Master project: A strongly driven NV-center as accurate magnetometer
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The simple canonical setup of a strongly driven two-level system (where one level is periodically swept through the other) is well understood and forms by now textbook material. But in reality, when strong driving is applied to a quantum device, often *more* than two levels are intrinsically at play. Theoretical work on the resulting multi-level quantum dynamics is however sparse.

Recently, I started investigating these multi-level dynamics, first for the (simplest) case of a *three*-level system where one level is periodically swept through a pair of static levels [1]. We discovered a new type of three-level resonance, appearing whenever the splitting between the static levels matches the driving frequency. These results were not only fundamentally interesting, but also provided an explanation for recent experimental data measured on strongly driven double quantum dots [2].

Going one step further, one could also think of actual applications of these three-level resonances: The low-energy part of the spectrum of a negatively charged NV-center in diamond consists actually of three levels (the three two-electron states with total spin $S = 1$, their relative energies are sketched in Fig. 2a). The splitting between the upper two levels (with $m_s = \pm 1$) only depends on the external magnetic field, to very high precision. Therefore, if we could measure this splitting accurately, the NV-center could be used as a very sensitive magnetometer.

Within a rotating-wave approximation, the effect of an oscillating magnetic field $\tilde{B}\cos(\omega t)$ on this three-level system is (i) a shift $E_3 \to E_3 + \hbar\omega$ and (ii) a coupling of strength $\frac{1}{2}\tilde{B}$ between level 3 and levels 1 and 2. One would thus expect that if we *modulate* the driving frequency in time, $\omega \to \omega(t)$, but do this modulation slowly compared to $\omega(t)$ itself, we can separate time scales, and E_3 effectively becomes time-dependent with $\hbar\omega \to \hbar\omega(t)$. We thus can imagine that a driving field $\tilde{B}\cos\left[g(t)\right]$, with an 'instantaneous driving frequency' $\hbar\omega(t) = \hbar\frac{d}{dt}g(t) = \varepsilon_0 + A\cos(\tilde{\omega}t)$, produces a time-dependent spectrum as shown in Fig. 2b, which is exactly that of the driven three-level system investigated in [1]. The three-level resonances would now appear whenever $E_1 - E_2$ matches the driving frequency: a resonant response in the experiment would thus provide a direct quantitative measure of the magnitude of the external magnetic field.

We should carefully investigate the regime of validity of the rotating-wave approximation when using a non-monochromatic field $\tilde{B}\cos\left[g(t)\right]$, and understand the limits of applicability of standard Landau-Zener theory in a rotating frame. If we can find a useful parameter regime where the proposal works, then it will be better than most other ideas for NV-center-based magnetometry.

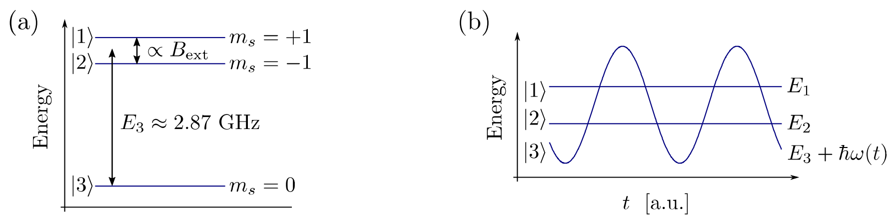

Figure 2: (a) Level structure of the three lowest levels of a negatively charged NV-center in diamond, in the presence of an external magnetic field. (b) Spectrum of the driven three-level system investigated in [1].

[1] J. Danon and M. S. Rudner, Phys. Rev. Lett. **113**, 247002 (2014).
[2] E. A. Laird et al., Semicond. Sci. Technol. **24**, 064004 (2009);
J. Stehlik et al., Phys. Rev. Lett. **112**, 227601 (2014).