# Robust mode conversion in NV centers using exceptional points

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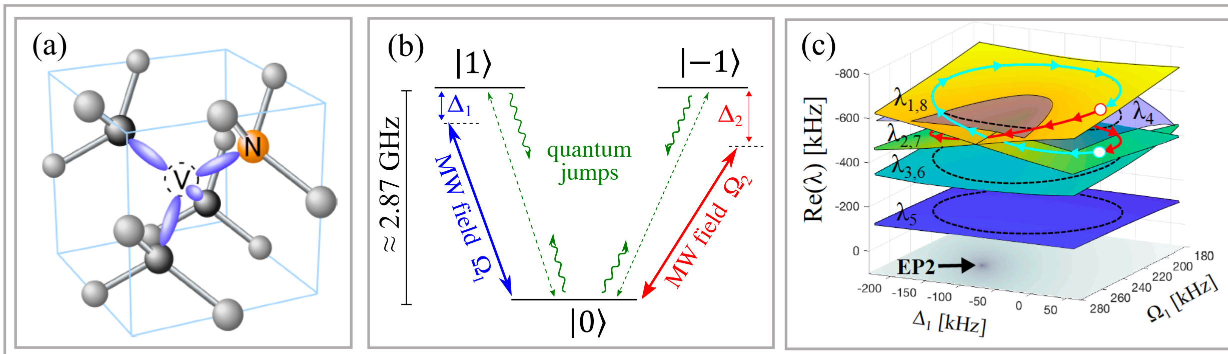
A new class of adiabatic protocols enables robust mode conversion in open systems that possess a special degeneracy called an exceptional point (EP), where multiple modes of the system coalesce [1]. EP-based mode switches have intriguing physical properties, such as topological protection and nonreciprocity [2], which were demonstrated experimentally in optical waveguides and optomechanics [3] and theoretically proposed for several additional systems [4]. Realizing robust nonreciprocal mode switching in quantum systems may have far-reaching consequences in quantum information processing and coherent control. In this talk, I will show how to realize EP-based mode switches in atomic and atom-like systems.

While previous work on EP-based mode switches applies only to pure states, the theoretical description of atom-like systems typically requires mixed states—statistical ensembles of different pure states—which evolve under the Lindblad master equation. To bridge this gap, we develop a theory of mode switching between mixed states. Our protocol applies to arbitrary three-level systems in the V configuration, and we perform numerical simulations using empirical parameters of nitrogen-vacancy (NV) centers—defects in diamond with exceedingly long coherence lifetimes and established mechanisms for initialization, manipulation, and readout of their spin state [5]. Our theory enables exploring new phenomena (e.g., high-order EPs in low-dimensional systems) and presents a crucial step toward incorporating EP-based mode switches in quantum technology. Our work provides guidelines for coping with the main challenges for experimental realization of this protocol: decoherence and mixed-state preparation. Key concepts of mode-switching in NV centers are explained in the figure.




(a) The NV center consists of a substitutional nitrogen and an adjacent vacancy in diamond (figure borrowed from Ref. 5). (b) Three lowest energy levels of the negatively charged NV center. Microwave fields drive transitions between the $|0\rangle$ and $|\pm1\rangle$ states, with Rabi frequencies $\Omega_{1,2}$ and detunings $\Delta_{1,2}$. Interaction with the environment causes incoherent quantum jumps. (c) Eigenvalues of the Lindblad master equation ($\lambda_1, \dots, \lambda_8$) are multivariate functions of the parameters ($\Omega_1$ and $\Delta_1$). The eigenmodes swap when encircling the EP, e.g., a system initially prepared in at the red point (i.e., in the state $\lambda_1$ or $\lambda_8$) evolves adiabatically into the cyan point (i.e., $\lambda_2$ or $\lambda_7$).

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