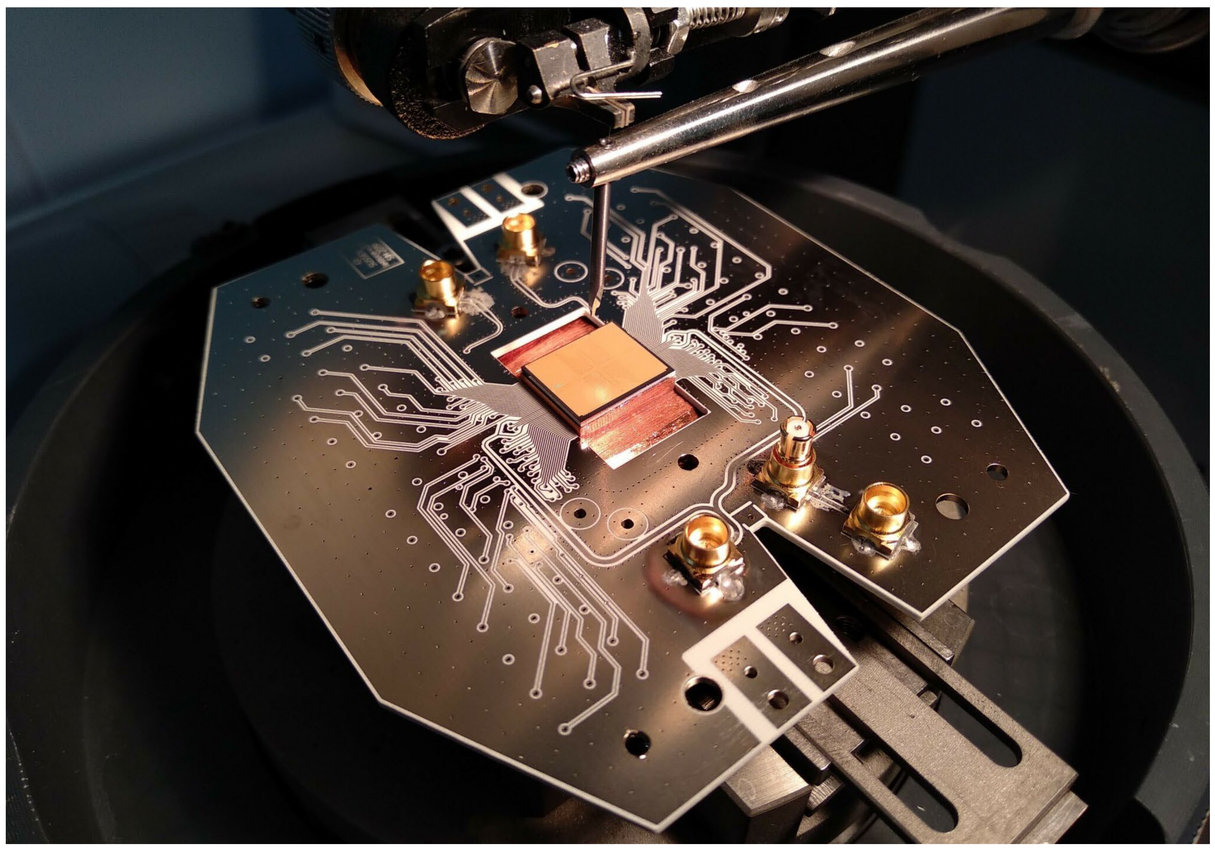
Toccata

Fully integrated trapped-ion quantum computer prototype

Targeting 50+ qubits running on a Si technology-based integrated quantum processing unit (iQPU) with error correction capabilities. Universal Quantum builds on RF-based gate technology with a fixed number of global RF-fields allowing to selectively address many qubits simultaneously using electronic control for maximum scalability.

- Full stack quantum computer
- End-user accessible cloud infrastructure
- High-speed real-time electronics
- Scalable control facilitated by an ASIC
- Global RF fields addressing multiple qubits
- Ultra-high vacuum chamber
- Mild cryogenics by operating at 70 K



Approach

Ion trapping technology is one of the most mature ways to building quantum computers. Since future applications are expected to require millions of qubits, we need scalable technology at all levels. Our system uses a highly scalable, fully integrated microchip module to run quantum gates on the ion qubits using our global RF-field technology. With this approach there is no need to increase the required number of RF fields to increase the number of qubits, greatly easing scaling.
Our approach also allows modules to be connected like puzzle pieces making them easy to exchange and reach economy of scale (see “Legato” QCI project).
Furthermore, while many other quantum computers must be cooled down to almost 0 Kelvin (ca. -270 °C), our technique operates with mild cooling at approximately 70 Kelvin.

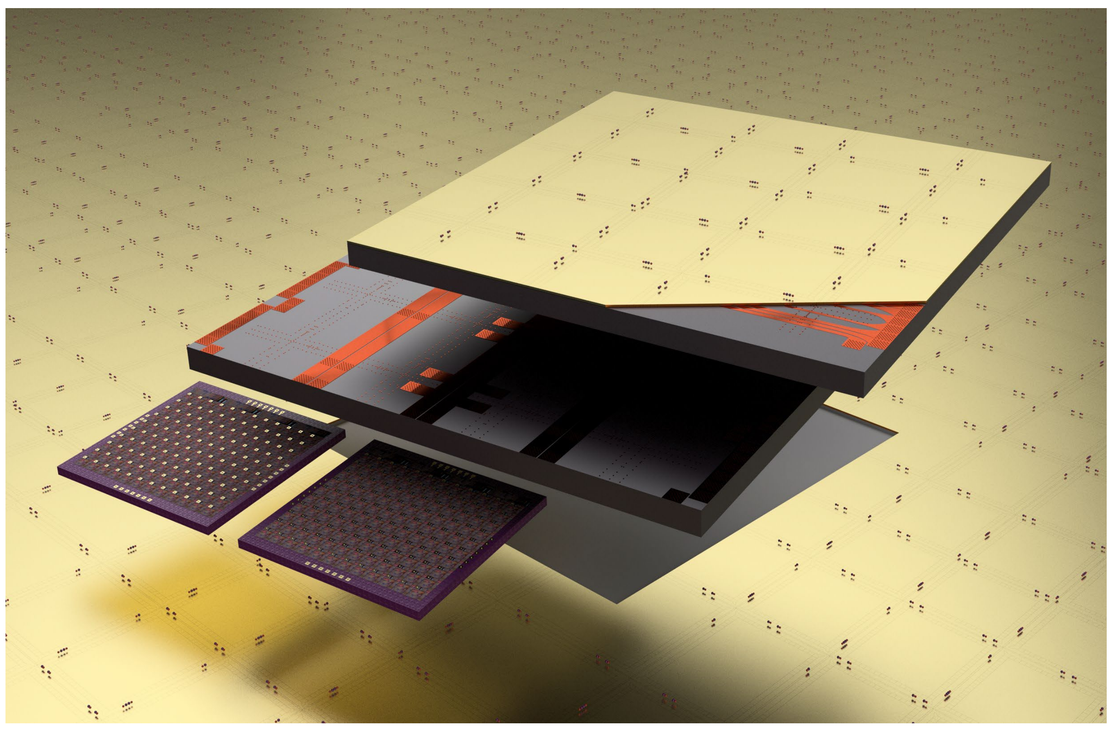


Fig. 1: Schematic of the iQPU: Qubit layer, microchip layer and classical control layer are shown

Building Germany’s Quantum Work Force

Overcoming the technological challenges of a large-scale quantum computer requires a highly interdisciplinary team. UQ features top tier quantum physicists, chip and packaging engineers, software developers and a well experienced electronics team, besides our fantastic operations and business development departments. Attracting great talent is one of the biggest joys at UQ!

Fig. 3: The growing Germany team in Hamburg

Challenges

Our architecture enables global RF-field quantum gates to be implemented on a highly parallel system. The heart of our quantum computers is a fully integrated quantum computer module. This is based on a vertically integrated trapped-ion chip with an application-specific integrated circuit (ASIC). It was specifically designed for efficient ion shuttling. This module forms Universal Quantum’s integrated quantum processing unit (iQPU). The module is designed to operate at temperatures of approximately 70 Kelvin to simplify thermal management. The temperature reduces ion heating, ion loss and ultimately the error rate in quantum gate execution. The qubits are moved back and forth on the chip, resulting in high connectivity between the qubits and greatly increasing the computing power.

Technology Milestone: ASIC

Our advanced packaging techniques and in-house developed cryogenic integrated circuit libraries have paved the path to this major milestone. These technologies allow us to fully integrate the qubit control systems directly into the qubit chip architecture, not only unlocking scalability but also improving noise performance, response times and power efficiency, something near impossible with other quantum computing architectures that operate at temperatures much lower than ours.

- Built-in enabler of UQConnect, which is Universal Quantum’s powerful link technology capable of directly transferring qubits between chip modules at a world record rate of 2400 1/s and fidelity of 99.999993%, with further enhancements anticipated (see “Legato” QCI project)
- Built-in enabler of UQLogic, which is Universal Quantum’s RF technology capable of controlling qubits at any scale
- Facilitation of execution of quantum algorithms at any scale through enhanced connectivity between qubits
- Solves the 'wiring problem' common in quantum computing
- Can operate at Universal Quantum’s architecture temperature of 70K
- Will enhance quantum error correction by at least a factor of six by enabling qubit connectivity at scale

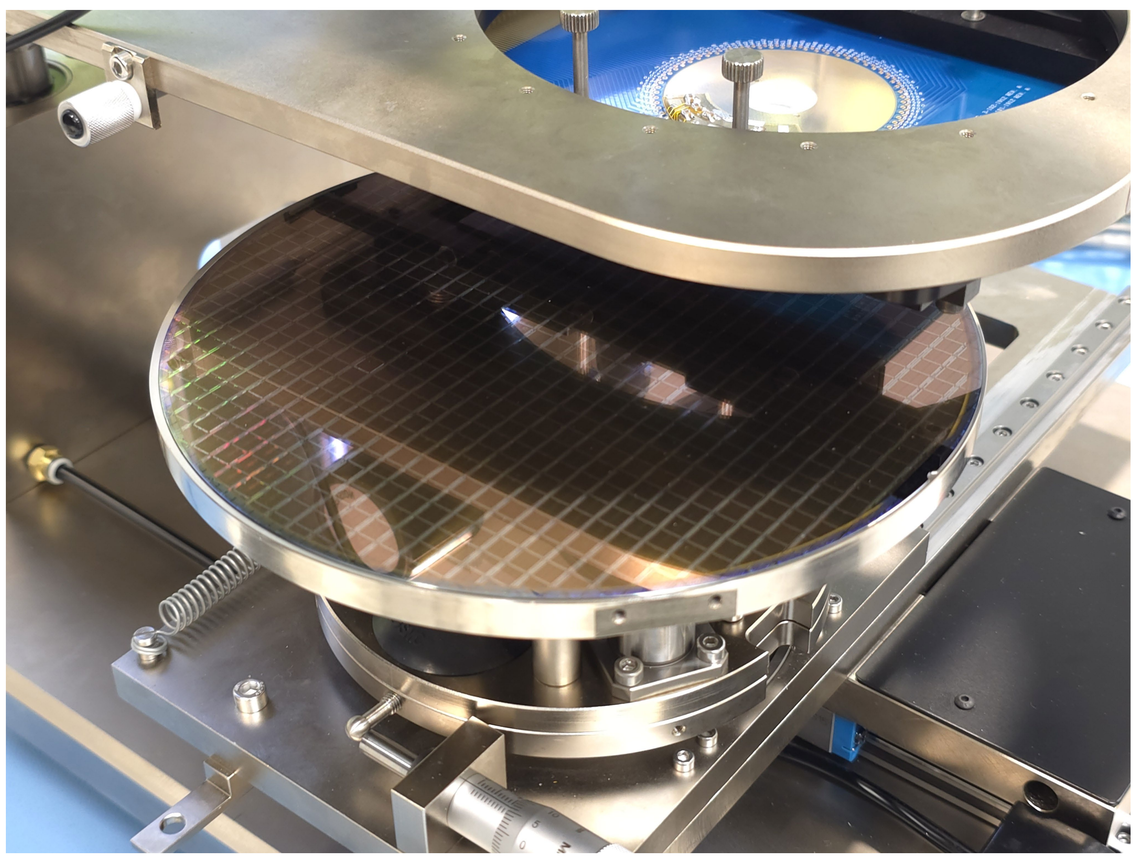


Fig. 2: A fabricated UQ ASIC wafer undergoing electrical verification tests

Delivery timeline

After a strong design and architecture focus in the 2023 deliveries, 2024 is the first year of hardware deliveries to the DLR Hamburg labs. It is greatly exciting to see electronic-, laser-, vacuum- and cryogenic systems moving in, awaiting the installation of our highly advanced integrated quantum processing unit! Our physics team readily prepares for the first quantum experiments with all the amazing support from our highly skilled engineers.

Find more information about this project on our website!

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DLR | QCI

Get in touch.
We enable quantum!

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