Tutorial Proposal for ISCA 2025

Title: Hybrid Oscillator-Qubit Quantum Processors: Instruction Set Architecture, Abstract Machine Models, and Applications

Organizers:

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- Huiyang Zhou, hzhou@ncsu.edu, Department of Electrical and Computer Engineering, North Carolina State University

Biography: Yuan Liu is an Assistant Professor of Electrical & Computer Engineering and Computer Science at North Carolina State University. He is also an affiliated faculty in Physics. Prior to joining the NC State faculty as an NSF Quantum Computing and Information Science Fellow, he was a postdoctoral researcher at the Massachusetts Institute of Technology. His research interests lie at the intersection of quantum computing, quantum engineering, quantum algorithms/architectures and applications. For more information, please visit https://yuanliu.group/.

Huiyang Zhou is a professor of Electrical and Computer Engineering at North Carolina State University. His research focuses on high performance microarchitecture, GPU computing, architecture support for security & dependability, compiler optimization, and quantum computing. For more information, please visit: https://hzhou.wordpress.ncsu.edu/

Expected duration of the tutorial: half-day.

Estimated number of attendees: 50~100. A modified version of the tutorial will be delivered at the American Physical Society National Meeting, March 2025, California, USA.

Tutorial Description: Quantum computing with discrete variable (DV, qubit) hardware is approaching the large scales necessary for computations beyond the reach of classical computers. However, important use cases such as quantum simulations of physical models containing bosonic modes, and quantum error correction are challenging for DV-only systems. Separately, hardware containing native continuous-variable (CV, oscillator) systems has received attention as an alternative approach, yet the universal control of such systems is non-trivial. Hybrid CV-DV hardware offers a great advantage in meeting these challenges, offering a powerful computational paradigm that inherits the strengths of both DV and CV processors. This tutorial [1] provides a pedagogical introduction to hybrid CV-DV computing, including their experimental realization, theoretical foundations and compilation techniques, instruction set architectures (ISAs), abstract machine models (AMMs), algorithms and practical applications, and open questions and challenges. This is a highly interdisciplinary topic, attendees from any background including computer science, engineering, and physics are welcome to attend.

Topics covered:

- *Physics and foundations of hybrid CV-DV quantum computation*: CV states, operators, representations; universal CV-DV quantum computation; Gaussian, non-Gaussian, and hybrid CV-DV gates; Experimental realizations. (1 hour)
- *Instruction Set Architectures and Abstract Machine Models:* ISAs and AMMs of hybrid CV-DV quantum processors, compilation methods and bosonic QEC, benchmarking. (1 hour)
- *Algorithms and Applications*: quantum signal processing; state transfer; quantum Fourier transform; quantum simulation; quantum decision-making. (1 hour)

[1] https://arxiv.org/abs/2407.10381

Slides will be available here before the tutorial.