Noisy Overparameterization of Quantum Systems

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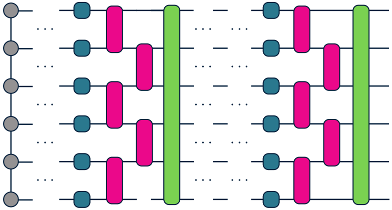
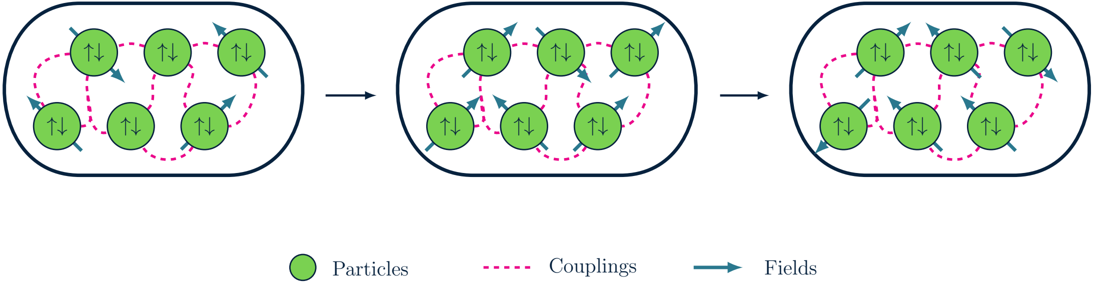


What Are We Able To Do With Current Quantum Systems?



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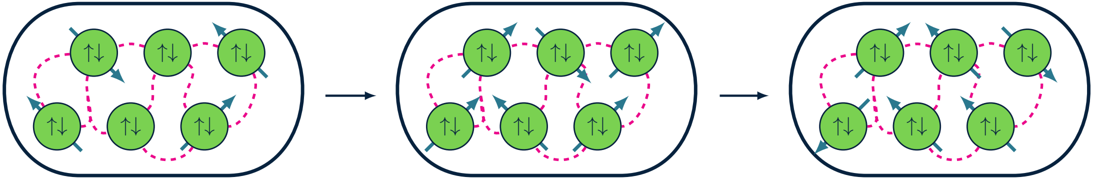
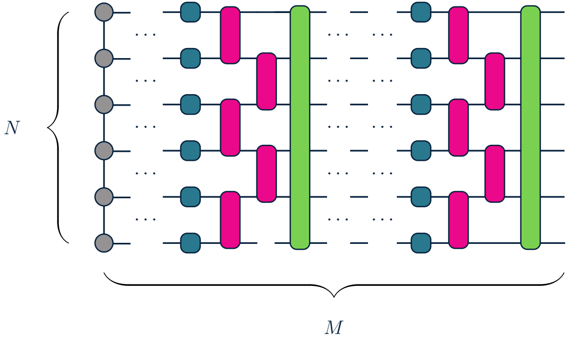


i.e) Unitary *compilation*, State *preparation*, with infidelity $\mathcal{L}_{\theta_\gamma} \to 0$

$$H_\theta^{(t)} = \sum_i \theta_i^{x\,(t)} X_i + \sum_i \theta_i^{y\,(t)} Y_i + \sum_i h_i Z_i + \sum_{i<j} J_{ij} Z_i Z_j \qquad (1)$$

How Do Circuit Depth And Noise Affect Our Capabilities?



How does the amount of *noise* γ and the *evolution depth* M

of a *constrained* system

affect its classical simulation and optimization, and resulting infidelities

$\mathcal{L}_{\theta^*\gamma}$?

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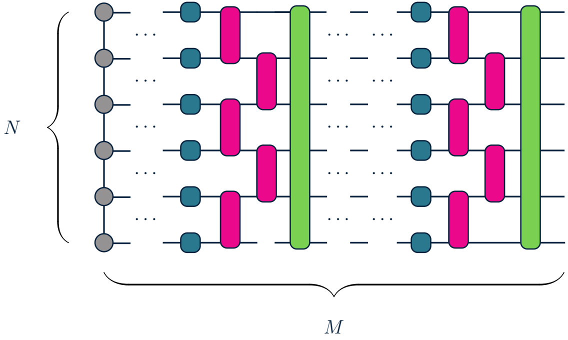
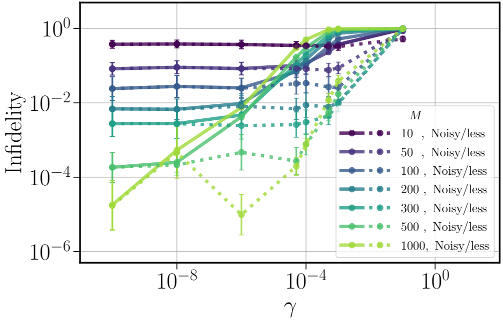


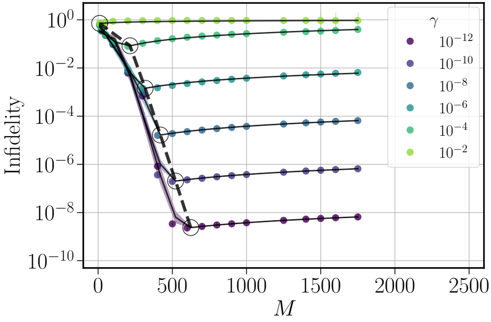
How can we leverage approaches from
quantum optimal control and *learning theory* to describe these relationships?

Noisy Optimization

- Haar random state preparation for $N = 4$ qubits, with independent dephasing



(a) Trained Noisy Infidelity, and Tested Infidelity of Noisy Parameters in Noiseless Ansatz



(b) Piecewise Fit of Noise Induced Critical Depth for Infidelity

Noise Induced Critical Depth

Noise induces a critical depth (Fontana *et al.* PRA **104** (2021))

$$M_{\gamma} \sim \log 1/\gamma \ , \tag{2}$$

meaning the minimum infidelity is *linear-quadratic* ($1 \leq \alpha \leq 2$) in noise

$$\mathcal{L}_{\theta^*\gamma|M_\gamma} \sim \gamma^{\alpha} \ , \tag{3}$$

and parameterized noise channels can therefore *mitigate* approximately

$$\bar{M}_{\gamma} \sim \gamma \log 1/\gamma \quad \text{errors} \ . \tag{4}$$

Is it possible to derive the M, γ scaling of the optimal $\mathcal{L}_{\theta^*\gamma}$ *analytically*?