Classical and quantum shortcuts to adiabaticity for scale-invariant driving

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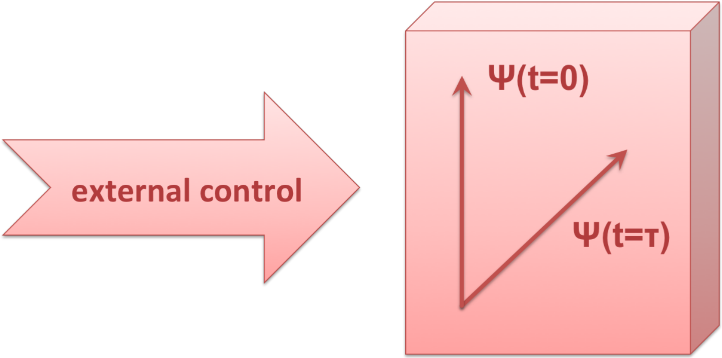
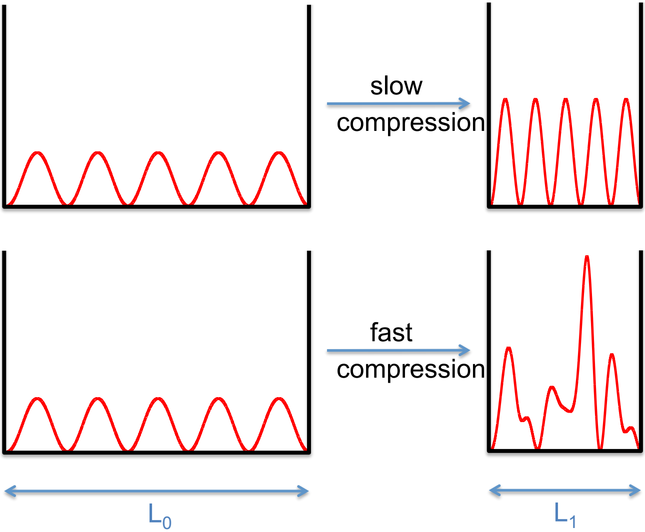
Control paradigm – least amount of dissipation

What is the optimal control with smallest dissipation?



Quantum adiabatic theorem



Shortcuts to adiabaticity – counterdiabatic driving

Torrontegui *et al.*, Adv. At. Mol. Opt. Phys. **62**, 117 (2013)

Problem:

- want to suppress excitations in driven system $H_0(t)$

Idea:

- apply additional field cancelling all transitions

Solution: Counterdiabatic driving

$$H(t) = H_0(t) + i\hbar \sum_n \left(|\partial_t n\rangle\langle n| - \langle n|\partial_t n\rangle\, |n\rangle\langle n| \right)$$

Demirplak & Rice, J. Phys. Chem. A **107**, 9937 (2003)

Demirplak & Rice, J. Phys. Chem. B **109**, 6838 (2005)

Berry, J. Phys. A **42**, 365303 (2009)

Shortcuts to adiabaticity – Scale invariant driving

Deffner, Jarzynski & del Campo, PRX **4**, 021013 (2014)

Problem: counterdiabatic field complicated

Solution: scale invariant driving

$$H_0(t) = \frac{p^2}{2m} + \frac{1}{\gamma_t^2}\, V\left(\frac{x - f_t}{\gamma_t}\right)$$

Then:

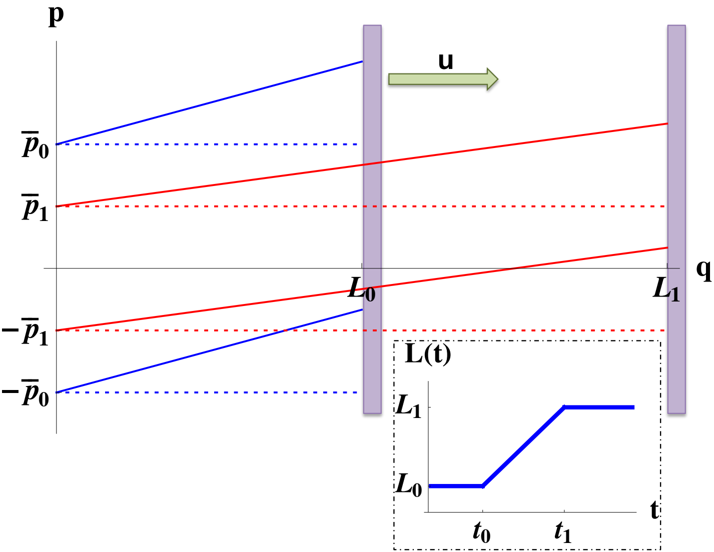
$$H(t) = H_0(t) + \frac{\dot{\gamma}_t}{2\gamma_t}\left[(x - f_t)\, p + p\, (x - f_t)\right] + \dot{f}_t\, p$$

Next problem: counterdiabatic field non-local and not realizable

Solution: use coordinate transformation

$$\bar{H}(t) = \bar{H}_0(t) - \frac{m}{2}\frac{\ddot{\gamma}_t}{\gamma_t}(\bar{x} - f_t)^2 - m\ddot{f}_t\, \bar{x}$$

Example: Particle in a box



Multiparticle systems and non-linear dynamics

➙ **Multiparticle quantum systems**

$$\hat{\mathcal{H}}_0 = \sum_{i=1}^{N} \left[-\frac{\hbar^2}{2m} \Delta_{q_i} + U(q_i, \boldsymbol{\lambda}(t)) \right] + \epsilon(t) \sum_{i<j} V(q_i - q_j)$$

Coordinate transformation:

$$\mathcal{U} = \prod_{i=1}^{N} \exp\left(\frac{im}{\hbar} \dot{f} \cdot q_i + \frac{im\dot{\gamma}}{2\hbar\gamma} (q_i - f)^2 - i \frac{m}{2} \int_0^t \mathrm{d}s \, \dot{f}^2 \right)$$

➙ **Non-linear dynamics**

$$i\hbar \, \partial_t \Psi(q,t) = \left[-\frac{\hbar^2}{2m} \Delta_q + U(q,t) + g_D |\Psi(q,t)|^2 \right] \Psi(q,t)$$

Take-home-message

- ➙ closed expression for counterdiabatic field for scale-invariant driving
- ➙ local counterdiabatic field by coordinate transformation
- ➙ local shortcuts for classical and quantum, single particle and multiparticle, and linear and non-linear systems

Deffner, Jarzynski & del Campo, PRX **4**, 021013 (2014)