Variational ansatz inspired by Quantum imaginary time evolution

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Introduction: imaginary time evolution on quantum computers with unitary gates

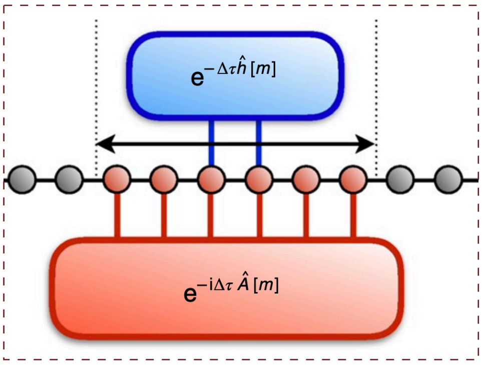
Quantum imaginary time evolution (QITE) reads

$$\frac{e^{-\Delta\tau H}}{||e^{-\Delta\tau H}|\psi\rangle||}|\psi\rangle = e^{i\Delta\tau\sum_i a_i\sigma_i}|\psi\rangle = \prod_i e^{i\Delta\tau a_i\sigma_i}|\psi\rangle + \mathcal{O}(\Delta\tau^2)$$

Unitary gates $e^{i\Delta\tau a_i\sigma_i}$ can be realized using basic quantum gates.

In principle, the number of σ_i grows as 4^n, which can not be extended to large-scale problems.

Fortunately, for **finitely correlated** systems and **local** interacting Hamiltonian, the number of σ_i can be reduced to a constant(See left



QITE of a finitely correlated system

Method: Symmetry reductions of gates and optimize parameters variationally [arXiv:2307.13598]

Use **Twirling projection** to solve symmetry constrains:

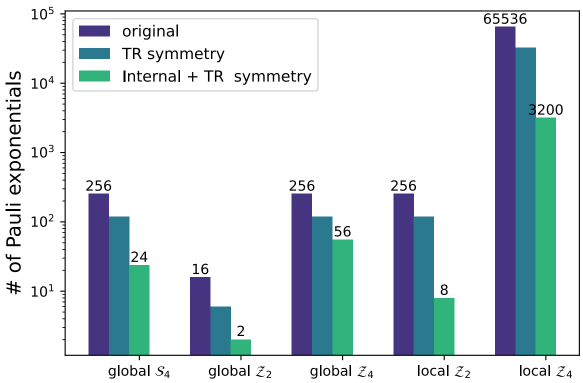
For example:

- Particle number preserving systems $[H,\hat{N}]=0$:

$$\mathcal{T}(\sigma) = \int_0^{2\pi} d\alpha\ e^{i\alpha\hat{N}}\sigma e^{-i\alpha\hat{N}},\quad \hat{N}=\sum_i \hat{a}_i^\dagger\hat{a}_i$$

- Lattice gauge theory $[H,\hat{G}_x]=0$:

$$\mathcal{T}(\sigma) = \int\mathcal{D}\alpha\prod_x e^{i\alpha_x\hat{G}_x}\ \sigma\ \prod_x e^{-i\alpha_x\hat{G}_x},\ \hat{G}_x=(e\psi_x^\dagger\psi_x)+\hat{E}_x-\hat{E}_{x-1}$$



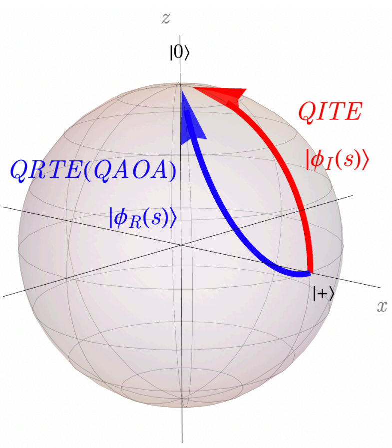
Number of gates reduced by symmetries

Numerics: Comparison to QAOA and study on Ising critical behavior [PhysRevA.**108**.022612]

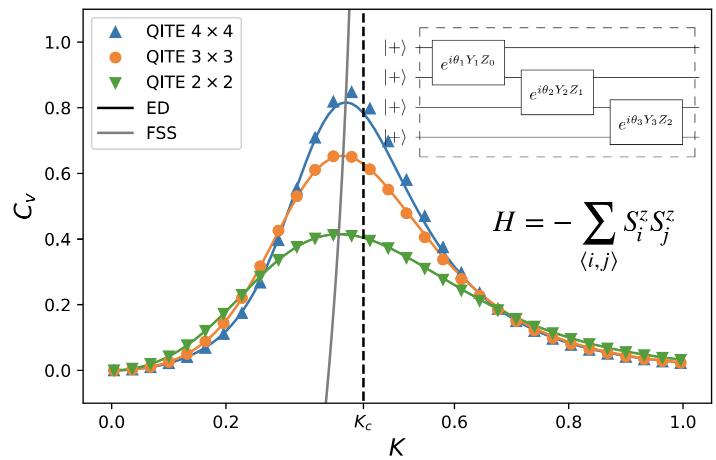
Real or Imaginary?

$|\phi_{\mathrm{Real}}(s)\rangle = e^{i\frac{\pi}{4}sX}e^{i\frac{\pi}{4}sZ}|+\rangle$

$|\phi_{\mathrm{Imag}}(s)\rangle = e^{i\frac{\pi}{4}sY}|+\rangle$



Two paths on Bloch sphere



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