Squeezing and Quantum Approximate Optimization

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Abstract:

Variational quantum algorithms offer fascinating prospects for the solution of combinatorial optimization problems using digital quantum computers. However, the achievable performance in such algorithms and the role of quantum correlations therein remain unclear. Here, we shed light on this open issue by establishing a tight connection to the seemingly unrelated field of quantum metrology: Metrological applications employ quantum states of spin-ensembles with a reduced variance to achieve an increased sensitivity, and we cast the generation of such squeezed states in the form of finding optimal solutions to combinatorial problems (e.g., MaxCut) with increased precision. On the one hand, by solving this optimization problem with a quantum approximate optimization algorithm (QAOA), we show numerically as well as on an IBM quantum chip, how highly squeezed states are generated in a systematic procedure that can be adapted to a wide variety of quantum machines. On the other hand, squeezing tailored for the QAOA of the MaxCut relates to quantum correlation in the form of entanglement, it permits us to propose a figure of merit for future hardware benchmarks, and it can resource-effectively boost the averaged final energy of QAOA optimization obtained in MaxCut of random graph instances. Further exploitation of this connection between metrology and optimization may uncover solutions to prevailing problems and push the scope of precision in both fields.

References

Santra, Gopal Chandra, Fred Jendrzejewski, Philipp Hauke and Daniel J. Egger, *arXiv preprint arXiv:2205.10383* (2022).

Figures

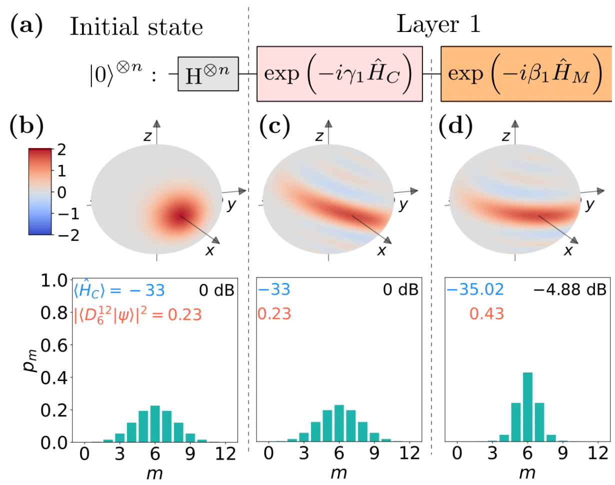

Figure 1: Squeezing generated by QAOA: (a) Circuit representation of QAOA with alternating application of cost-function and mixer Hamiltonian. Wigner quasi-probability distribution on the Bloch spheres (above row) and histograms (below row) from (b) to (d) show the state after the corresponding gate in the optimized QAOA circuit. Negativity in the Wigner distribution indicates that the states are non-Gaussian. The squeezing (in dB, black), energy expectation $\langle H_c \rangle$ (in blue) and overlap probability density with the target Dicke state $|\langle D_6^{12}|\psi\rangle|^2$ (in orange) are shown inside each histograms.