

PRESS RELEASE

PRESS RELEASEOctober 23, 2026 || Page 1 | 4

QSolid Shows What German Quantum Technology Can Achieve

For nearly five years, 26 research institutions, companies and start-ups have joined forces in QSolid to develop a quantum computer using cutting-edge German technology: a 30-qubit quantum chip with low error rates. With several competitive demonstrators, the project has more than achieved this goal. In addition to a 10-qubit system that has already been tested and made accessible to users, the consortium is currently testing a 30-qubit system, with promising results. Using demonstration applications, such as the modelling of spin resonance processes employed in chemical analysis and magnetic resonance imaging (MRI), the interaction between hardware and software could be investigated under realistic conditions.

One of the project's technological achievements is the development of a particularly fast quantum gate that sets new international benchmarks for switching speed. Quantum gates play a crucial role in quantum computers: they perform computational operations that can change the state of a qubit, thereby forming the basis for information processing in a quantum computer.

"The performance of a quantum computer depends on how many computational steps it can carry out while keeping errors to a minimum. There are two main ways to achieve this: we can either ensure that qubits retain their quantum states for longer or speed up gate operations, allowing more computational steps to be performed in the same amount of time," explains Prof. Frank Wilhelm-Mauch of Forschungszentrum Jülich, who coordinates the large-scale project.

"In QSolid, we have made important methodological advances, particularly in gate speed, that extend far beyond the project itself. They demonstrate that we have highly capable components and that the integration of hardware and software has already reached a high level of maturity," says the quantum physicist and Director of the Peter Grünberg Institute for Quantum Computing Analytics (PGI-12).

Fraunhofer IPMS: Established semiconductor technology supports the scalable manufacturing of quantum processors

Fraunhofer IPMS has made significant contributions to the development of scalable quantum processors through QSolid. The focus was on the cryogenic characterization of CMOS circuits in collaboration with GlobalFoundries, ADMOS, and RacyICs. In addition, an innovative advanced packaging solution was developed with Fraunhofer IZM-ASSID as part of the Center for Advanced CMOS and Heterointegration Saxony (CEASAX). So-called interposers are used to connect the quantum chip and the control

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chip in a space saving manner. The key challenge is to reliably transmit signals while simultaneously protecting the sensitive quantum chips from heat. The work builds on proven processes from industrial silicon semiconductor manufacturing and contributes to the future realization of quantum processors with significantly more qubits.

PRESS RELEASE

October 23, 2026 || Page 2 | 4

Dr. Benjamin Lilienthal-Uhlig of Fraunhofer IPMS explains: "Through our work on the QSolid project, we have demonstrated how proven technologies from industrial semiconductor manufacturing can be leveraged for the development of future quantum computers. The combination of cryogenic control electronics and innovative interconnection technologies is an important step toward making quantum processors more powerful and more scalable in the future."

Collaboration Between Research and Industry

One of QSolid's key achievements has been to bring together expertise previously distributed across numerous locations and partners and channel it into the joint development of a large-scale scientific instrument.

"With QSolid, we have demonstrated that here in Germany we can design, manufacture and operate functional quantum processors from scratch within a short period of time. This is a crucial prerequisite for the further development of the German quantum ecosystem and a major achievement for the highly skilled students, scientists and engineers who made it possible," explains Prof. Rami Barends, Director of the Peter Grünberg Institute for Functional Quantum Systems (PGI-13) at Forschungszentrum Jülich, which was established shortly before the project began.

A professional, collaborative systems engineering approach, building on methods originally developed for the space sector, enabled specialised partners to test their technologies together and successfully combine and further develop them into integrated quantum systems. Alongside Forschungszentrum Jülich, the Leibniz Institute of Photonic Technology (Leibniz-IPHT) in Jena, the CiS Forschungsinstitut für Mikrosensorik in Erfurt, the Karlsruhe Institute of Technology (KIT) and the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig contributed their expertise.

The software also reflects the close collaboration within the consortium. The software stack of the current demonstrators combines solutions from Zurich Instruments, Qruise, Bull, ParityQC and HQS Quantum Simulations. Innovative hardware components, such as connectors from Rosenberger and cables from Supracon, have also made a significant contribution to improving the performance of the quantum computers.

Successful closing of the project

From 27 to 29 October, project participants from different parts of Germany will gather in Jülich for the project's closing event to present their results and discuss insights gained from their collaborative work. The achievements range from tested quantum computer prototypes accessible via the cloud to expertise that has already been translated into concrete products and services. The project, which received 76.3 million euros in funding from the Federal Ministry of Research, Technology, and Space (grant number 13N16150) has pooled expertise from across Germany and brought together partners from research and industry. By jointly developing a quantum ecosystem, the consortium has given companies early access to this emerging technology and strengthened their technological capabilities and independence.

PRESS RELEASE

October 23, 2026 || Page 3 | 4

About Fraunhofer IPMS

Fraunhofer IPMS is a world-renowned research and development service provider specializing in electronic and photonic microsystems. Our technologies are used in industries such as mobility, biotechnology, and medical technology. We are also addressing key future fields, such as quantum technologies and neuromorphic computing. Through our research in green microelectronics, we contribute to a sustainable and resource-efficient world.

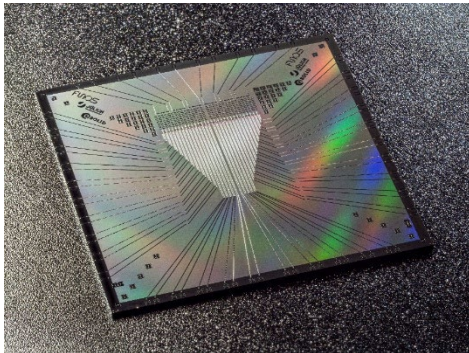
With the Center Nanoelectronic Technologies (CNT), Fraunhofer IPMS offers applied research on 300 mm wafers for microchip producers, suppliers, device manufacturers and R&D partners.

About project QSolid

Acronym	QSolid
Title	Quantum Computer in the Solid State
Project duration	January 2022 - December 2026
Budget	€ 76.3 million (of which 89.8 % is funded by the BMFTR)
Partners	Forschungszentrum Jülich, Fraunhofer IZM und IPMS, Karlsruhe Institute for Technology, Leibniz IPHT, ParityQC, HQS Quantum Simulations, Rosenberger, Ulm University, Physikalisch-Technische Bundesanstalt, Qruise, University of Stuttgart, Freie Universität Berlin, IQM, University of Konstanz, University of Cologne, Heinrich-Heine University Düsseldorf, Supracon, ParTec, Racyics, AdMOS, LPKF Laser & Electronics, MKS Atotech, s+c / Eviden, Globalfoundries, CIS Forschungsinstitut für Mikrosensorik, Zurich Instruments
Website	www.q-solid.de

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Images



30-qubi chip
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Close-up of quantum computer hardware
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Close-up of the cryostat
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PRESS RELEASE

October 23, 2026 || Page 4 | 4
