Coherent coupling between ferromagnetic magnon and superconducting qubit

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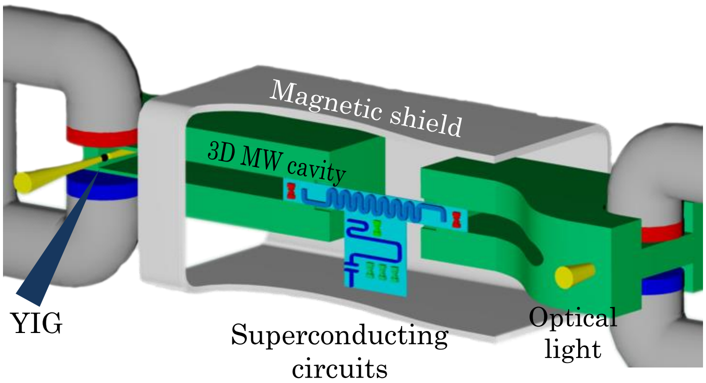
Coherent coupling between paramagnetic spin ensembles and superconducting quantum circuits is now widely studied for quantum memories and microwave-to-optical quantum transducers. One of the ultimate applications that use memories and transducers is a quantum repeater. A quantum repeater has two or more optical inputs/outputs to connect adjacent nodes, processes information from others, and sends photons according to a protocol. Superconducting qubits are a promising candidate for building quantum information processors. Fast and precise control, long coherence time up to 0.1 ms, as well as accurate measurement have been experimentally demonstrated.

Here, we propose a novel quantum repeater in which superconducting qubits sit as a memory and processors. To send and receive photons to/from adjacent nodes, it incorporates quantum transducers, which coherently converts quantum information in optical photons to that in microwave circuits, for our case, superconducting qubits. The figure below shows a scheme of our quantum repeaters. An incoming optical photon is coherently converted to an excitation in a superconducting qubit. The superconducting circuits successively process the information, for example, unitary operations, entangling and disentangling of excitations, and measurements.



The key feature in our microwave-to-optical transducer is that it incorporates a ferromagnet as a converter material. Given that quantum transducers require fast and accurate conversion, the collective excitations (magnons) in ferromagnetic spins need to couple strongly with microwave fields, and have enough coherence time. We focus on yttrium iron garnet (YIG), a typical ferromagnetic insulator, which is known to have a high spin density of ~10^{22} spins/cm^3 and a narrow ferromagnetic-resonance (FMR) linewidth.

In this poster, we demonstrate strong coupling between a 3D microwave cavity and the uniformly precessing spin mode as a first step. We further demonstrate coherent control and measurement of magnons using superconducting circuits. Our approach provides a versatile tool for control and measurement of the magnon excitations in the quantum regime, and opens a path toward superconducting-qubit-based quantum repeaters.