Single and Multi-Photon Coherent Transition in a Detuned Regime

Chiorescu, I. (NHMFL-FSU); Bertaina, S. (CNRS-Marseille, France); Martens, M. (NHMFL-FSU); Eggels, M. (CNRS-Marseille, France); Barakel, D. (CNRS-Marseille, France)

Introduction

We have studied a quasi-harmonic 6 level system corresponding to the quasi-isotropic spin S=5/2 of Mn highly diluted in MgO. In the past, during Dr. Bertaina's tenure at MagLab as a postdoc, we performed single and multi-photon Rabi oscillations [1,2], using the NHMFL facilities. The measurements demonstrated the possibility of coherently manipulating spin states in such a multi-level quantum system. The equipment specification imposed that we used a single tone (or resonant frequency) to excite the system at resonance with the applied Zeeman field. We are currently studying the use of a double-tone to excite and then read-out the spin state.

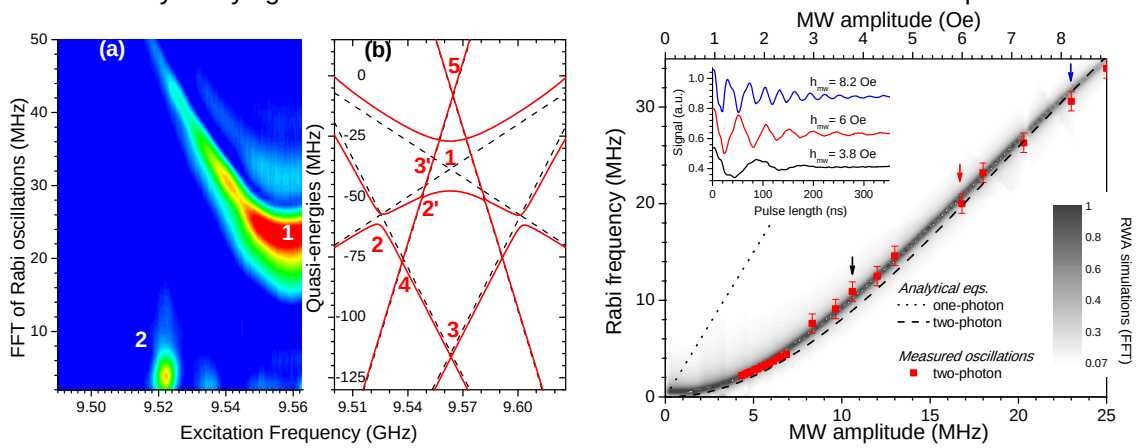

Fig.1 (left) (a) Fourier transform of coherent spin oscillations showing detuned (lateral increase for 1) single and double photon drives. At higher powers (not shown), 3 and 4 photon processes become evident. **(b)** Rotating frame eigenvalues of the spin Hamiltonian. The external field is at the 1,3,5-photon resonance, while the pump frequency can be detuned to match the 2 and 4-photon processes. **(right)** Rabi frequency for the 2-photon process vs microwave amplitude (red). The contour plot shows numerical simulations, while the dashed line is an analytical approximation. **Insert:** Three examples of Rabi oscillations for the 2-photon process, at powers as indicated by the small vertical arrows.

Experimental

The experiments were done at CNRS-Marseille in collaboration with Dr. Bertaina. The new double-tone protocol uses one off-resonance (or detuned) microwave pulse to excite the spin system anywhere in the rotating frame energy diagram (see Fig1 left b). A second pulse engineered to be in resonance with the ½ <-> -½ resonance (marked 1 in Fig1 left b) is used to read out the changes in spin population.

Results and Discussion

The new method allows to excite multi-photon resonances shifted away from the main resonance, as shown by the numbers "2" and "4" in Fig.1 left b. Moreover, by choosing a specific amount of detuning, the 1-photon resonance can be accelerated greatly, in agreement with the well-known Rabi formula in the detuned case. Fourier transforms of such Rabi oscillations are shown in Fig.1 left a. We can also perform a detailed study of the 2-photon resonance as a function of the applied microwave power (Fig.1 right). The results are in very good agreement with both numerical diagonalization results and an analytical approximation (dashed line).

Conclusions

We demonstrate a new and richer way to tap into the manipulation of quantum multi-level systems by using a double-tone technique. Thus, we can both accelerate Rabi oscillations by detuning and chose the number of photons of a particular spin transition.

Acknowledgements

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References

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[2] S. Bertaina, L. Chen, N. Groll, J. Van Tol, N.S. Dalal, I. Chiorescu, Phys. Rev. Lett. **102**, 050501 (2009).