

Precession-induced nonclassicality of the free induction decay of NV centers by a dynamical polarized nuclear spin bath

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The ongoing exploration of the ambiguous boundary between the quantum and the classical worlds has spurred substantial developments in quantum science and technology. Recently, the nonclassicality of dynamical processes has been proposed from a quantum-information-theoretic perspective, in terms of witnessing nonclassical correlations with Hamiltonian ensemble simulations. To acquire insights into the quantum-dynamical mechanism of the process nonclassicality, here we propose to investigate the nonclassicality of the electron spin free-induction-decay process associated with an NV⁻ center. By controlling the nuclear spin precession dynamics via an external magnetic field and nuclear spin polarization, it is possible to manipulate the dynamical behavior of the electron spin, showing a transition between classicality and nonclassicality. We propose an explanation of the classicality-nonclassicality transition in terms of the nuclear spin precession axis orientation and dynamics. We have also performed a series of numerical simulations supporting our findings. Consequently, we can attribute the nonclassical trait of the electron spin dynamics to the behavior of nuclear spin precession dynamics.

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