universität innsbruck

FWF
Der Wissenschaftsfonds.
START 2017

Efficient local counter-diabatic driving in adiabatic quantum computing

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Quantum annealing

Speed limit: Adiabatic theorem

Counter-diabatic driving

M. Demirplak and S.A. Rice
J.Phys.Chem.A **2003**, 107

AH and Wolfgang Lechner
New. J. Phys. **21** 043025 (2019)

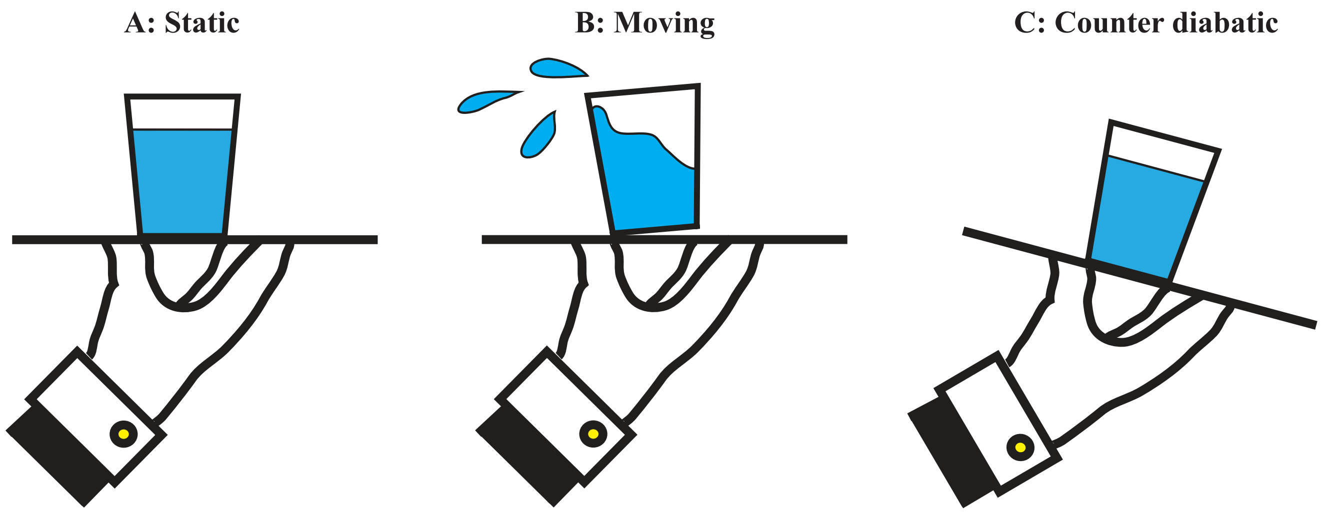
Large enhancement for finite sweep times

Inhomogeneous Driving

Yuki Susa et al *PRA* **98** 042326 (2018)

AH and Wolfgang Lechner
PRA, **100**, 032110 (2019)

Basic idea



D. Sels, A. Polkovnikov, PNAS, **114** 3909 (2017).

Goals

- Fast protocols for quantum annealing
- High ground state fidelity

Analysis:

Moving frame: $|\tilde{\psi}\rangle = U^{\dagger}(\lambda)\,|\psi\rangle \xrightarrow{\text{Schrödinger Eq.}}$

Hamiltonian in moving frame

$$\tilde{H}_m = \tilde{H} - \dot{\lambda}\tilde{A}_\lambda$$

$\tilde{H} = U^{\dagger} H U$

diagonal

$\tilde{A}_\lambda = i\hbar U^{\dagger}\partial_\lambda U$

adiabatic gauge potential **responsible for transitions**

Full Hamiltonian: $H(t) = H_0 + \dot{\lambda}A_\lambda$

Counter-diabatic Hamiltonian: $H_{\mathrm{CD}}(t) = \dot{\lambda}A_\lambda$

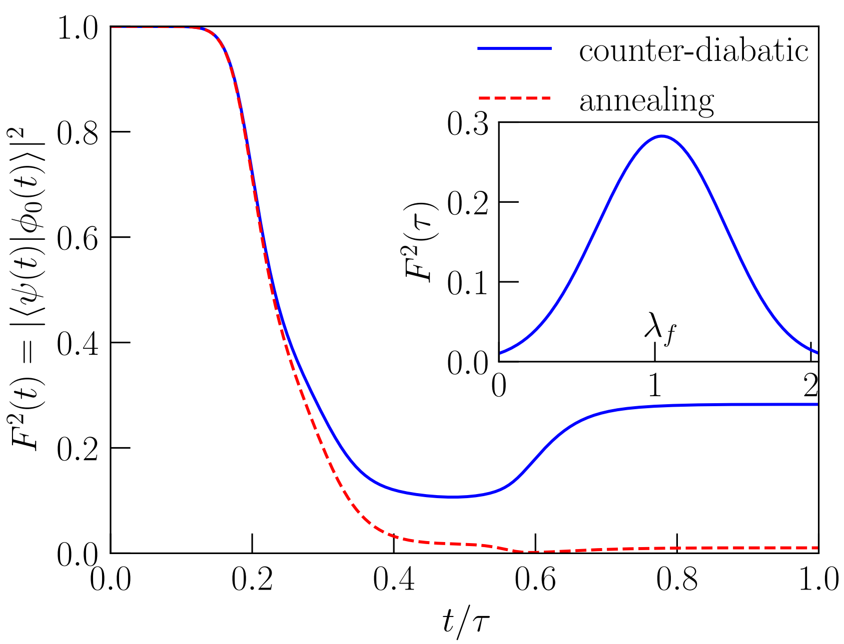
How does adiabatic gauge potential A_λ look like?

Adiabatic gauge potential:

Exact form: $H_{\mathrm{CD}}(t) = \dot{\lambda} A_\lambda = i\hbar \sum_{m \neq n} \sum_{n} \frac{|m\rangle\langle m|\partial_t H_0|n\rangle\langle n|}{E_m - E_n}$

Requires a priori knowledge of system's eigenstates

Iterative change



Approximate local CD driving

Ansatz: $A^*_\lambda = \sum_{i=1}^{N_p} \alpha_i \sigma_i^y$

Strategy: Find **optimal** expression for α_i by **minimising operator distance** between exact and approximate solution

Quantum annealing + analytical variation

Additional iterative variation of parameters

AH and Wolfgang Lechner, *New. J. Phys.* **21** 043025 (2019)

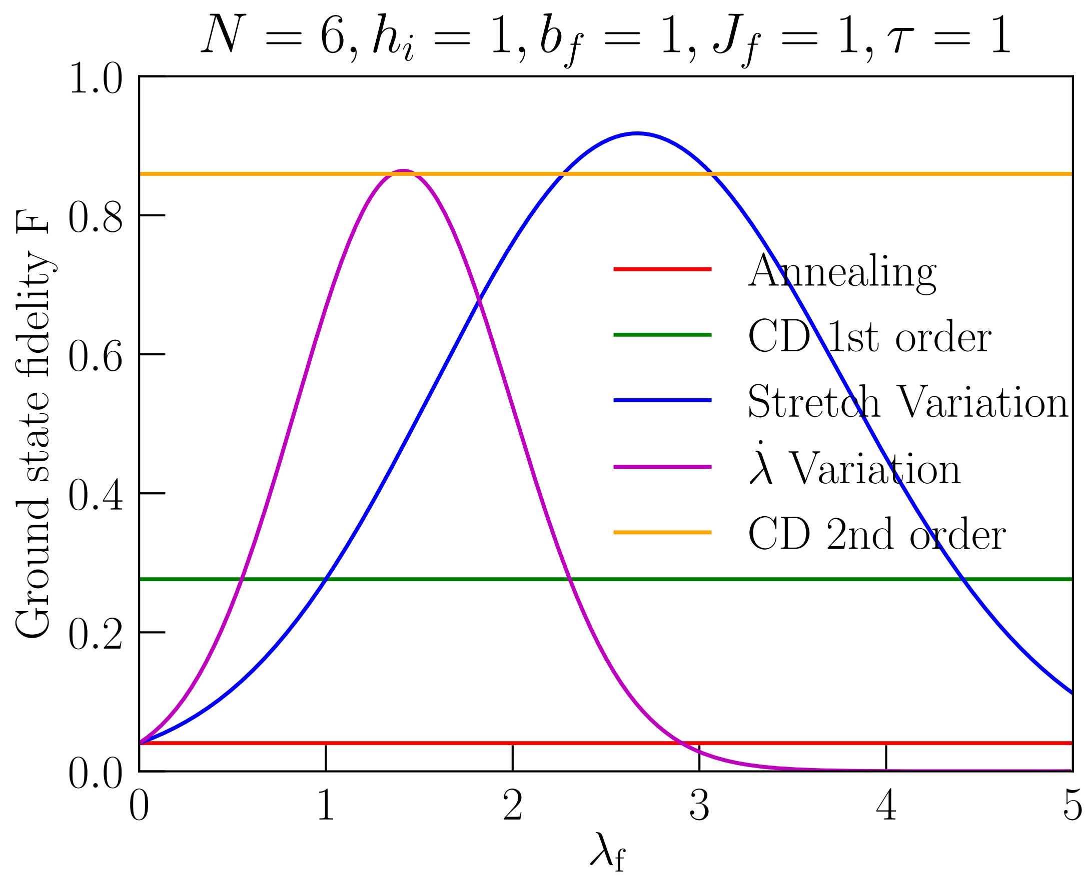
Efficient local counter-diabatic driving:

Solutions: $H_{\mathrm{CD}}(t) = \dot{\lambda} A_\lambda^* = \sum_{i=1}^{N} \Gamma_i \sigma_i^y$

$$\Gamma_i = \{\alpha_i, \beta_i, \gamma_i, \lambda_f, \dots\}$$

Analytical variational optimization

$$\boxed{\frac{\delta\, Tr[G_\lambda(\mathcal{A}_\lambda^*)^2]}{\delta \mathcal{A}_\lambda^*} = 0}$$



Numerical variational optimization

$$\dot{\lambda}(t) = \lambda_f \frac{\pi^2}{4\tau} \sin\left[\frac{\pi}{\tau}t\right] \sin\left[\pi \sin^2\left(\frac{\pi}{2\tau}t\right)\right]$$

Can even outperform **2-spin** CD driving $\sigma_i^y \sigma_j^z, \sigma_i^y \sigma_j^x$

Outlook: Using whole family of solutions!

Forthcoming publication