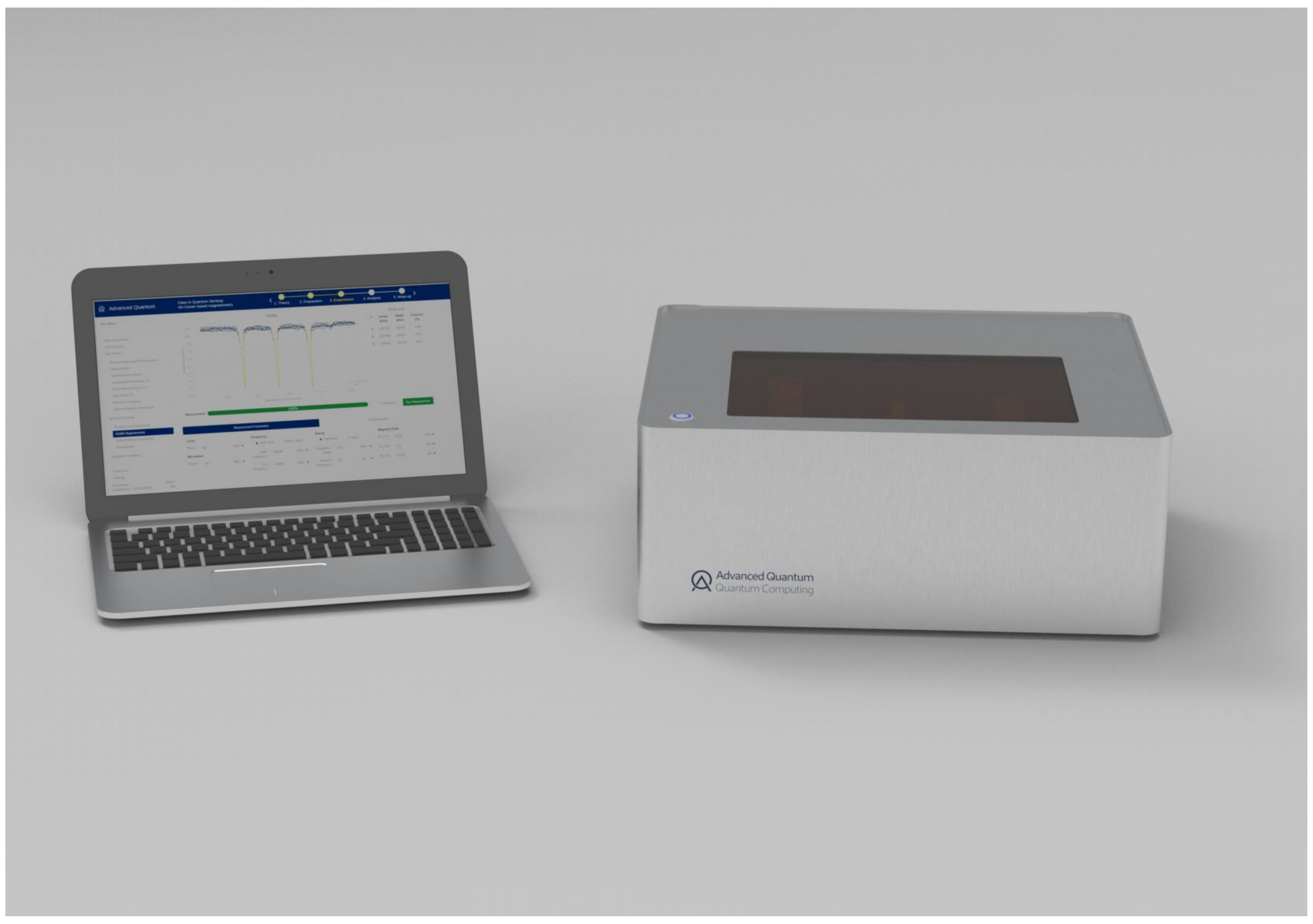
KompaQD
Compact quantum computing demonstrator

The KompaQD project is creating a compact and mobile two-qubit quantum computing demonstrator based on solid-state spins in silicon carbide. In addition to using the demonstrator for training and further education, the system demonstrates that quantum technology can also be used outside of laboratories.

- Solid-State Spin
- Quantum Computer
- Silicon Carbide



Motivation

Quantum computers are large, fragile systems and their theoretical foundations full of complex mathematics make them inaccessible and incomprehensible to the layman. We would like to counter these prejudices with a platform. The aim is to use a compact and mobile system to make the hardware and thus the fundamentals tangible, so that the interaction between the control electronics, the physical quantum system and thus the operational basis can be better communicated.
There are many different types of quantum computers – and each has its own pitfalls and tricks. This results in various advantages and disadvantages, which are often confused. The system provides a valuable bridge by answering the question: "What is fundamentally needed for a quantum computer?" and a simple demonstration of how an algorithm on a quantum computer can process information with fewer operations than on a classical computing system.

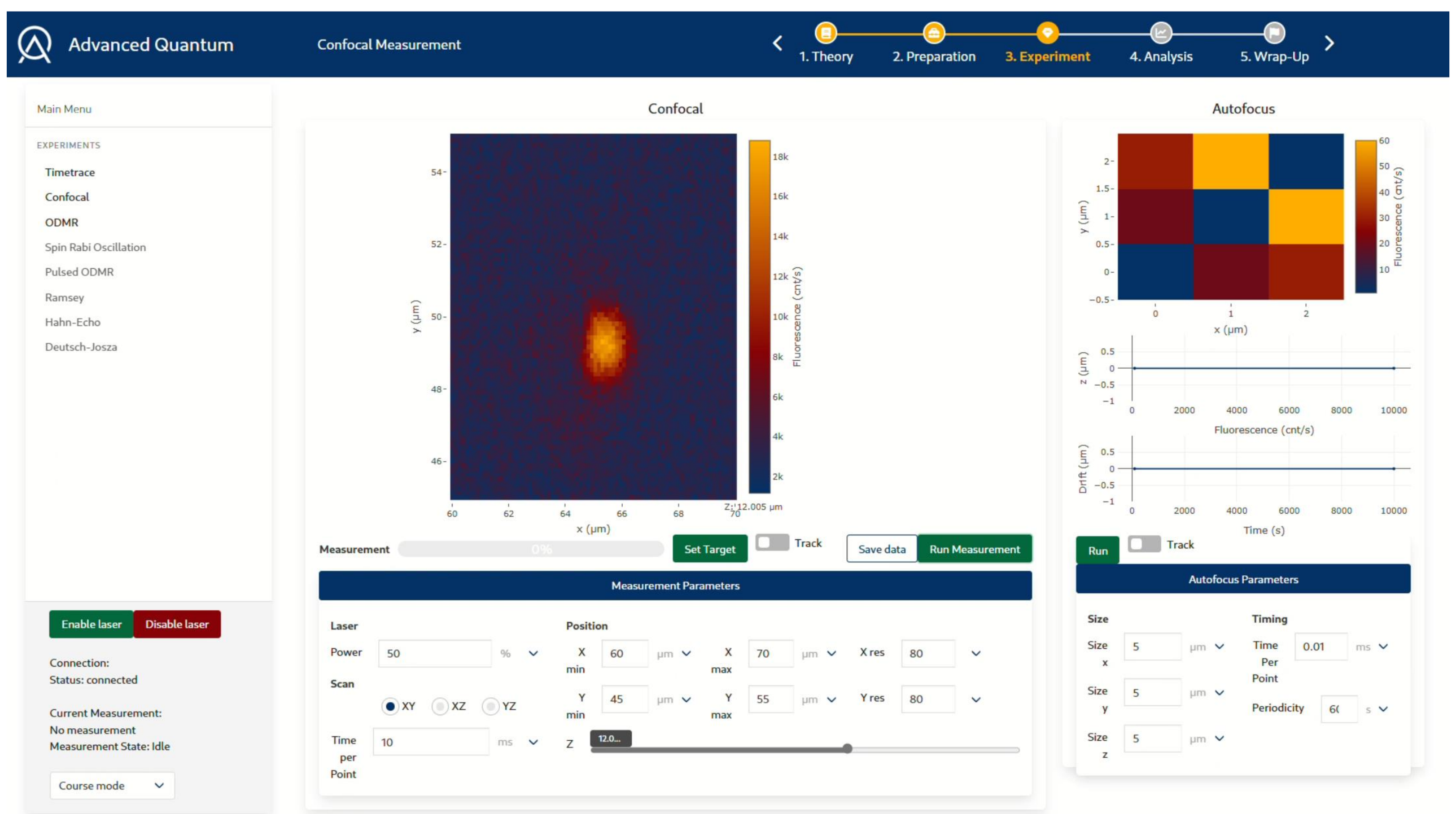
Challenge

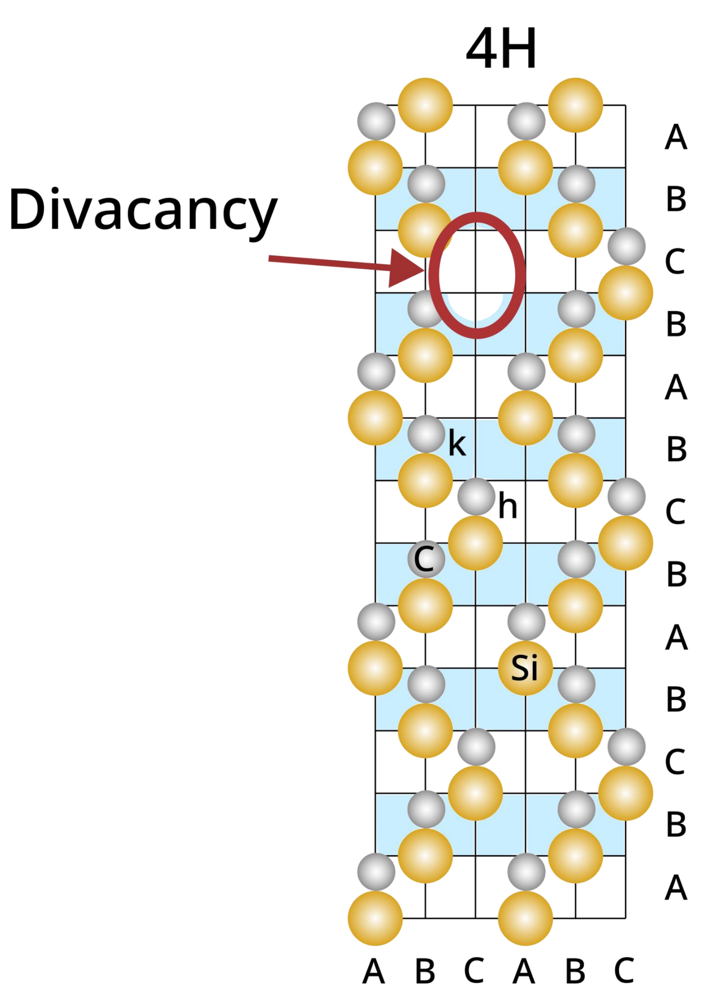
One of the innovations in the project is the use of silicon carbide as a base material. This material is already widely used in the semiconductor industry for power components, but is still a young technology in quantum technology. The advantages of the material lie in its availability, mature production technology and a large zoo of available defect centres with different properties for various applications. However, the new material platform also raises new issues, such as the integration of special detectors. Another challenge is the robust operation outside of laboratory environments and the compact design of the system. Temperature fluctuations, ambient noise and vibrations disrupt the sensitive quantum states. However, with clever solutions and engineering expertise, these challenges can also be overcome in a compact system.

Didactic Concept

The didactic concept provides for a browser-based, intuitive user interface that includes guided courses. These lead from the theoretical foundations of a chapter, through the preparation of the experiment to the experiment on the qubit itself. After that, the evaluation is made possible and the "lessons learned" are consolidated in a summary using questions.
Courses for users with different prior knowledge or objectives can be selected. The system can cover a wide range of levels, from explanations for people with no prior knowledge, such as those required for an exhibition at a trade fair, to courses for quantum physicists, and can be adapted to the respective needs.

This means, for example, that employees in a company can be given an introduction to the hardware-based implementation principles of qubits or the basis of quantum algorithms can be explained clearly. In terms of content, many courses are possible, from the basics of optics, microscopy, fluorescence, magnetic spin resonance & nuclear spins, coherence times, DiVicenzo criteria to the derivation of the requirements for control technology & electronics based on the quantum mechanical principles.





Material and Qubits

The host material used for the spin qubits of the quantum computing demonstrator is silicon carbide (SiC). SiC is characterized by one of the lowest spin-phonon interactions of all solids and thus shows the longest qubit relaxation times. SiC has a polytype-dependent band gap in the range of approx. 2.5 to 3.3 eV, so that qubits can be optically addressed. SiC contains numerous color centers that have an electron spin and can serve as qubits. In this project, solid-state spins of PL6 or PL5 centers in SiC are used. Their exact constitution is still unknown, but they are associated with the divacancy center. The divancacy center in 4H silicon carbide (red circle) is formed from the absence of a silicon atom (yellow) and a carbon atom (gray) at neighboring lattice sites. The 4H polytype results from the stacking order of the different layers in sequence ABCB, where four indicates the stacking periodicity and H indicates a hexagonal lattice structure.

Target Groups

For a successful didactic concept, a targeted approach to a well-defined target group is crucial. Thanks to the flexible, integrated digital course system, several target groups with different levels of knowledge can be addressed even within one course. The following target groups should be addressed:

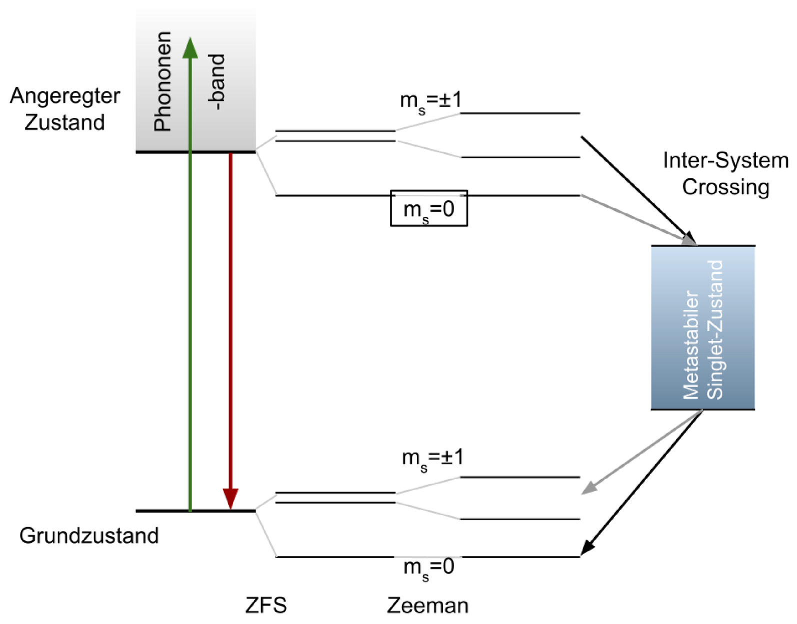
- Training of new employees within the DLR QCI
- Non-specialist audience at trade fair appearances (public outreach)
- Introductions and training for potential industrial users.

Training Material

The browser-based user interface allows the course content to be adapted to the target group and the necessary prior knowledge. The training materials primarily consist of courses integrated into the system. The browser-based interface allows the training materials to be designed interactively, which helps to improve the learning and demonstration effect.

Energy Level Scheme

Zero-field splitting due to crystal field, Zeeman splitting and non-radiative relaxation path to spin-state polarization are shown.



More information about the project on our website

A project of
Deutsches Zentrum für Luft- und Raumfahrt

Contractor
Advanced Quantum

Contact
Kim Demian Kafenda
Matthias Niethammer

Get in touch. We enable quantum!

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag