Coupling Microwave Cavity Fields to Nitrogen-Vacancy Centres in Diamond using Spherical Dielectric Resonators for Magnetic Sensing Applications

Ali Fawaz[a,b], Lyra Cronin[a,b], Gavin Brennen[a,b], Sarath Raman Nair[a,b] and Thomas Volz[a,b]

[a]*School of Mathematical and Physical Sciences, Macquarie University, New South Wales 2190, Australia.*

[b]*Centre of Excellence in Engineered Quantum Systems, Macquarie University, New South Wales 2190, Australia*

We investigate the coupling of microwave cavity fields to an ensemble of Nitrogen-Vacancy (NV) centre spins using a new and original spherical dielectric resonator arrangement. The need for coupling fields to spins using resonators is vital since natural coupling between electronic spins and electromagnetic fields is generally weak. With the electronic spin transition of NV centres situated in the microwave region of the electromagnetic spectrum, spin manipulation is performed with microwave fields. Microwave fields coupled to NV centres are essential for phenomena such as superradiance masing action [1][2] and techniques to enhance spin-readout for magnetic field sensing [3] with broad applications such as nanoscale sensing, astronomy, metrology and telecommunications. Due to their morphology and dielectric properties, spherical dielectric resonators are known to exhibit Mie resonances [4]. When two spherical resonators are spatially separated, microwave hotspots are formed between the resonators . We aim to demonstrate that the microwave hotspots formed by spherical dielectric resonators can be used to couple microwave fields to NV centres and serve as a low power, robust, and novel way of reaching higher spin-photon coupling strength.

[1] Q. Wu et al. A superradiant maser with nitrogen-vacancy center spins. Science China Physics, Mechanics & Astronomy, 65(1):217311, January 2022.

[2] J.D. Breeze et al. Continuous-wave room-temperature diamond maser. Nature, 555(7697):493–496, March 2018.

[3] E.R. Eisenach et al. Cavity-enhanced microwave readout of a solid-state spin sensor. Nature Communications, 12(1):1357, December 2021.

[4] B.R. Johnson. Theory of morphology-dependent resonances: shape resonances and width formulas. Journal of the Optical Society of America A 10(2), 343 (1993). URL https://opg.optica.org/abstract.cfm?URI=josaa-10-2-343.