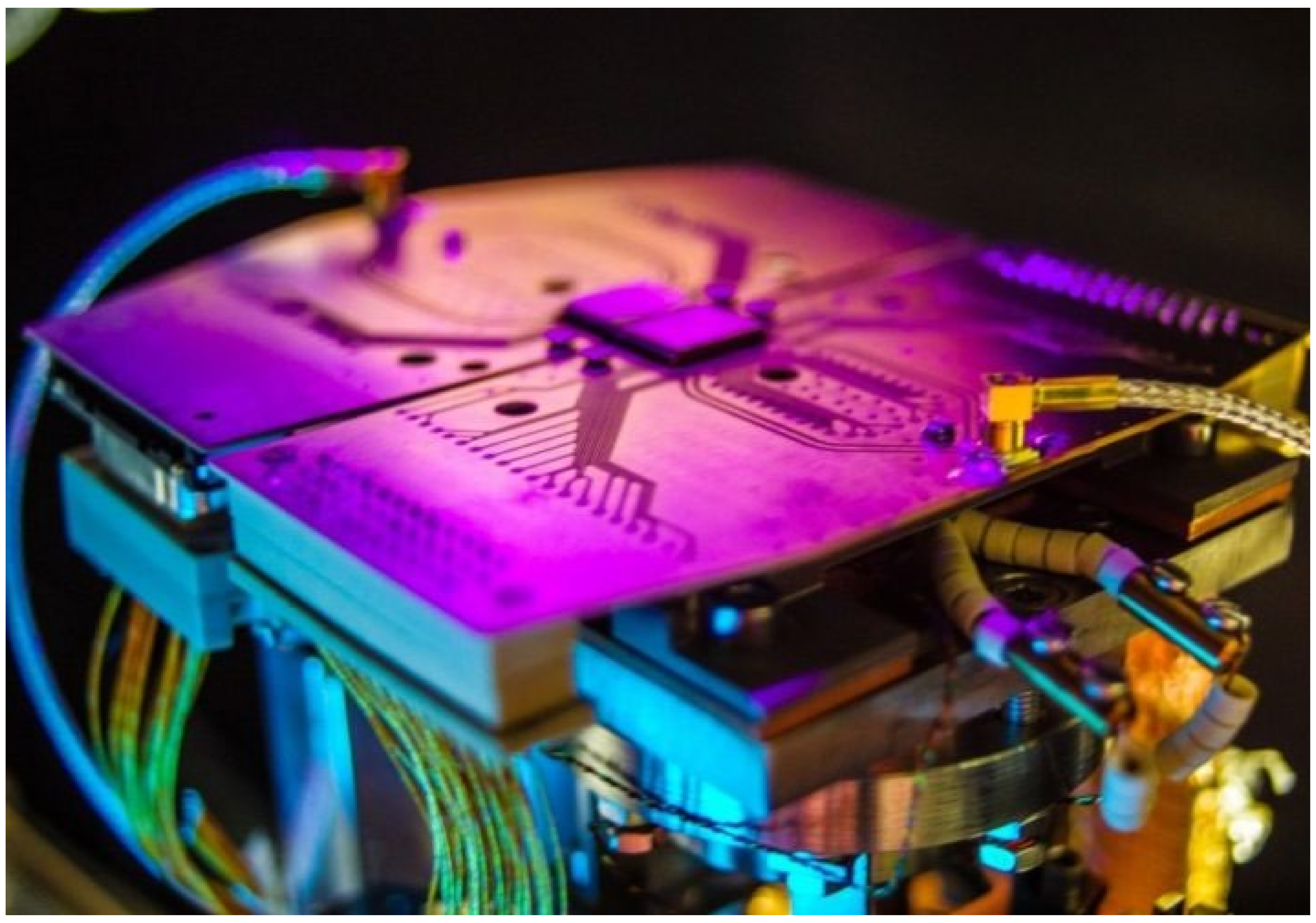
Legato

Multi-Module Trapped-Ion Quantum Computer Prototype

Targeting 20+ qubits running on multiple closely aligned Si technology-based integrated quantum processing units (iQPU). Our key technology UQConnect allows the modules to be directly interconnected, which means qubits can be rearranged across neighbouring iQPUs as if they are held on a single continuous surface.

- 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

One path leading to the realization of quantum computers with millions of qubits is to develop a basic module that can perform all the essential quantum operations and then connect many such modules together.
Using this approach, we will build a trapped-ion quantum computer with interconnected modules. These modules are based on Si chip technology and are similar to those being used in the QCI project "Toccata".

Initially, we will design modules with at least 10 qubits and interconnect at least two modules. However, the design can accommodate more qubits and can be scaled up to a larger networked system. To do this, we align the edges of neighboring modules so closely, that the ion qubit does not see the difference between both surfaces anymore – a pure electrical link is generated that allows the ions to hop from one module to another (Fig. 1-3).

Since a single ion-trap wafer can contain at most a few hundred qubits, modularity is crucial for realizing trapped-ion quantum computers with millions of qubits. The interconnection of individual quantum computer modules is often described as one of the biggest problems in this regard.

We solve the problem of interconnectivity using electric field connections between neighboring quantum computing modules. We call this approach UQConnect. It enables connection speeds that are orders of magnitude faster than other methods. Despite this, it utilizes much simpler technology. For example, in an experimental demonstration of UQConnect (Fig. 1-3), we were able to realize coherent transport of a qubit between two neighboring modules with a connection rate of 2424 connections per second and a transmission fidelity of 99.999993 %.

Similar to the "Toccata" QCI project we use our global RF-field technology for the execution of quantum gates across the modules. The advantage is that the number of microwave fields required remains the same, even if the number of qubits is increased. In addition, while in many other quantum computing approaches the chip must be cooled almost to absolute zero, our technique works with mild cooling to approximately 70 K (ca. -200 °C), which significantly simplifies the design and reliability of the system.

Akhtar, M et al. A high-fidelity quantum matter-link between ion-trap microchip modules. *Nature communications*, *14*(1), 531 (2023)

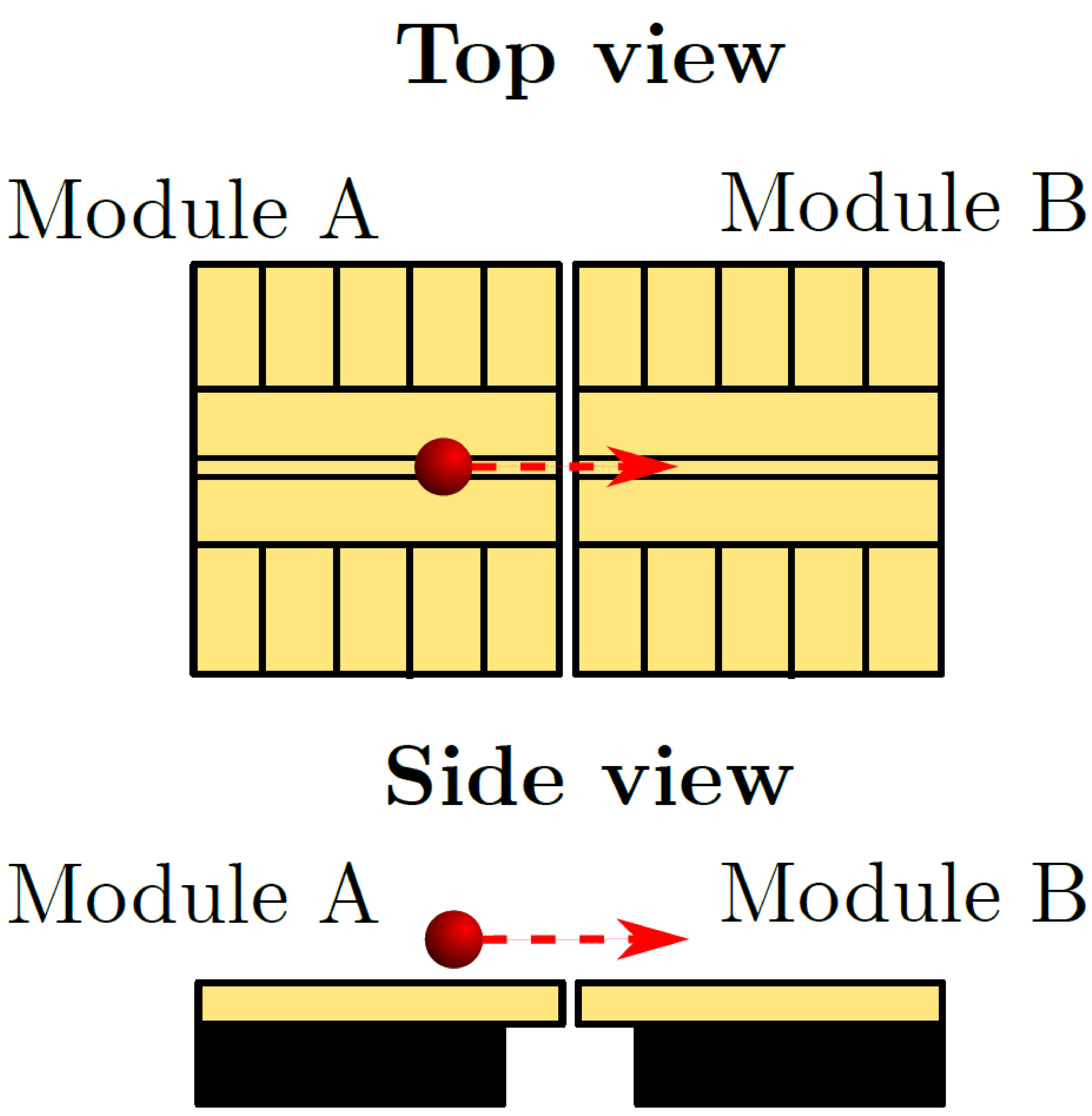


Fig. 1: Schematic of ion transport between iQPU modules facilitated by UQConnect

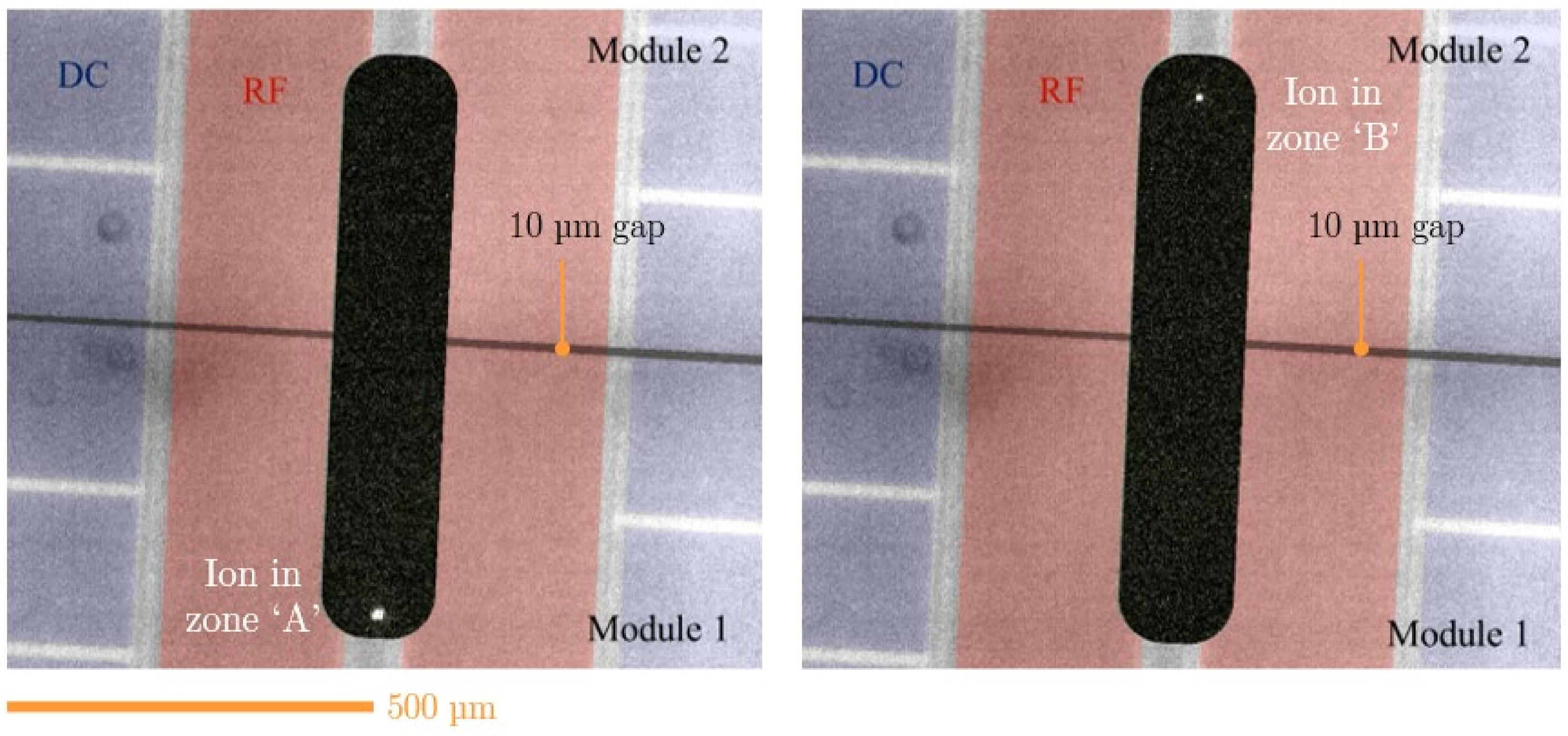


Fig. 2: "Legato" enabler: UQConnect module-to-module ion transport demo by Universal Quantum/University of Sussex

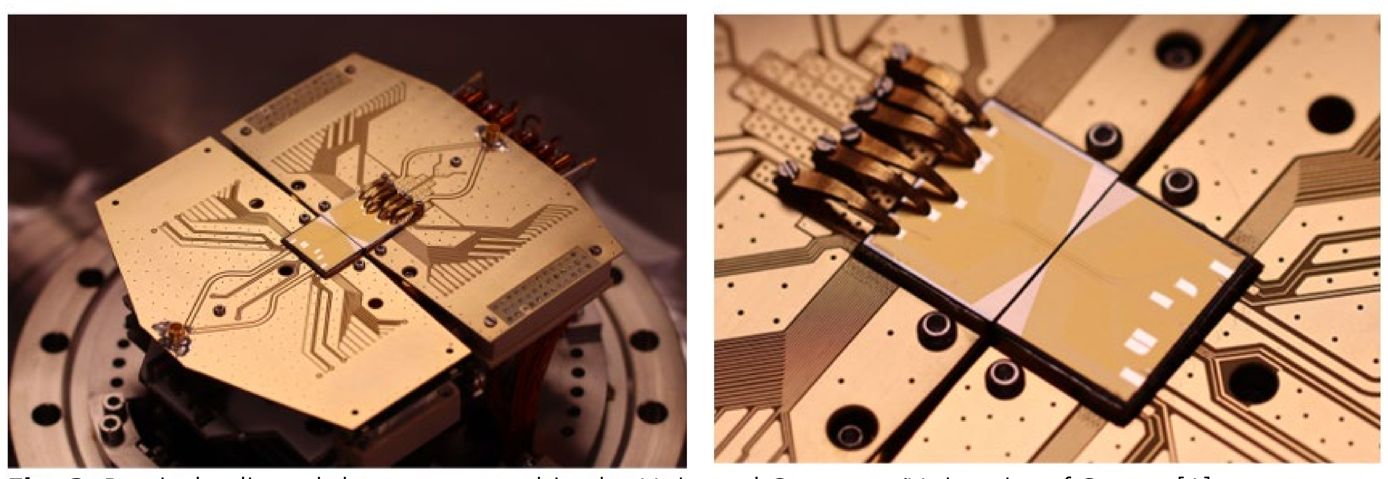


Fig. 3: Precisely aligned demonstrator chips by Universal Quantum/University of Sussex [1]

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 units! Our physics team readily prepares for the first quantum experiments with all the amazing support from our highly skilled engineers.

For Legato a special challenge lays in the assembly and alignment of multiple iQPU modules in one vacuum system at the target operating temperature. Different materials shrink at different rates when cooled down, even though UQ operates under mild cryogenic conditions at 70 K (ca. -200 °C) which eases the problem to some extent. Solving the remaining challenges required careful planning and innovation from our Germany team.

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. 4: The growing Germany team in Hamburg

Find more information about this project on our website!

Contractor

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Get in touch. We enable quantum!

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