On the Interactions Between a Cavity Mode and Fe_8 Single-Molecule Magnets

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Introduction

There is growing interest in the interaction of single-molecule magnets (SMMs) with electromagnetic radiation in an attempt to understand the coupling between photons and an ensemble of spins for applications in quantum information science. In fact, experimental evidence for quantum entanglement between photons and SMMs in the form of a vacuum-Rabi splitting of the EPR spectrum of an Fe_8–cavity system has recently been claimed [1].

Experimental

EPR experiments were carried out on a 0.05 mm^3 single-crystal of the Fe_8 SMM that was loaded into a transmission cavity. A spectrometer system was employed that is equipped with a Millimeter-wave Vector Network Analyzer (as a microwave source and detector) and a 7 T transverse superconducting split-pair magnet.

Results and Discussion

A 129.75 GHz cavity resonance mode was employed at a temperature of 1.9 K, at which essentially all of the S = 10 spins associated with the Fe_8 molecules occupy the ground m_s = -10 state. The ground state EPR transition from m_s = -10 to -9 for 129.75 GHz occurs at 0.56 T. The false-color contour plot of the transmission through the Fe_8-loaded cavity is shown in Fig. 1a. As can clearly be seen, the cavity resonance frequency is shifted and the transmission suppressed in the field range from 0.5 to 0.65 T.

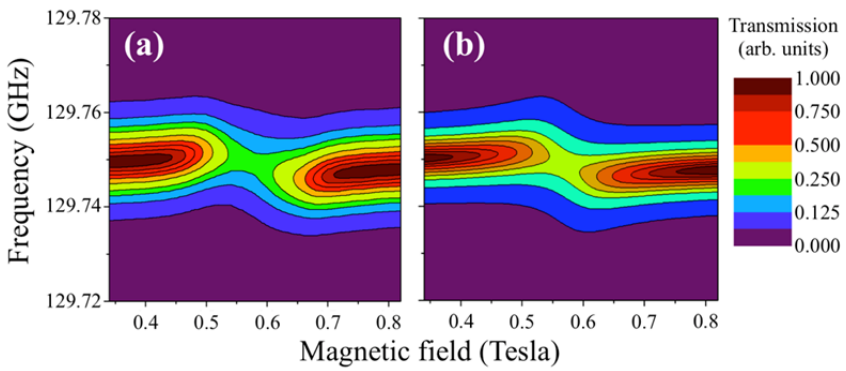

Figure 1. False-color contour plot of the perturbed cavity transmission as a function of field and frequency: (a) experimental data; (b) simulation.

From cavity perturbation theory, these phenomena can be simulated [Fig. 1(b)] using the following classical formula: $\Delta\widehat{\omega}/\widehat{\omega} = -\beta\hat{\chi}$, where $\widehat{\omega}$ the complex frequency, β is the filling factor that depends on the sample volume and the resonance mode, and $\hat{\chi}$ is the complex susceptibility that depends on the Maxwell-Boltzmann population of spin states. It is found that the frequency shift and transmission suppression follow the Maxwell-Boltzmann population when the temperature is varied, which confirms the applicability of classical cavity perturbation model in this case; evidence for vacuum Rabi splitting was not found.

Conclusions

It is found that the coupling between Fe_8 SMMs and a 129 GHz cavity mode can be perfectly explained by a classical cavity perturbation model at a temperature of 1.9 K, in contrast to what was previously reported [1].

Acknowledgements

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References

[1] Eddins, A.W., *et al.*, http://arxiv.org/abs/1210.7330.