From Multi-Photon Entanglement to Quantum Computational Advantage

J W Pan[1]

[1] *University of Science and Technology of China, Hefei, China*
Contact Email: pan@ustc.edu.cn

Photons, the fast flying qubits which can be controlled with high precision using linear optics and have weak interaction with environment, are the natural candidate for quantum communications. By developing a quantum science satellite Micius and exploiting the negligible decoherence and photon loss in the out space, practically secure quantum cryptography, entanglement distribution, and quantum teleportation have been achieved over thousand kilometer scale, laying the foundation for future global quantum internet. Surprisingly, despite the extremely weak optical nonlinearity at single-photon level, an effective interaction between independent indistinguishable photons can be effectively induced by a multi-photon interferometry, which allowed the first creation of multi-particle entanglement and test of Einstein's local realism in the most extreme way. By developing high-performance quantum light sources, the multi-photon interference has been scaled up to implement boson sampling with up to 76 photons out of a 100-mode interferometer, which yields a Hilbert state space dimension of 1030 and a rate that is 1014 faster than using the state-of-the-art simulation strategy on supercomputers. Such a demonstration of quantum computational advantage is a much-anticipated milestone for quantum computing. The special-purpose photonic platform will be further used to investigate practical applications linked to the Gaussian boson sampling, such as graph optimization and quantum machine learning.