Rabi Oscillations of Fullerene Qubits

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The electron spin of a phosphorus or nitrogen atom encapsulated in a C_{60} fullerene molecule is operated as a solid-state qubit at room temperature. The endohedral fullerenes P@C_{60} and N@C_{60} are embedded in a polycrystalline C_{60} matrix and manipulated as an ensemble by pulsed electron spin resonance. At room temperature, many Rabi oscillations were observed in N@C_{60} and in P@C_{60} (see Fig. 1). At T = 10 K, single-shot measurements were found to be sufficient for state manipulation and read-out (by free induction decay).

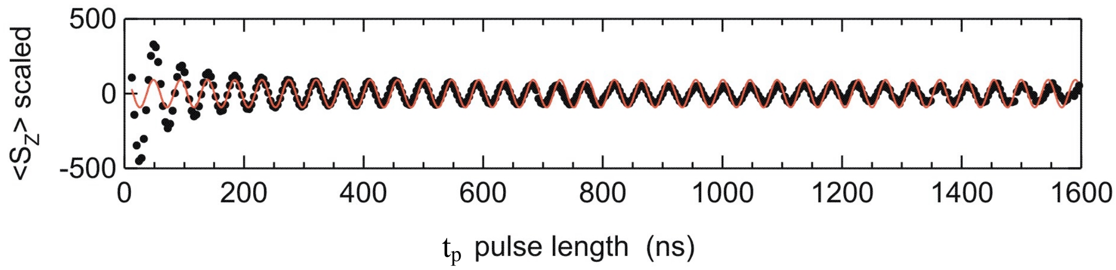

Fig. 1. Rabi oscillations for a P@C_{60} qubit ensemble at room temperature. The data (black dots) have been scaled by exp(t_p/0.5μs) to correct for relaxation due to inhomogeneities of the ensemble. The homogeneous phase coherence time for this sample is T_2 ~ 1.3 μs at room temperature. The solid red curve is a fit with a cosine function.

Also revealed in these experiments are the special properties of the S = 3/2 spin system. In general, there are three transitions connecting the four Zeeman states (m = ±1/2, ±3/2). In the low-field limit (microwave field small compared to the fine structure splitting), the Rabi frequencies of these transitions become different (see Fig. 2). This allows in principle to use the four levels as two qubits, an "inner" (m = ±1/2) and an "outer" (m = ±3/2) qubit. As an example with the data of Fig. 2, a non-selective microwave pulse of length t_p ~ 5.8 μs would perform an inversion (NOT) of the outer qubit and leave the inner qubit unchanged (NOP).

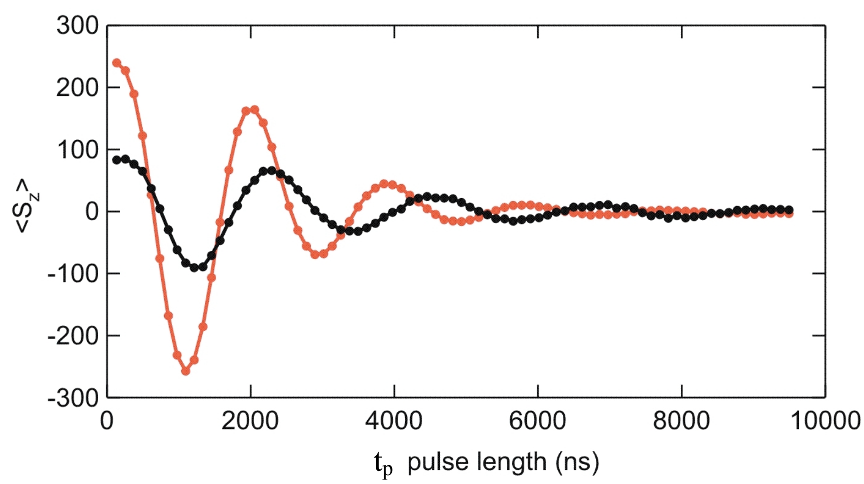

Fig. 2. Transient nutation of P@C_{60} at T = 10 K (raw data, T_2 ~ 3.5 μs) at low driving field (~ 89 times smaller than in Fig. 1). Here, the Rabi frequencies for the (1/2,–1/2) transition (red) and the (±3/2,±1/2) transition (black) are different due to a fine structure term *SDS* in the Hamiltonian of P@C_{60}. This effect is only visible when the driving field is small compared to *SDS*. At large fields B_1, all transitions have the same Rabi frequency of $\omega_R = \gamma B_1$.