**Field-Induced Narrowing and Broadening of a Magnetic Resonance**

**in a Bichromatic Microwave Field**

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We report on theoretical and experimental work with bichromatic driving of a spin system by two equally strong, nearly degenerate fields. Such perturbation enables addressing populations of individual spin states, characterization of their interaction with thermal bath, and measurements of their relaxation/decoherence rates.

With such addressing in an open two-level system we observe nested composite magnetic resonances with widths having nontrivial dependence on microwave (MW) field intensity: while the width of one of the MW-resonances undergoes strong power broadening, the other one exhibits peculiar MW-field-induced stabilization.

Our theoretical modelling based on coherent population oscillations [1] very well explains these observations and relates the phenomenon with the dynamics of the bright and dark superposition states and their interaction with the reservoir. Specifically, we have found that the analysis of the structure of the composite resonances and their power broadening offer a sensitive way of studying the relaxation/decoherence mechanism of spin ensembles. Since the Fourier transform of the composite resonances represents multiexponential decay of populations and coherence of the system [2], the developed methodology provides a useful alternative to standard time-resolved studies of spin dynamics. This two-field methodology enables addressing of individual spin states and studies of their interaction with environment which is impossible with standard measurements where the resonances are jointly affected by both relaxation rates. In particular, relaxation rates of the unperturbed populations of individual states and their coherence can be determined with high accuracy.

To verify theoretical analysis, we have performed experiment with ensemble of nitrogen vacancy (NV) color centers in diamond crystal excited by a green light and perturbed by two microwave (MW) fields of comparable strengths and nearly resonant frequencies. By studying the composite resonances we have demonstrated that their components are indeed very differently perturbed by MW field: while one component is strongly power-broadened, the other is nearly broadening-free. We regard this behavior as *field-induced narrowing* or *stabilization* of spin states by strong driving field and interpret it as analogy to the well-known quantum interference effect with dark and bright state superpositions. We also demonstrated light-power narrowing of these composite resonances.

Although the reported theory and measurements are focused on spin ensemble in NV diamond, the analysis and discovered phenomena are quite general and may be applied for precision characterization of spin dynamics of various paramagnetic samples.

*Acknowledgements*: Financial support of the Polish National Science Centre (NCN, grant no. 2016/21/B/ST7/01430), and Ministry of Science and Higher Education (7150/E-338/M/2018) is greatly acknowledged.

REFERENCES

[1] M. Mrózek, A. Wojciechowski, D. Rudnicki, J. Zachorowski, P. Kehayias, D. Budker, W. Gawlik, *Coherent
 population oscillations with nitrogen-vacancy color centers in diamond,* Phys.Rev. B **94**, 035204 (2016); and to be
 published (2019)

[2] J. Flakowski, M. Osmanov, D. Taj and H. C. Öttinger, *Biexponential decay and ultralong coherence of a
 qubit*, European Physics Letters, **113**, 40003 (2016)