Danylo Lykov

Education

University of Chicago Chicago, IL
ongoing PhD in Computer Science *Jan 2022 - Present*

- Quantum variational algorithms, numerical optimization methods.
- Tensor network contraction algorithms, High-Performance GPU simulations.

Research supervisors: Dr. Yuri Alexeev and Dr. Frederic T. Chong

Northern Illinois University, Physics Department DeKalb, IL
Masters in Physics *Sep 2019 - Dec 2021*

- Quantum information science and quantum computing.
- Solid-state physics, nanophysics, statistical physics

Research supervisor: Dr. Andreas Glatz

Moscow Institute of Physics and Technology Dolgoprudnyy, Russia
Bachelor, Applied mathematics and physics *Sep 2015 - Jun 2019*

- Quantum mechanics, nanophotonics, statistical physics, mathematical analysis

Thesis research: Quantum Metrology with Linear Optics
Research supervisor: Prof. Dr. Gordey Lesovik

Employment

JPMorgan Chase & Co.
New York, NY *Global Technology Research Intern* *June 2023 - Sept 2023*
Research directions: efficient distributed GPU simulation of quantum algorithms

QuEra
Boston, MA *Quantum Information Science Intern* *June 2022 - Sept 2022*
Research directions: graph algorithms, simulation of neutral atom quantum computing

ColdQuanta
Boulder, CO *Quantum Information Science Intern* *May 2021 - Aug 2021*
Research directions: variational quantum algorithms, optimization of parameters for quantum algorithms, comparison of performance of quantum and classical combinatorial optimization algorithms.

Argonne National Laboratory
Chicago, IL *Research Assistant* *Sep 2019 - Present*
Research directions: classical simulation of quantum circuits, high-performance computing, variational quantum algorithms, graph decomposition algorithms

Laboratory of Physics of Quantum Information Technology
Dolgoprudnyy, Russia *Research Assistant* *March 2018 - July 2019*
Research directions: quantum computing and informatics, quantum metrology, quantum optics and tomography, quantum thermodynamics, artificial quantum systems

Skolkovo Institute of Science and Technology
Center for Computational and Data-Intensive Science and Engineering
`https://crei.skoltech.ru/cdise`
Moscow, Russia *Research Intern* *Aug 2018 - Feb 2019*
Research directions: efficient numerical algorithms, deep learning, quantum enhanced computation and simulations

Research interests

- Quantum simulations, quantum informatics, optimisation algorithms, tensor network contraction
- Graph deep convolutional neural networks, Natural Language Processing
- Quantum computing, qubit fabrication technologies, artificial quantum systems, quantum optics

Primary research work

Approximate quantum simulation using tensor networks [2, 16] *Sep 2022 - June 2023*

Developed a stochastic noisy quantum circuit simulation method which allowed to simulate noisy circuits at a reduced cost. Applied GPU-based compression algorithms to tensor network contraction and analyzed simulation error, which allowed to increase simulation system sizes.

Quantifying quantum advantage of QAOA [14] *June 2021 - Aug 2022*

Used the theoretical performance of the fixed angle mode of QAOA to compare it to state-of-the-art classical solvers of MaxCut. Demonstrated that a large depth of $p \geq 12$ is required to reliably achieve advantage on large graphs.

Quantum embedding for machine learning [6] *Jan 2021 - March 2021*

Used QTensor to evaluate usage of quantum embedding in few-shot learning. Identified important circuit bypass problem, which impacts the quantum machine learning field

Parameter study of QAOA [3, 4, 18] *Dec 2020 - May 2021*

Described symmetries of QAOA parameter landscape, developed a set of universally applicable parameters for QAOA algorithm which increased theoretical QAOA runtime by a factor of 1000x.

GPU performance optimization for tensor network contractions [8, 10] *May 2021 - Dec 2021*
Performed study of various linear algebra operations implemented in NumPy, CuPy and PyTorch on GPU and CPU. Applied the study data to create an approach of Hybrid CPU/GPU tensor contraction backend which improved simulation speed by 3 times compared to simple GPU backend and by 170 times compared to CPU backends.

Large-scale QAOA simulations [1, 5, 7, 9–13] *Mar 2020 - Dec 2020*
Led the development of an open-source library for simulation of large quantum circuits, which currently provides the fastest QAOA energy calculations available. Developed an improved slicing algorithm that reduces algorithmic complexity of tensor network contratitons. To improve numerical performance wrote custom plain C++ and MKL-based kernels for contraction of tensor networks.

An adaptive algorithm for quantum circuit simulation [15] *Aug 2018 - Feb 2019*
Improved state-of-the-art quatnum circuit simulation algorithm with possibility to optimally compute arbitrary set of output state probabilities. Implemented the quantum circuit simulator in Python. Web demo: `http://lykov.tech/qg`.

Quantum Metrology with Linear Optics [19] *Nov 2018 - Jun 2019*
Created an all-optical experimental realization of the phase estimation algorithm, which has a wealth of applications in quantum metrology. Used convolutional neural networks for regression towards phase value based on patttern recognition.

Publications, patents and presentations

[1] Yuri Alexeev, Alexey Galda, and Danylo Lykov. Quantum simulation, U.S. Patent Pending US2023047145, 2023. URL: https://patents.google.com/patent/US20230047145A1.

[2] W. Berquist, D. Lykov, M. Liu, and Y. Alexeev. Stochastic approach for simulating quantum noise using tensor networks. In *2022 IEEE/ACM Third International Workshop on Quantum Computing Software (QCS)*, pages 107–113, Los Alamitos, CA, USA, nov 2022. IEEE Computer Society. doi:10.1109/QCS56647.2022.00018.

[3] Alexey Galda, Eesh Gupta, Jose Falla, Xiaoyuan Liu, Danylo Lykov, Yuri Alexeev, and Ilya Safro. Similarity-based parameter transferability in the quantum approximate optimization algorithm. *Frontiers in Quantum Science and Technology*, 2, July 2023. URL: https://doi.org/10.3389/frqst.2023.1200975, doi:10.3389/frqst.2023.1200975.

[4] Alexey Galda, Xiaoyuan Liu, Danylo Lykov, Yuri Alexeev, and Ilya Safro. Transferability of optimal qaoa parameters between random graphs. In *2021 IEEE International Conference on Quantum Computing and Engineering (QCE)*, pages 171–180, 2021. doi:10.1109/QCE52317.2021.00034.

[5] Cameron Ibrahim, Danylo Lykov, Zichang He, Yuri Alexeev, and Ilya Safro. Constructing optimal contraction trees for tensor network quantum circuit simulation. In *2022 IEEE High Performance Extreme Computing Conference (HPEC)*. IEEE, September 2022. URL: https://doi.org/10.1109/hpec55821.2022.9926353, doi:10.1109/hpec55821.2022.9926353.

[6] Minzhao Liu, Junyu Liu, Rui Liu, Henry Makhanov, Danylo Lykov, Anuj Apte, and Yuri Alexeev. Embedding learning in hybrid quantum-classical neural networks. In *2022 IEEE International Conference on Quantum Computing and Engineering (QCE)*. IEEE, September 2022. URL: https://doi.org/10.1109/qce53715.2022.00026, doi:10.1109/qce53715.2022.00026.

[7] Danylo Lykov and Yuri Alexeev. IEEE Quantum Week Conference presentation. QTensor: Parallel quantum simulator using tensor networks, 2020. URL: https://qce.quantum.ieee.org/quantum-simulation/.

[8] Danylo Lykov and Yuri Alexeev. IEEE Quantum Week Conference presentation. QTensor: Tensor Network Simulator for HPC, 2021. URL: https://events.cels.anl.gov/event/167/page/75-workshop-agenda.

[9] Danylo Lykov and Yuri Alexeev. Importance of diagonal gates in tensor network simulations. In *2021 IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*. IEEE, July 2021. URL: https://doi.org/10.1109/isvlsi51109.2021.00088, doi:10.1109/isvlsi51109.2021.00088.

[10] Danylo Lykov, Angela Chen, Huaxuan Chen, Kristopher Keipert, Zheng Zhang, Tom Gibbs, and Yuri Alexeev. Performance Evaluation and Acceleration of the QTensor Quantum Circuit Simulator on GPUs. In *2021 IEEE/ACM Second International Workshop on Quantum Computing Software (QCS)*, pages 27–34, 2021. doi:10.1109/QCS54837.2021.00007.

[11] Danylo Lykov, Cameron Ibrahim, Filip Mazurek, and Yuri Alexeev. QTensor github repository, 2020. URL: https://github.com/danlkv/QTensor.

[12] Danylo Lykov, Roman Schutski, Alexey Galda, Valeri Vinokur, and Yuri Alexeev. Tensor network quantum simulator with step-dependent parallelization. In *2022 IEEE International Conference on Quantum Computing and Engineering (QCE)*, pages 582–593, 2022. doi:10.1109/QCE53715.2022.00081.

[13] Danylo Lykov, Roman Schutski, Valerii Vinokur, and Yuri Alexeev. Supercomputing Conference 2020 presentation. large-scale parallel tensor network quantum simulator, 2020. URL: https://sc20.supercomputing.org/proceedings/workshops/workshop_pages/ws_qcs110.html.

[14] Danylo Lykov, Jonathan Wurtz, Cody Poole, Mark Saffman, Tom Noel, and Yuri Alexeev. Sampling frequency thresholds for the quantum advantage of the quantum approximate optimization algorithm. *npj Quantum Information*, 9(1), July 2023. URL: https://doi.org/10.1038/s41534-023-00718-4, doi:10.1038/s41534-023-00718-4.

[15] Roman Schutski, Danil Lykov, and Ivan Oseledets. Adaptive algorithm for quantum circuit simulation. *Phys. Rev. A*, 101:042335, Apr 2020. URL: https://link.aps.org/doi/10.1103/PhysRevA.101.042335, doi:10.1103/PhysRevA.101.042335.

[16] Milan Shah, Xiaodong Yu, Sheng Di, Danylo Lykov, Yuri Alexeev, Michela Becchi, and Franck Cappello. GPU-Accelerated Error-Bounded Compression Framework for Quantum Circuit Simulations. In *2023 IEEE International Parallel and Distributed Processing Symposium (IPDPS)*, pages 757–767, 2023. doi:10.1109/IPDPS54959.2023.00081.

[17] Ruslan Shaydulin, Changhao Li, Shouvanik Chakrabarti, Matthew DeCross, Dylan Herman, Niraj Kumar, Jeffrey Larson, Danylo Lykov, Pierre Minssen, Yue Sun, Yuri Alexeev, Joan M. Dreiling, John P. Gaebler, Thomas M. Gatterman, Justin A. Gerber, Kevin Gilmore, Dan Gresh, Nathan Hewitt, Chandler V. Horst, Shaohan Hu, Jacob Johansen, Mitchell Matheny, Tanner Mengle, Michael Mills, Steven A. Moses, Brian Neyenhuis, Peter Siegfried, Romina Yalovetzky, and Marco Pistoia. Evidence of scaling advantage for the quantum approximate optimization algorithm on a classically intractable problem, 2023. URL: https://arxiv.org/abs/2308.02342, doi:10.48550/ARXIV.2308.02342.

[18] Jonathan Wurtz and Danylo Lykov. Fixed-angle conjectures for the quantum approximate optimization algorithm on regular maxcut graphs. *Phys. Rev. A*, 104:052419, Nov 2021. URL: https://link.aps.org/doi/10.1103/PhysRevA.104.052419, doi:10.1103/PhysRevA.104.052419.

[19] V. V. Zemlyanov, N. S. Kirsanov, M. R. Perelshtein, D. I. Lykov, O. V. Misochko, M. V. Lebedev, V. M. Vinokur, and G. B. Lesovik. Phase estimation algorithm for the multibeam optical metrology. *Scientific Reports*, 10(1), May 2020. URL: https://doi.org/10.1038/s41598-020-65466-3, doi:10.1038/s41598-020-65466-3.