Exact Rotating Wave Approximation for Strongly Driven Qubit

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(Dated: February 7, 2018)

In a quantum computer, an important figure of merit is the number of quantum gate operatorations that can be carried out before decoherence spoils the computation. Short gates are thus desirable, requiring, in turn, pulses of high amplitude. When the ratio of the pulse amplitude and qubit resonance frequency becomes appreciable, rapid oscillations on the time scale of the inverse qubit's resonance frequency—effects not captured when applying the rotating wave approximation (RWA) to the Hamiltonian—become noticeable. We have derived an effective Hamiltonian that contains explicit corrections to the RWA Hamiltonian. These corrections have been determined for constant-drive amplitudes, and they constitute shifts to the qubit frequency, found by Bloch and Siegert [1], and of the Rabi frequency. Real pulses, however, have time-dependent amplitudes. Considering real pulses, we employed the Magnus expansion [2] to determine an effective Hamiltonian which has no fast Fourier coefficients with respect to the qubit frequency. Figure 1 shows a number of qubit trajectories, among which are smooth curves generated by our effective Hamiltonian and which agree at periodic times with the real trajectory. We expect that using our effective Hamiltonian will reduce computational resources when designing pulse shapes for high-fidelity quantum gates.

[1] F. Bloch and A. Siegert, Physical Review **57**, 522 (1940).

[2] S. Blanes, F. Casas, J. Oteo, and J. Ros, European Journal of Physics **31**, 907 (2010)

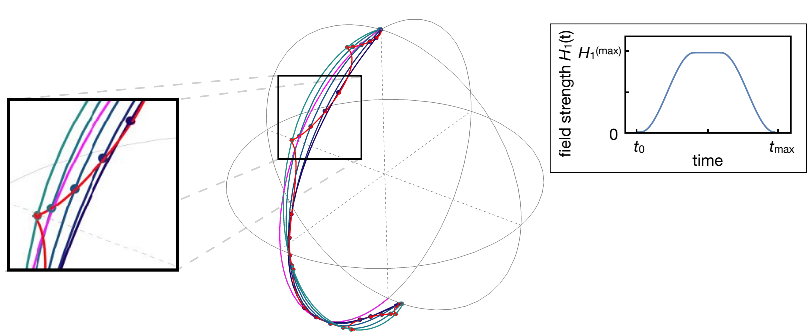

FIG. 1: Evolution of qubit initialized to $|\uparrow\rangle$ under perpendicular drive for an envelope pulse form shown by inset. Trajectories are obtained via exact integration (red), the RWA (magenta), and our effective Hamiltonian (multiple colors).