Generating non-classical states of spins coupled to a cavity by optimal collective fields

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We investigate theoretically the generation of non-classical states of spins coupled to a common cavity by means of a collective driving of the spins. The system is similar to the one considered in recent high sensitivity electron spin resonance experiments [1, 2]. Our purpose is achieved by driving the cavity with coherent and squeezing control fields [3] (see Fig. 1).

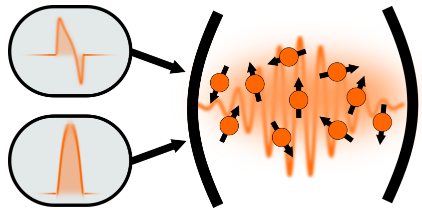

Fig. 1 : sketch of the system. The state of a spin ensemble coupled to a cavity is modified using a sequence of coherent and squeezing pulses.

We first analyze the controllability of the system and, using dynamical Lie algebra computation, we show the advantage of using squeezing fields in the generation of unitary transformations. Then, pulse sequences are designed by using numerical control techniques [4] to optimize the generation of different kinds of non-classical states, typically in a minimum time. We consider specific target states, such as symmetric and antisymmetric states, but also the maximization of a measure of non-classicality. Calculations are performed with ensembles of two and four spins. We also investigate to which extent optimal control fields can reduce the detrimental effect of cavity damping. We find that symmetric and antisymmetric states can be generated only asymptotically, but a good fidelity can be reached for control duration longer than the longest Rabi-oscillation period of the spin ensemble. For these specific examples, the use of a squeezing field leads to qualitatively similar results than the ones obtained using only coherent control. Additionally, we highlight the existence of an optimal value of the detuning parameter to generate antisymmetric states and find that the process is highly limited by the cavity damping (even in the good cavity regime). Finally, we show that optimizations using a measure of non-classicality can enhance the entanglement process in situations where a simple state-to-state transfer is limited. In this case, the squeezing field provides a considerable gain [5].

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