Low-Temperature Photophysics of Single Nitrogen-Vacancy Centers in Diamond

J. Bocquel[1,*], J. Happacher[1], D.A. Broadway[1], H. Dinani[2], J.R. Maze[3], and P. Maletinsky[1]

[1]*Department of Physics, University of Basel, Switzerland*
[2]*Escuela de Ingeniería, Facultad de Ciencias, Ingeniería y Tecnología, Universidad Mayor, Santiago, Chile*
[3]*Facultad de Física, Pontificia Universidad Católica de Chile, Santiago, Chile*
[*]juanita.bocquel@unibas.ch

The Nitrogen-Vacancy (NV) center in diamond is a versatile spin system used in quantum sensing and quantum information processing due to its outstanding quantum coherence properties. Practical applications at low temperatures, such as remote spin-spin entanglement and nanoscale magnetic imaging, rely on efficient optical NV spin initialization and readout, two key features emerging from properties of the NV's orbital excited states.

Here we present the magnetic field dependent photophysics of individual NV centers under cryogenic conditions [1]. At distinct magnetic fields, we observe significant and unwanted reductions in the NV photoluminescence rate, which we assign to excited state level anti-crossings. We observe these dips at specific magnetic fields which strongly depend on the effective field, a combination of the local strain and the electric field environment, experienced by the NV center. These results demonstrate a new way to efficiently characterize the structure of the NVs' excited states. Using this method, we investigate their strain-dependent evolution from cryogenic to room temperature [2]. All our observations are in excellent agreement with our extensive theoretical model. This advances our fundamental understanding of the NV photophysics and gives new perspectives for mitigating the decrease of spin contrast at low temperatures. We also show electrometry and vector electric field tuning of a single NV center, which allow for significant strain-splittings and the near complete restoration of the C3v symmetry of the NV. This way, we establish an electromagnetic field sensing scheme at cryogenic temperatures, which leverages the NV's orbital excited states' high sensitivity to electric fields. This all-optical sensing approach achieves a higher electrometry sensitivity compared to techniques relying on optically detected magnetic resonance [3].

References

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