Theory of Single Photon Detection by a Photoreceptive Molecule and a Quantum Coherent Spin Center

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The long spin coherence times in ambient conditions of color centers in solids, such as nitrogen-vacancy (NV^{-}) centers in diamond, make these systems attractive candidates for quantum sensing. Quantum sensing provides remarkable sensitivity at room temperature to very small external perturbations, including magnetic fields, electric fields, and temperature changes. A photoreceptive molecule, such as those involved in vision, changes its charge state or conformation in response to the absorption of a single photon. We show the resulting change in local electric field modifies the properties of a nearby quantum coherent spin center in a detectable fashion. Using the formalism of positive operator values measurements (POVMs), we analyze the photo-excited electric dipole field and, by extension, the arrival of a photon based on a measured readout, using a fluorescence cycle, from the spin center. We determine the jitter time of photon arrival and the probability of measurement errors. We predict that configuring multiple independent spin sensors around the photoreceptive molecule would dramatically suppresses the measurement error[1].

[1] N. J. Harmon and M. E. Flatté, arXiv:1906.01800