Photon counting statistics in nitrogen vacancy centres

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Nitrogen vacancy (NV) centres in diamond are promising candidates for use in a variety of quantum computing and sensing applications due to their unique optical and spin properties. These defects in the diamond lattice consist of a nitrogen atom adjacent to a vacancy in the carbon lattice. They can be initialized and read out using laser excitation, making them suitable for use as qubits and nanoscale sensors. When an NV centre is optically excited, it can absorb a photon and transition to an excited state, and then relax back to its ground state by emitting a photon.

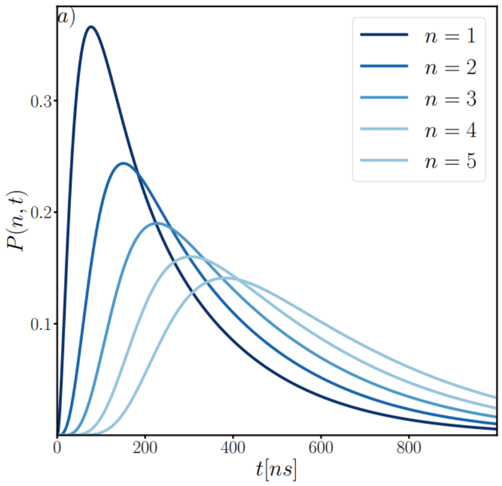

Figure 1. Probability P(n,t) of emitting n photons by an NV excited by a green laser as a function of time.

The photon counting statistics of light sources a crucial aspect in determining their performance [1-6]. These statistics provide information about the probability of detecting a certain number of photons over a specific time interval and can be used to assess the degree of bunching or antibunching in photon emission, as well as the distinguishability of the interrogated quantum state. Understanding how we can physically discriminate the state of our NV center helps us to better understand its behaviour and develop techniques to optimize the state readout [7, 8, 4]. Furthermore, the study of photon statistics enables the examination of sensitivity and quantum fluctuations within a system and allows for accurate predictions of the number of detected photons in an experiment [9, 10]. Photon counting statistics are relevant because are a phenomenological framework that relates what we want to measure, the quantum state of our NV centre, with what we measure at the lab, the stream of photons that arrive at the detector. In this work, we apply a quantum jump formalism to an energy level model of the NV centre to derive the photon emission statistics, as seen in Figure 1. We use this result to better understand the dynamics of the NV centre in different scenarios. We analyse the autocorrelation function from the photon statistics and compare them with experimental measurements and discuss how these statistics allows to optimize the state readout through the Chernoff information. We can use this model to simulate characterization measurements such as the saturation curve of the NV and continuous wave ODMRs.

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