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Quantum computing versus classical computing: which is better and how can one integrate them?

Quantum computers have the potential to provide advantage over classical computers in several tasks, going all the way from factorization of large integers to applications in optimization and machine learning, as well as in materials science and chemistry. There are two main limitations to achieving such quantum advantage: the first one is that the current quantum computing hardware still has a rather large error rate, and the second is the limited number of quantum algorithms with demonstrable advantage. In the first part of this presentation an overview of the current practical quantum computing capabilities will be given, including approaches to benchmark quantum versus classical computers [1]. In the second part a practical example for a hybrid quantum/classical algorithm for the use in materials science will be presented. The method takes advantage of the strengths of classical and quantum computers by integrating tensor networks for preparing ground states on classical computers with quantum computers for evaluation of dynamics [2]. For these simulations we use our recently released python tree tensor networks simulation package pyTTN [3]. Finally, an outlook will be given on the main open challenges towards the achievement of practical quantum advantage.

[1] D. Lall et al., A Review and Collection of Metrics and Benchmarks for Quantum Computers: Definitions, Methodologies and Software, arXiv:2502.06717; https://qcmet.npl.co.uk

[2] F. Jamet et al, Anderson impurity solver integrating tensor network methods with quantum computing, APL Quantum 2, 016121 (2025).

[3] L. P. Lindoy et al., pyTTN: An Open Source Toolbox for Open and Closed System Quantum Dynamics Simulations Using Tree Tensor Networks, J. Chem. Phys. 163, 202501 (2025); https://github.com/pyttn/pyttn