Does counter-diabatic driving implement adiabaticity by opening energy gap of bare Hamiltonian?

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1 Introduction

Counter-diabatic Hamiltonian is given as:

$$H_{CD} = H_0 + \dot{\lambda} A_\lambda \tag{1}$$

When $\dot{\lambda} \gg 1$, then $H_{CD} \approx \dot{\lambda} A_\lambda$

2 Two level system

$$H_{LZ} = \Delta \sigma_z + \lambda(t) \sigma_x \tag{2}$$

where $\lambda(t) = 2(t-1)/\tau$. Hence, $\dot{\lambda} = 2/\tau$. We are going to start off ground-state of Hamiltonian with $\lambda = -2$ at time $t_i = 1 - \tau$ and end our protocol with $\lambda = 2$ at $t_f = 1 + \tau$. Hence, duration of our protocol is 2τ.

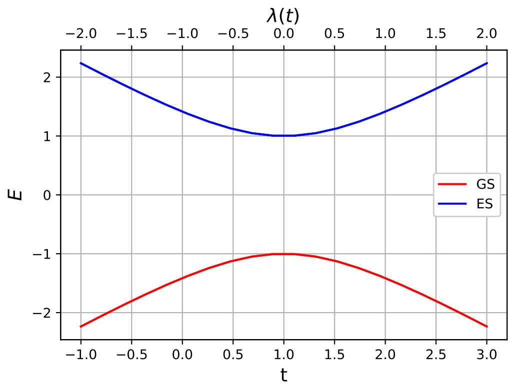

Figure 1: Avoided level crossing as a function of effective magnetic field with $\Delta = 1$

In this case, we know that gauge potential is

$$A_\lambda = \frac{\hbar}{2} \frac{\Delta}{\Delta^2 + \lambda(t)^2} \sigma^y \tag{3}$$

Hence, counter-diabatic Hamiltonian is ($\hbar = 1$):

$$H_{CD} = \Delta \sigma_z + \lambda(t) \sigma_x + \frac{\dot{\lambda}}{2} \frac{\Delta}{\Delta^2 + \lambda(t)^2} \sigma^y \tag{4}$$

It seems that energy gap opens up!

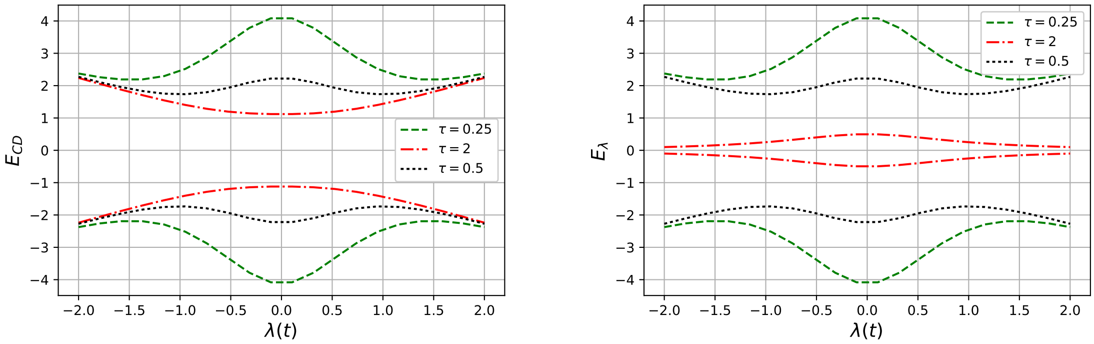

Figure 2: a) Energy E_{CD} of H_{CD} b) Energy E_λ of $H = \dot{\lambda} A_\lambda$

3 Three level system

3.1 Spin 1 LZ model

$$H_{LZ} = \Delta S_z + \lambda S_x \tag{5}$$

$$A_\lambda = \frac{\hbar}{2} \frac{\Delta}{\Delta^2 + \lambda(t)^2} S^y \tag{6}$$

3.2 NV model

$$H_{NV} = \Delta S_z^2 + \lambda S_x$$