Low-depth amplitude estimation via statistical eigengap estimation

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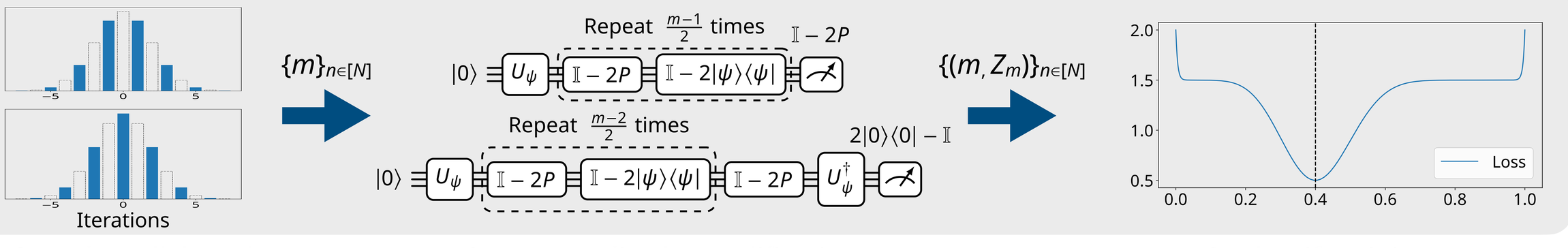
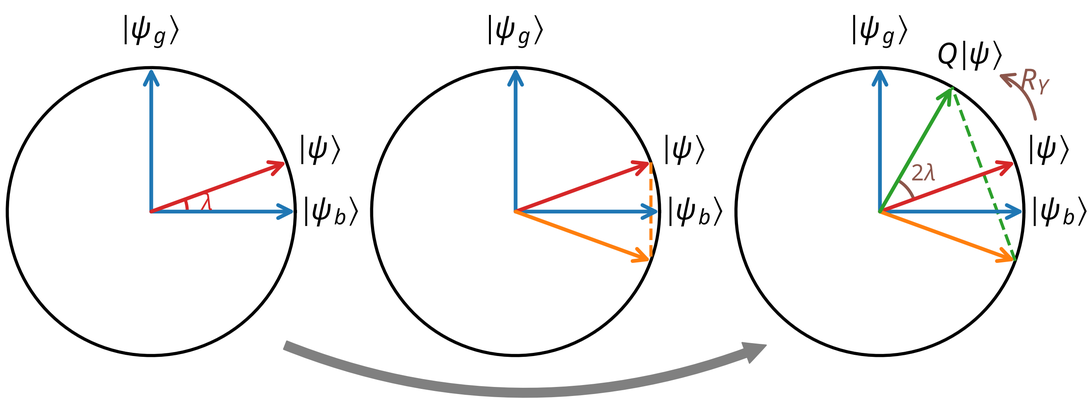
Algorithm Overview



1. Sample walk length
2. Run amplitude amplification
3. Identify minimum

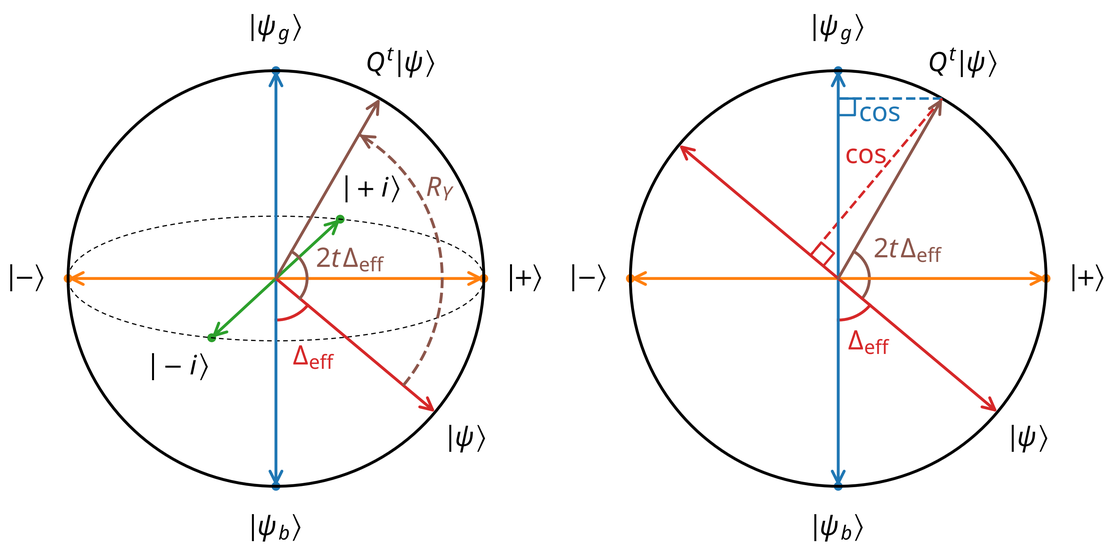
Theoretical Background

1. Amplitude amplification is discrete-time evolution.

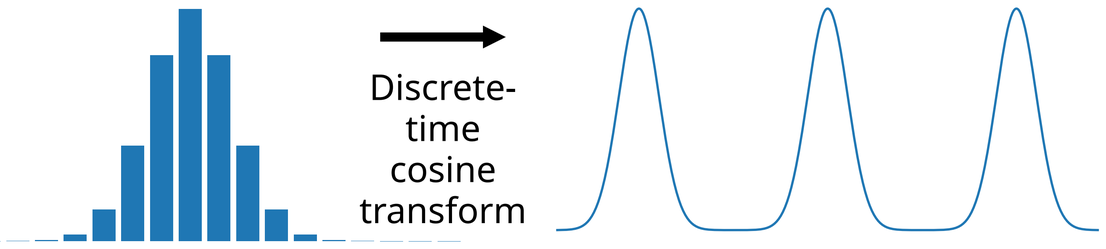


$Q = e^{-iH_{\text{eff}}t}$ (Pauli Y rotation in subspace)

2. QPE-free amplitude estimation is eigengap estimation.



3. Signals induces discrete-time cosine transform of Gaussian.

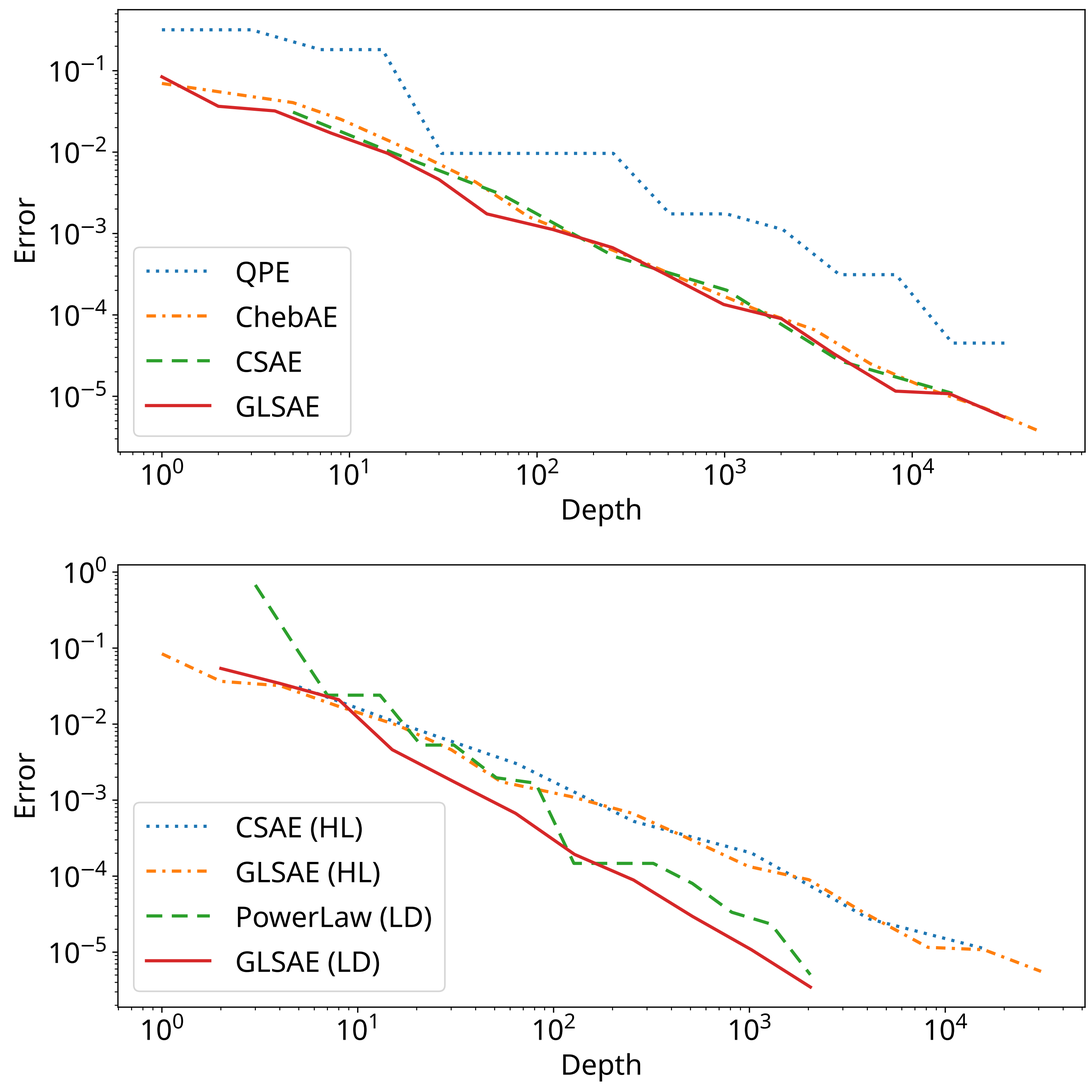


4. Query–depth product satisfies the invariance $\mathcal{DN} \in \widetilde{\mathcal{O}}(\epsilon^{-2})$

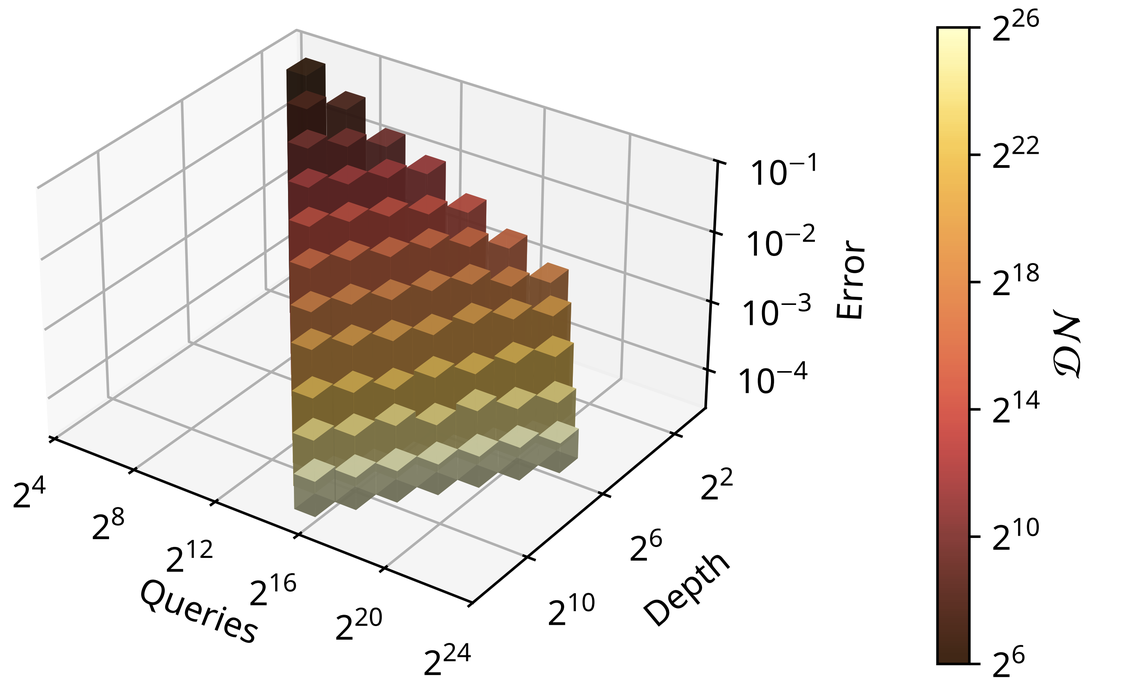
	Sample (Width)	Depth	Query (Volume)
Heisenberg	$\mathcal{O}(\log(\epsilon^{-1}))$	$\mathcal{O}(\epsilon^{-1})$	$\widetilde{\mathcal{O}}(\epsilon^{-1})$
In-between	$\widetilde{\mathcal{O}}(\epsilon^{-2\beta})$	$\widetilde{\mathcal{O}}(\epsilon^{-1+\beta})$	$\widetilde{\mathcal{O}}(\epsilon^{-1-\beta})$
Monte Carlo	$\mathcal{O}(\epsilon^{-2})$	$\mathcal{O}(1)$	$\mathcal{O}(\epsilon^{-2})$

Numerics

Comparable to SOTA at Heisenberg limit and better than prior result for low-depth regime.



Achieves near-optimal depth-query tradeoff of $\mathcal{DN} \in \widetilde{\mathcal{O}}(\epsilon^{-2})$.



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