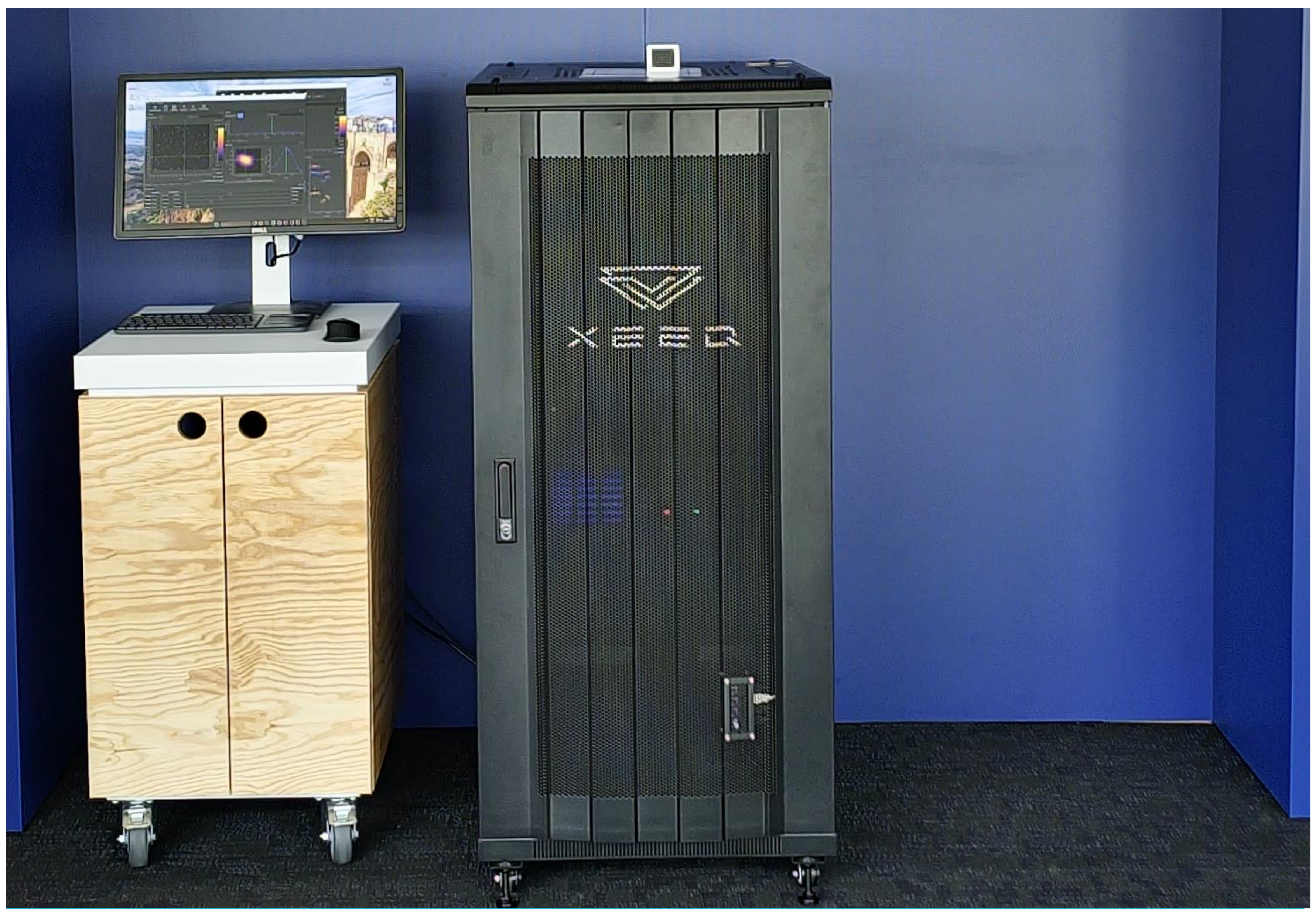
XeedQ GmbH

XQ*i*: Quantum computers based on NV centers in diamond

We are developing a fully functional, robust and scalable diamond spin-based quantum computer with more than 32 qubits for use in office and home environments.

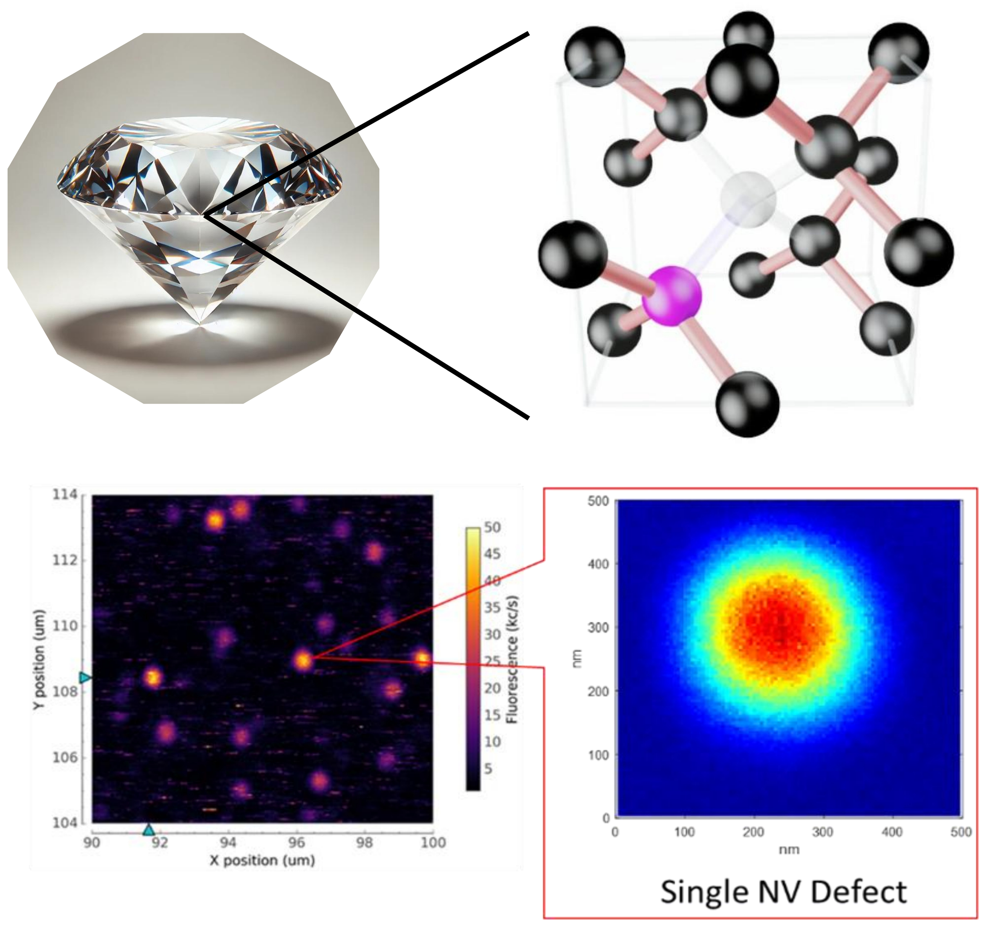
- NV-Centers
- Quantum Computer



Motivation

Today, most quantum computers are accessed remotely through the cloud due to significant infrastructure requirements for their operation. In contrast, our quantum processor systems function at room temperature, are powered by a standard power outlet, and are robust enough to be used in office and home environments. Our goal is to provide high-quality quantum information processing systems for both businesses and industry partners. These systems serve as tools for innovation, enabling them to easily integrate quantum advantages into their products. This approach democratizes access to quantum computing.

We utilize Nitrogen-Vacancy (NV) centers in diamonds for our quantum processors. These NV defects exhibit unique quantum properties: they are atom-sized, embedded in robust diamond material, fully functional and controllable at room temperature, and integrated into extremely small diamond chips. They require no special cooling, operating with minimal power consumption and space requirements. In an industry landscape dominated by large, power-hungry quantum processing units, diamond qubits represent a turning point. They pave the way for the democratization of quantum computing, allowing quantum computers to move from lab settings to everyday use.

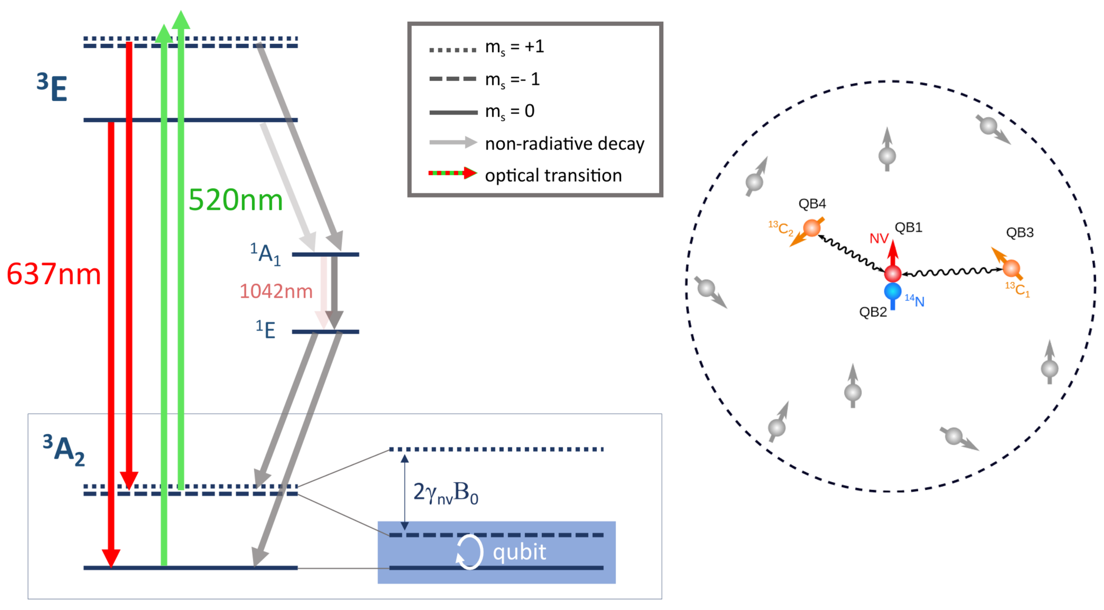


Nitrogen vacancy center inside diamond used as a platform for quantum computing.

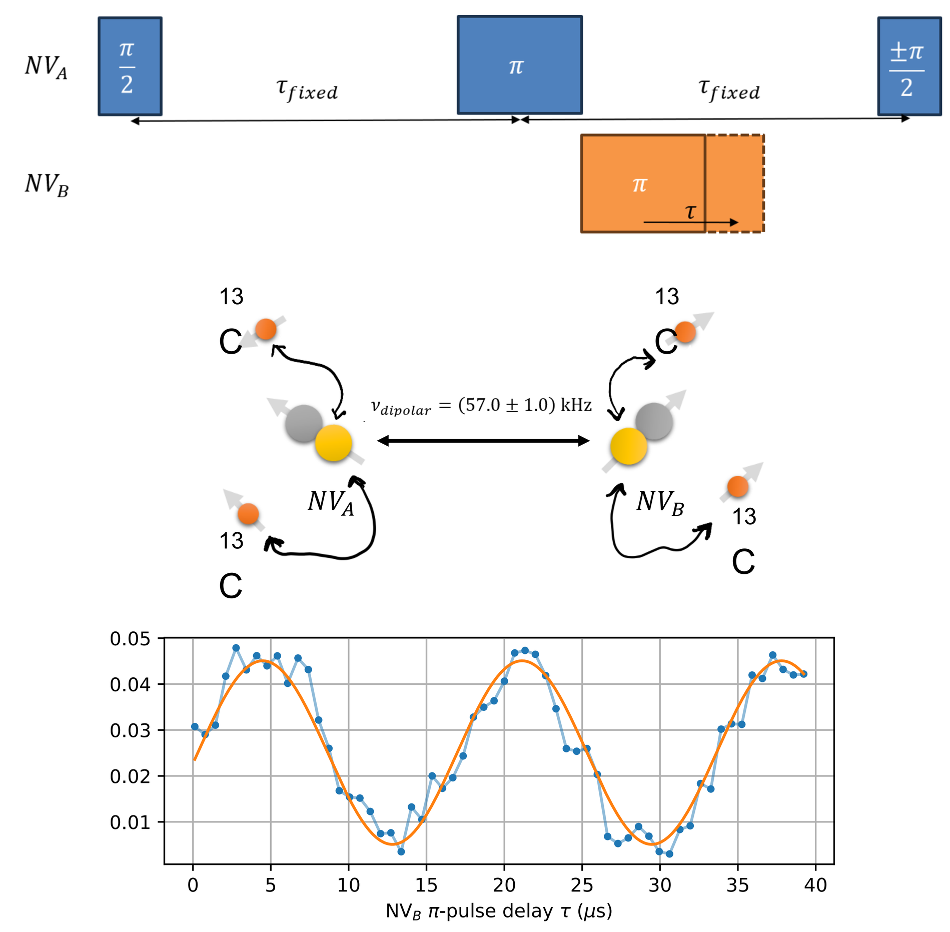
XQ mobile quantum processors

The XQ mobile quantum processors utilize a star topology in which qubits are centrally connected and controlled via a central spin node. This configuration allows each qubit to interact through a shared point, facilitating communication across the network of qubits. In this setup, specific operational techniques are applied to distinct types of spins:

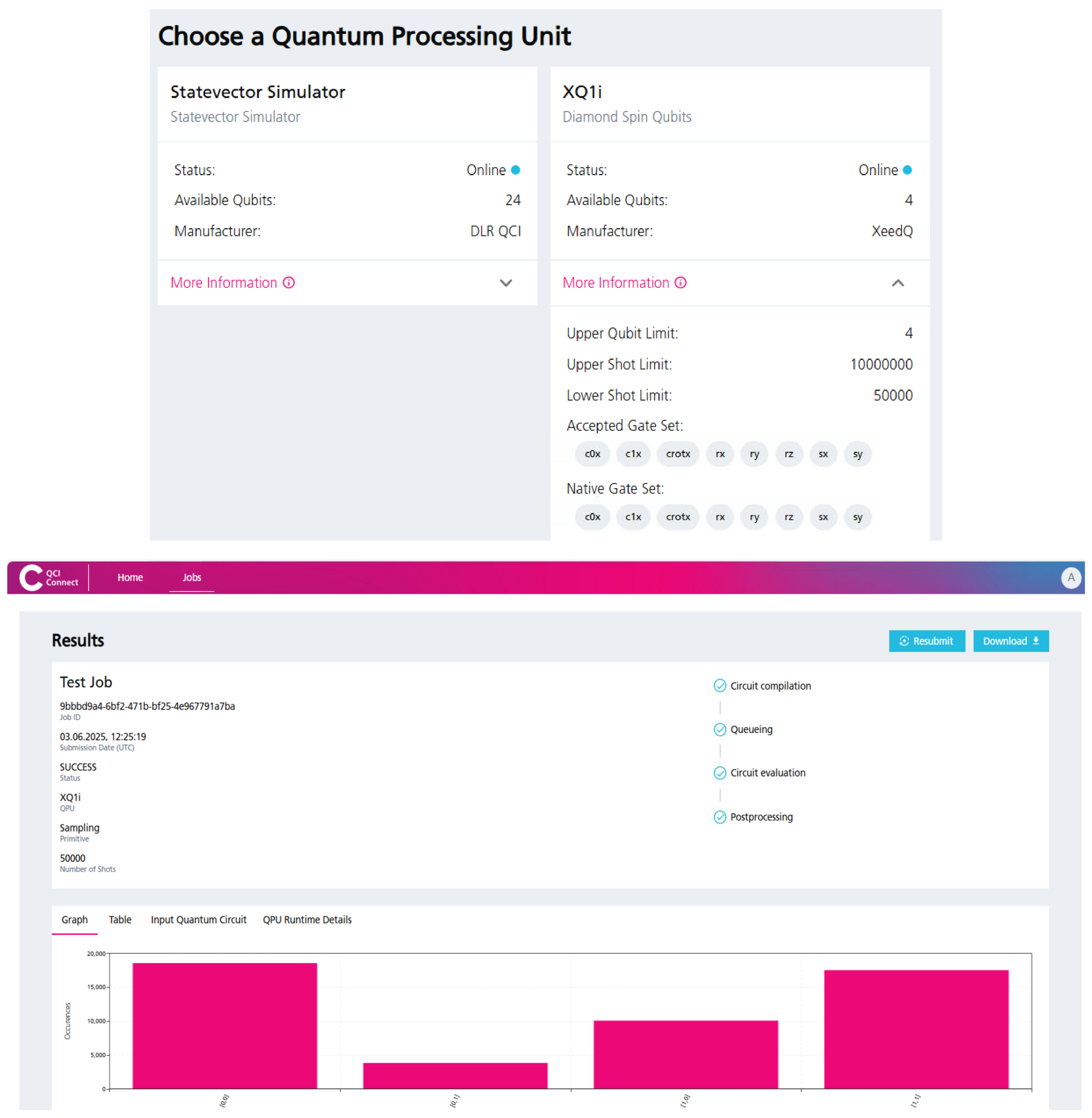
- **Electron Spin of the NV Center:** The electron spin within the Nitrogen-Vacancy (NV) center acts as the central "satellite" spin and is directly addressed through microwave excitation. This spin serves as the primary mediator within the star topology, enabling communication and coordination across qubits.
- **Intrinsic Nitrogen Spin:** The NV center's nitrogen nucleus spin is separately controlled via radiofrequency (RF) fields. This ability to address the nitrogen spin independently provides an additional degree of freedom in quantum operations, crucial for creating more complex quantum states and maintaining coherence within the system.
- **Coupled Carbon-13 Spins:** Surrounding Carbon-13 (^{13}C) spins, which naturally occur in diamond, require indirect manipulation via the electron spin. The electron spin's interaction with ^{13}C allows for quantum state transfer and more complex entanglement operations. This indirect addressing is pivotal for expanding the qubit register and allows additional spins to be coherently integrated within the NV-based system.
- **Coupled NV electron spins:** For scaling the qubit architecture, multiple NV centers positioned closely enough for effective dipole-dipole coupling are required. This proximity allows direct qubit-qubit interaction through magnetic dipolar fields, paving the way for larger and interconnected qubit networks. NV-NV interaction is probed via Double electron-electron resonance (DEER) techniques. However, achieving such precise pair configurations poses significant technical challenges, particularly in the fabrication of diamond chips with reliably spaced NV centers and consistent quality. Advanced nanofabrication techniques are critical to producing these diamond substrates with the required structural and quantum coherence properties.



Left: Level scheme of the NV center showing the basic ingredients that allow it to function as a qubit. Right: Schematic of the qubit topology of XQ1*i*, containing four spin qubits: NV electron spin (QB1; red), nitrogen nuclear spin (QB2; blue), and two ^{13}C nuclear spins (QB3,QB4; orange). Additional weakly coupled ^{13}C nuclear spins in the vicinity of the NV-center are shown in grey, but do not form part of the XQ1*i* qubit register.



Towards XQ2*i*: DEER measurement showing coupling between two NV centers (top: pulse sequence, bottom: measured signal). In this example, the coupling strength of about 60 kHz indicates an upper bound of 12 nm for the separation between the two NVs.



Screenshots from the DLR QCI Connect web interface (http://qc-plat-pro.dlr.de). Top: QPU selection page, showing the XQ1*i* machine as ready to receive jobs. Bottom: Result view of a job after finishing execution.

XQ1*i* integration into the DLR's QCI Connect platform

In recent months, we successfully integrated our XQ1*i* 4-qubit quantum processing unit (QPU) into the DLR QCI connect platform, marking an important milestone for our project and the broader QCI ecosystem. As one of the first hardware teams to make a quantum device accessible through the platform, we are helping to pave the way for practical user engagement with emerging quantum technologies. The XQ1*i* system is now fully connected via the REST API defined by the DLR Clique project, enabling seamless interaction with the QPU. Through this interface, users can submit quantum jobs, monitor queue status, query execution results, and inspect detailed information about the QPU's characteristics and operational status. This integration demonstrates the maturity and versatility of our diamond-based spin-qubit technology, while opening new opportunities for collaborative research and benchmarking across the QCI network.

Challenge

The first major achievement was transitioning quantum computers from the lab to practical applications. This was accomplished by significantly reducing the complexity of laboratory systems, resulting in a compact and robust mobile system. However, the real challenge lies ahead: enhancing the performance of these systems. This is the central focus of Project XQ*i*. Our aim is to develop scalable, high-capacity quantum systems based on compact, mobile NV-center quantum computers, while maintaining simplicity and practicality to make them suitable for the mass market.

More information about the project on our website

A project of

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Get in touch.
We enable quantum!

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