Why Fraunhofer IAF?

Together with national and international partners from science and industry, Fraunhofer IAF contributes to building a European ecosystem of powerful quantum systems and to quickly bring the advantages of this key technology into application. Thanks to the expertise of its researchers, its large network, and its unique research infrastructure, the institute covers the entire quantum computing value chain: from material generation and the development of quantum processors to the optimization of algorithms.

In addition, Fraunhofer IAF has decades of experience in running complex international research projects and collaborating with customers from industry and small and medium-sized enterprises. This enables an equally efficient and flexible cooperation in the application-oriented research and development of innovative quantum technologies as well as in the customized implementation of orders.

What we offer:

- Generation of spin qubits based on NV centers in diamond
- Exploration of spintronic quantum gates and registers with high quality
- Development of scalable quantum processors
- Design and construction of peripherals for hybrid computing architectures
- Application-specific testing of algorithms on different hardware architectures

Would you like to learn more about our research activities and range of services in the field of quantum computing? We will be happy to present our work and various cooperation opportunities to you in person.

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Quantum computing based on NV centers and nuclear spins in diamond

Spin qubit quantum computing

Enabling scalable and hybrid computing architectures

Fraunhofer IAF is working on different approaches for the realization of qubits that ensure longest possible coherence times, small error rates, low resource consumption, high connectivity, and good scalability. One particularly promising approach is the generation of qubits based on nitrogen-vacancy (NV) centers in diamond connected by spin coupling.

Creating flexible quantum advantages

Diamond-based spin quantum processors have the potential to form the basis of superior quantum computers as well as to be connected to classical computers to combine the advantages of both worlds in hybrid architectures. This is because the technology does not rely on cryogenic cooling, yet maintains entanglement for a long time and couples qubits in large numbers and over large distances.

Fields of application

- Superior computing architectures for complex problems
- Edge computing for medical technology, satellite constellations, robotics and autonomous systems
- Molecular dynamics simulations for predicting complex quantum chemical reactions

NV centers and spins in diamond

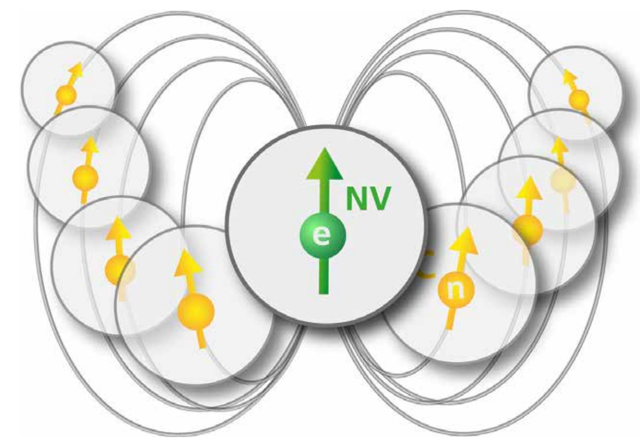
In the construction of a spin-photon quantum computer, local registers of qubits are realized by coupling spins to photonic resonators, allowing minutes lasting coherence times while maintaining high connectivity within each register. These registers are connected via optical networks to form a quantum processor, which enables a universal quantum computer with fully programmable connectivity of the registers.

In this way, two-qubit gates can be implemented both locally, within a register, and globally, between two registers. With this architecture, the researchers combine three key advantages of a solid-state-based spin-photon system:

- Precise quantum control
- Long coherence time
- Strong spin-photon coupling

Spin-coupled quantum registers

To realize scalable quantum processors, researchers at Fraunhofer IAF also use spintronic quantum registers built on optically addressable NV centers in diamond: Here, the electron spin of an NV center is used as a read-in and read-out qubit and coupled to about ten nuclear spins of surrounding ^{13}C atoms. Since the strength of the coupling between the electron spin and the ten nuclear spins far exceeds their decoherence rate, two-qubit gates can be realized between electron spin and nuclear spin or between nuclear spins (indirectly coupled via electron spins). In addition, the individual nuclear spins are used as one-qubit gates.



Electron spin of a NV center coupled to eight nuclear spins

In addition to the ten or so strongly coupled nuclear spins, the quantum register contains another 20 to 40 nuclear spins, which are more weakly coupled to the electron spin of the NV center due to their greater distance and are used to build a quantum memory.