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Controlling geometric phase optically in a single spin in diamond[1]

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Geometric phase, or Berry phase, is an intriguing quantum mechanical phenomenon that arises from the cyclic evolution of a quantum state. Unlike dynamical phases, which rely on the time and energetics of the interaction, the geometric phase is determined solely by the geometry of the path travelled in parameter space. As such, it is robust to certain types of noise that preserve the area enclosed by the path, and shows promise for the development of fault-tolerant logic gates. Here, we demonstrate the optical control of geometric phase within a solid-state spin qubit, the nitrogen-vacancy center in diamond[3]. Using stimulated Raman adiabatic passage (STIRAP), we evolve a coherent dark state along 'tangerine slice' trajectories on the Bloch sphere and probe these paths through time-resolved state tomography. We then measure the accumulated geometric phase through phase reference to a third ground spin state. In addition, we examine the limits of this control due to adiabatic breakdown as well as the longer timescale effect of far-detuned optical fields. Finally, we intentionally introduce noise into the experimental control parameters, and measure the distributions of the resulting phases to probe the resilience of the phase to differing types of noise. We also examine this robustness as a function of traversal time as well as the noise amplitude. Through these studies, we demonstrate that geometric phase is a promising route toward fault-tolerant quantum information processing.

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[2]In collaboration with F. J. Heremans, B. B. Zhou, A. Auer, G. Burkard, and D. D. Awschalom.

[3]C. G. Yale*, F. J. Heremans*, B. B. Zhou,* A. Auer, G. Burkard, D. D. Awschalom, *Nature Photonics*, **10**, 184 (2016).