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(G*) Optomechanical interface between telecom photons and spin quantum memory

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Optically active defects in solids—colour centres—are one of the most promising platforms for implementing quantum technologies. Their spin degrees of freedom serve as quantum memories that in some cases can operate at room temperature. Their control can be achieved with microwave spin control and resonant optical excitation but is hindered by the broadening of optical transitions from thermal phonons and spectral diffusion. Furthermore, spin-qubit optical transitions are often outside the telecommunications wavelength band required for long-distance fiber optic transmission. Harnessing the coupling between mechanical degrees of freedom and spins has emerged as an alternative route for controlling spin-qubits. However, connecting spin-mechanical interfaces to optical links to realize a spin-photon interface has remained a challenge. Here we demonstrate such an interface using a diamond optomechanical cavity that does not depend on optical transitions and can be applied to a wide range of spin qubits.

Our device consists of a diamond microdisk resonator studied in [Optica 3, 963-970 (2016)]. The microdisk is fabricated from optical grade diamond that contains ensembles of NV centres. We use an optical mode at 1564 nm with the quality factor Qo = 150k. The mechanical mode which we use to couple to the NV spin state is a radial breathing mode with a frequency of around 2.1 GHz with the quality factor Qm = 4k. The device operates in the sideband resolved regime enabling optomechanical self-induced oscillations for sufficiently high optical input power of a blue detuned laser. These oscillations can produce the stress of a few MPa, large enough to drive the electronic spins of NV centers. We use a standard diamond NV confocal microscope to initialize and readout the NV state. The MW pulses transfer the population between |-1⟩<->|0⟩ and |+1⟩<->|0⟩ state. We wait for 0.7 us with the mechanical drive that drives the |-1⟩<->|+1⟩ transition.

In our measurements, we observe a coinciding dip in the |+1⟩ population and a peak |-1⟩ population, that verifies that the spins are being optomechanically driven. On calibrating this signal with the MW Rabi contrast and the background signal, we estimate a driving rate of 2pix170kHz and ˜45% transfer of spin population between |±1⟩ states. Feasible improvements in device geometry will increase the optomechanically-induced driving rate by a few orders of magnitude allowing for coherent control of NV spins using an optomechanical resonator.

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