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Hybrid Quantum Systems with Rare-Earth Spin Ensembles

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Quantum communication networks are considered to distribute entangled states over a large scale computing architecture. The core elements of future quantum networks, i.e., quantum repeaters as well as network nodes, can be realized by using qubits and quantum memories of diverse physical nature. Solid-state systems such as superconducting quantum circuits, nanomechanical devices, and spin doped solids potentially offer larger scalability and faster operation time compared to systems based on the single atom approach. However, such solid-state devices operate at microwave and rf's, which are less suitable for long-range quantum communication than optical channels due to losses in cables and the high noise temperature of antennas. To establish a fiber-optical link between them, one has to use a quantum media converter, i.e., a device which coherently interfaces matter and photonic qubits.

One of the promising ways towards implementation of such a converter relies on using optically active spin ensembles in a hybrid quantum architecture. Among these, rare-earth (RE) ion doped crystals are very attractive for application in hybrid systems due to their high spin tuning rate and long optical and spin coherence time. Yet only erbium ions offer a unique opportunity of a coherent conversion of microwave photons into the telecom C band at 1.54 μm, which is used for long distance fiber-optical communication.

In my talk, I will overview the field of hybrid quantum systems and will present our recent microwave circuit-QED experiments with different erbium spin ensembles at millikelvin temperatures.

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