Time-Optimal Universal Control of Two-Level Systems under Strong Driving

Chen Avinadav, Ran Fischer, Paz London, and David Gershoni

Department of Physics, Technion, Israel Institute of Technology, Haifa

In this work we study the problem of implementing time-optimal single-qubit quantum gates, in the regime of strongly driven two-level systems, where the driving field has a fixed orientation and bounded amplitude. The method of resonant harmonic excitation at this regime fails due to the breakdown of the rotating wave approximation, and new driving techniques must be considered. Using tools of optimal control theory we prove that time-optimal solutions to this problem consist only of bang pulses, where the spin is driven by the maximum available control field, and drift periods, where the control field is zero, and explicitly find these sequences by numerical optimization, for several important classes of single-qubit gates.

We then propose a novel approach for creating a well-controlled strongly-driven spin system, using radiation-dressed of electron spins in nitrogen-vacancy centers in diamond. We realize this proposal and achieve a spin system which is driven four times faster than its Larmor frequency. Using this unique system we demonstrate our designed optimal pulse sequences, where the spins undergo complete pi-rotations in less than half of their Larmor period, and characterize the designed gates using quantum process tomography. Finally we implement a dual-axis control sequence with more than a hundred operations with an inter-pulse delay of only two spin Larmor cycles, representing a regime of high-density pulse sequences which is impossible to reach with traditional weak driving.