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Distributed Quantum Computing and Quantum Networks with Photons and Atoms

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Zoom Link

Host: Prof. Yong Chen

Connecting two N-qubit remote quantum computers classically, the dimension of their combined Hilbert space is only $2\times2^{N}=2^{(N+1)}$. If they are fully connected though quantum links, the dimension of the combined Hilbert space could reach $2^{(2N)}$ which is much more powerful than two independent quantum computers. To network remote quantum computers with photonic links to extend their joint Hilbert space beyond the classical connection requires efficient conversion between local computing qubits and flying photonic qubits. However, there have been no such modules for existing leading quantum computing platforms, such as superconducting circuits, trapped ions, and neutral atom arrays. This is due to the fact that a qubit based on a single atom or ion (or artificial atom such as superconducting circuit or quantum dot) has a small cross section to interact with a single photon. On the other side, photonic systems have demonstrated power in solving intractable problems like Boson sampling, but face challenges for practically scalable universal quantum computing because it is extremely difficult for a single photon to control another deterministically. The widely used scheme with linear optics, making use of probabilistic measurement induced effective "nonlinearity", is practically not efficient for large scale implementation because it requires enormous amount of ancilla photons and computational time. In this talk, I describe a hybrid approach to address this issue with a universal distributed quantum computing scheme based on photonic polarizations and efficient atomic-ensemble ground-state quantum memories (QMs). Single-qubit photonic operations can be implemented with linear optics. To introduce nonlinear interaction between two qubits, we convert the photonic qubit states into atomic-ensemble-based QM states and implement two-qubit controlled gate with Rydberg blockade effect. As the quantum circuit elements are spatially distributed and connected via optical modes, this hybrid photon-atom scheme can be used to build a distributed quantum computer. Our scheme provides a natural quantum network interface for cloud quantum computing with remote quantum computers.

Dr. Shengwang Du is currently a Professor of Physics and the Francis S. and Maurine G. Johnson Chair at The University of Texas (UTD) at Dallas. Prior to joining UTD in 2021, he was a Professor of Physics and Professor of Chemical and Biological Engineering, and the Director of Super-Resolution Imaging Centre, at The Hong Kong University of Science and Technology; and an elected member of The Hong Kong Young Academy of Sciences. Dr. Du's interdisciplinary and cross-field research activities range from fundamental quantum physics to applied optical engineering, including AMO physics, quantum optics, atom chip and atomtronics, quantum networks, quantum computing, quantum sensing, optical neural networks for artificial intelligence, optical microscopy for solid mechanics and bioimaging. Dr. Du's PhD work on atom chips made an important contribution to the start-up of ColdQuanta, now a leading company in cold atom technologies and neutral atom quantum computing. Dr. Du is a co-founder of the Light Innovation Technology International Limited for developing and commercializing advanced optical microscopies and bioimaging techniques. Dr. Du is a Fellow of The American Physical Society (APS) and of Optica (formerly The Optical Society of America - OSA).