been a staff member at the institute and since February 2022 he occupies the new position of the research coordinator "Quantum Computing" (QC). He moved to the Palatinate specifically because his career has so far taken place in Münsterland: He completed his bachelor's degree and then his master's degree in chemistry at the Westphalian Wilhelms University in Münster, where he then earned his doctorate at the Institute of Physical Chemistry. At the same time, his focus was on a completely different field: new methods for investigate solids using nuclear magnetic resonance spectroscopy. In addition to his chemistry studies, Koppe also earned a bachelor's degree in business administration.

A wide-ranging academic combination, in other words that led him to the institute. "I would describe myself as a physicist rather than a chemist," notes Koppe. And now financial mathematics? How does that fit together? Very well, because the research focus on quantum computing is a mixture of physics, computer science and mathematics, as so is the position as research coordinator.

Coordinator Quantum Computing at the Pulse of Research

"In our department, the main task in the position of research coordinator is to create scientific foundations. I observe ongoing research from an application perspective," says Koppe. "That means a lot of reading, writing, coordinating and making sure that we as experts are visible in the research community and on the pulse of the times. We want to be prepared for current developments, but also to play an active role in shaping state-of-the-art research."

To this end, a number of QC projects are already underway, mainly with purely public funding. Abbreviations such as EniQmA, QuSAA, AnQuC or EnerQuant give the research projects names and direction. EnerQuant, for example, has set itself the goal of exploring the potential of new computing technologies for the energy industry. QuSAA focuses on asset allocation and aims to make the most efficient use of the available hardware. Investment strategies for asset allocation aim at diversifying a portfolio using different asset classes such as bonds, shares or real estate – familiar terrain for the department.

Diversity of Projects and Networking

"In the projects, we as a team can usually build on our expertise in financial mathematics. It forms the basis and the technical work is similar. The new technology is the real challenge." Then it is a matter of analyze together how much potential quantum computing really has – in direct comparison with classical hardware and approaches. Some of the companies involved in the translation into the quantum world are companies with which the department is already working on other projects, such as the R+V Insurance.

In the daily work is not only a close networking with the other ITWM departments important, but also with other Fraunhofer institutes. The heart of the network is the "IBM Quantum System One" in Ehningen near Stuttgart, on which Fraunhofer exclusively calculates.

Quantum computing has a Hype problem

Despite all the quantum computing activity, Koppe cautions, "The topic has a classic hype problem right now: Interest and reporting are enormous. But we're at a point where we can't make any promises yet. There will certainly be successful applications, but we are still in our infancy. There will probably be disillusionment before the applications offer a real quantum advantage," says the 33-year-old.

"Our shared understanding of the practicalities, but also the limitations, of the new technology are just beginning to emerge." Nevertheless, Koppe is optimistic and expects the team to produce competitive products that support companies as early as 2023.

The young technology is facing an exciting turning point, just like the young researcher himself. "The subject matter has little to do with my previous specialized knowledge. But that's why I like being in research." And Koppe is not only discovering new things in science, but also in his new life in Kaiserslautern: "I was surprised to discover how beautiful it is here in the Palatinate Forest and the surrounding. I also played the saxophone in a Big Band for a long time and I'm thinking about starting again." Smaller (quantum) leaps will hopefully soon to be found in all areas of the researcher.

www.itwm.fraunhofer.de/fm

Contact

Dr. Jonas Koppe
research coordinator
"Quantum Computing"
Department "Financial Mathematics"
Phone +49 631 31600-4110
fm@itwm.fraunhofer.de

Changing the World with Research Results

A scientist sits in his quiet chamber and does research ... and then? In the interview, Dr. Jens Krüger talks about how research findings find their way into companies and from there into people's everyday lives. He is Fraunhofer expert for the strategic research field of "Next Generation Computing". This stands on three pillars: the first pillar is based on classical architectures. The second pillar is neuromorphic computers, which function in much the same way as our brain, and the third pillar is quantum computers.

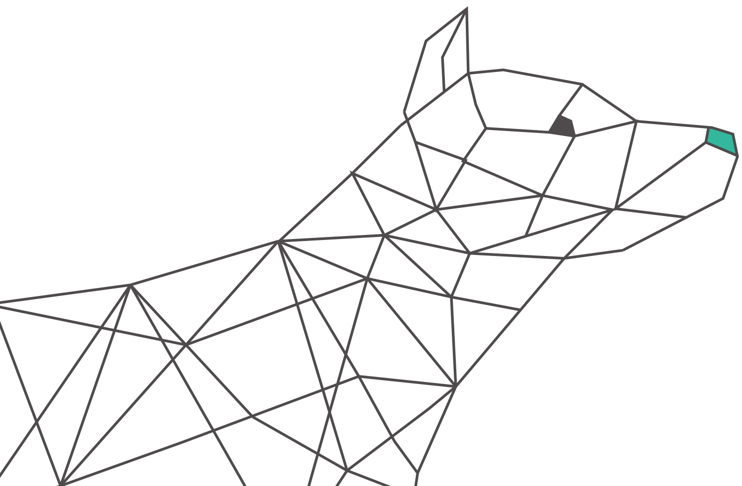
Please briefly summarize what drives you as a researcher?

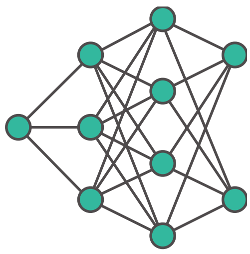
I am a curious person. I want to try out new ideas and develop them further into products that will then benefit our society and the economy. This goes from the development of highly efficient processors to the optimization of artificial neural networks for mobile devices. One example are smart watches that record your ECG. In this way, the device can detect an approaching heart attack and trigger the alarm at an early stage. This technology has the potential to save people's lives.

National science competitions often give research impulses. In March 2021, your team won a prize in the pilot innovation competition "Energy-efficient AI systems" of the Federal Ministry of Education and Research (BMBF). What was that about?

The task was to develop the most energy-efficient AI hardware possible that detects cardiac arrhythmias and atrial fibrillation in ECG data with at least 90 percent accuracy. We entered the competition with was called HALF, which stands for "Holistic AutoML for FPGAs". Our approach was to have an holistic automated machine learning (AutoML) optimization of the neural network model and the FPGA implementation. We investigated the interdependence of the energy consumption of the hardware and the neural network topology.

The choice of network has a considerable influence on the hardware complexity – and thus on the required energy and vice versa. We have optimized these dependencies and developed a new methodology that finds not only more energy efficient models, but also reduces the development time for optimal neural network topologies.



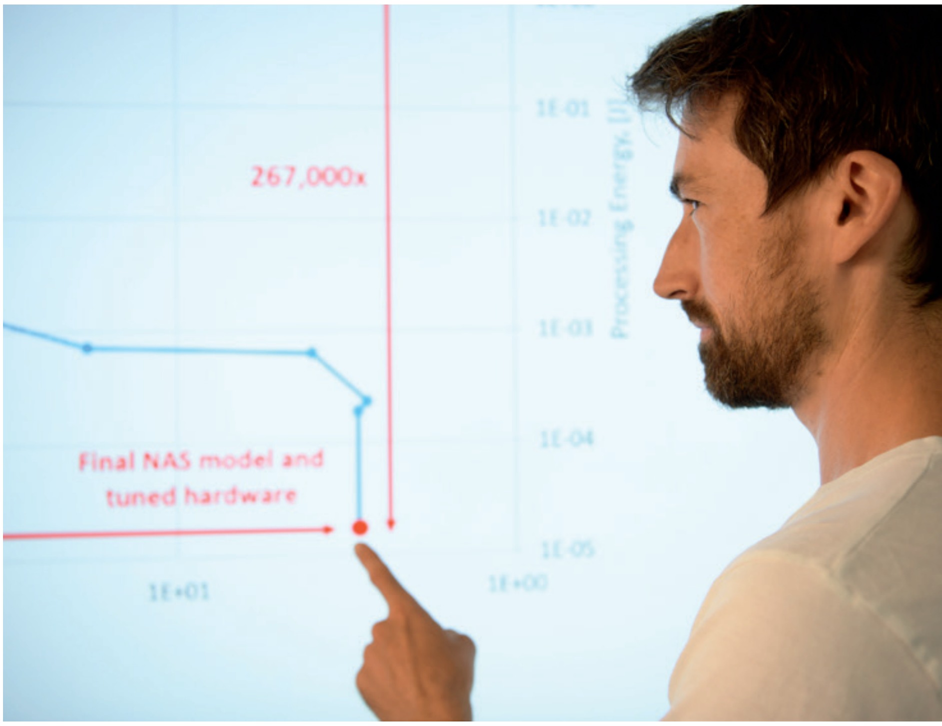


NASE – Neural Architecture Search Engine

What happened after you won the competition?

We now make our expertise available to companies so that they can develop their products accordingly. The AI chip in the competition was merely a test platform. In the follow-up project, we are now working directly with a manufacturer to develop the next generation of devices, which will then be used in clinical trials.

However, we can support all industries, because almost everyone faces the challenge that data volumes are constantly increasing and AI can help to process them. This is economically interesting for almost everyone, for example, for the automotive industry or the telecommunications industry. This gave rise to the software product »NASE« (Neural Architecture Search Engine).



NASE makes scientific expertise available to companies. How does this work?

Every job is individual, but one thing is clear: for us, efficiency starts with the algorithm. We use state-of-the-art methods of automatic neural network search to develop networks that can be efficient with respect to many aspects at the same time. We consider peculiarities of the underlying platform and incorporate them into the network design. The algorithm then adapts the networks to the hardware. For example we can provide our experience, the technology, and computing capacity. Companies provide us with the data sets that are relevant to them and define the requirements, such as accuracy and speed. We then use our supercomputers and our framework to find the best model. The network is then ready for immediate use.

To meet the demand for ever more and faster computing power your team is part of the European Processor Initiative (EPI) which develops highly efficient processors for Europe. What contribution does the Fraunhofer ITWM here?

Our contribution is the so-called Stencil and Tensor Accelerator (STX), which we are developing together with Fraunhofer IIS based on an architecture from ETH Zürich. We focus on the efficient execution of highly parallelizable applications with specific access patterns, as they occur in many applications – from fluid dynamics, climate and weather prediction to imaging techniques. Real-world applications are expected to become more energy efficient, easier to program, and lower cost. Interested parties can already test their own codes on our simulator. Next year, the next generation of test chips will be available. By 2025, we want to have the first complete system up and running. A major challenge, but also an important step toward a new national and European industry for high-performance processors and accelerators.

www.itwm.fraunhofer.de/NASE_EN

Contact

Dr. Jens Krüger
Speaker Division Management
"High Performance Computing"
Phone +49 631 31600-4541
jens.krueger@itwm.fraunhofer.de