Optically detected spin transitions in an Er-doped whispering-gallery resonator

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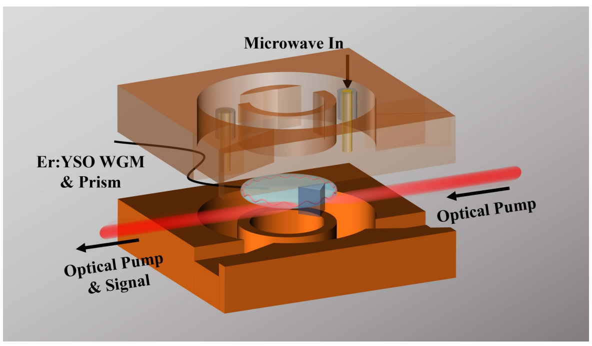
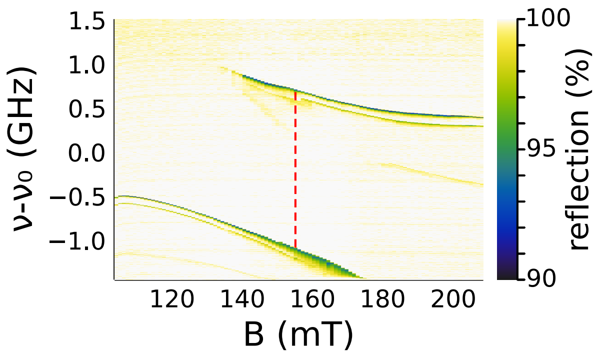
Whispering-gallery resonators are well known for being monolithic optical cavities with high quality factors (Q) and low mode volumes. We present a cryogenic (4 K) erbium-doped resonator with a Q exceeding 10^8 only 10 GHz away from an erbium optical transition. This optical resonator is embedded in a microwave cavity, designed such that the magnetic field of the microwave resonance should overlap with the optical mode, see Fig. 1(a).

The optical modes in such a resonator are strongly coupled to collective transitions of the erbium ions. Fig. 1(b) shows an optical mode, which is split by 1.8 GHz due to an optical transition, which is tuned by magnetic field. The microwave resonator likewise allows us to probe the spin transition within the Zeeman-split ground state.

We present a scheme based on optically-detected magnetic resonance (ODMR) to better characterise the microwave–optical response of the device by measuring the microwave response of only those ions that lie within the optical mode volume. Such a measurement allows us to characterise the system for possible future use of microwave–optical transduction, which will be useful to interconnect superconducting qubits through room-temperature links.



(a) Optical and microwave resonators



(b) Optical mode shift with magnetic field

Figure 1: (a) The erbium-doped Y_2SiO_5 whispering-gallery-mode resonator (Er:YSO WGM) sits in a microwave resonator. The setup is mounted inside a cryostat with a temperature of 4 K. An external microwave field can be applied by a superconducting magnet. (b) An optical mode with a frequency of $\nu_0 \approx 195$ THz shows an avoided crossing of 1.8 GHz (red line) due to coupling to an erbium transition.