Quantum Advantage in Multiparameter Sensing

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Abstract

Quantum sensors exploit the strong sensitivity of quantum systems to external disturbances to measure various signals in their environment with high precision [1]. These quantum sensors have the potential to be a revolutionary tool in material science, quantum information processing, and bioimaging. In addition to reaching novel sensing regimes, e.g., at the nanoscale, quantum sensors can provide a "quantum advantage" by exploiting quantum coherence and entanglement. Here I will show how we can use additional degrees of freedom – either synthetic ones introduced via driving, or ancillary qubits – to perform quantum sensing tasks that are not otherwise possible. These quantum-enhance sensors can for example improve the sensing bandwidth, by acting as a frequency mixer [2]. By further coupling to ancillary qubits, we can not only exploit entanglement to improve the sensitivity but also detect targets that are outside the coherence volume of the quantum sensor [3]. Multi-qubit sensors are needed in particular to perform multiparameter sensing, a frontier for quantum metrology [4]. Sensing the vectorial components of a field or its spatial variations provides important information about the underlying processes that generate it. Performing such measurement in an efficient way, and ideally at the quantum limit, is still a challenge, especially in the presence of noise and control imperfection, that can be tackled using ancillary qubits and control [5].
Overall, these novel sensing modalities expand the reach of quantum sensor applications to provide more robust and versatile devices.

References

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Figures

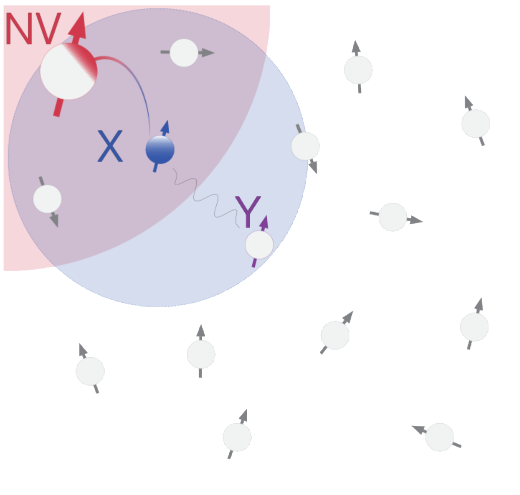

Figure 1: Controlling a dark spin (blue) coupled to a Nitrogen-Vacancy (NV) centre in diamond (red) enables sensing a target spin (purple) that lies outside the coherence volume of the NV, that is, whose coupling is too weak to be sensed within the NV coherence time (adapted from [3]