Experimental manipulation of atoms and photons: Applications in quantum communication, computation and simulation

Jian-Wei Pan

Quantum information science and atom optics are among the most active fields in modern physics. In recent years, many theoretical efforts have been made to combine these two fields. Recent experimental progresses have shown the in-principle possibility to perform scalable quantum information processing (QIP) with linear optics and atomic ensembles. One of our main activities is to use atomic qubits as quantum memory and exploit photonic qubits for information transfer and processing to achieve efficient linear optics QIP. On the one hand, utilizing the interaction between laser pulses and ultra-cold atomic ensembles we experimentally investigate the potentials of atomic ensembles in the gas phase to build quantum repeaters for long-distance quantum communication, that is, to develop a new technological solution for quantum repeaters making use of the effective qubit-type entanglement of two cold atomic ensembles by a projective measurement of individual photons by spontaneous Raman processes. On the other hand, building on our long experience in research on multi-photon entanglement, we are also working on a number of experiments in the field of QIP with particular emphasis on fault-tolerant quantum computation, photon-loss-tolerant quantum computation and cluster-state based quantum simulation. In future, by combining the techniques developed in the above quantum memory and multi-photon interference experiments, we will experimentally investigate the possibility to achieve quantum teleportation between photonic and atomic qubits, quantum teleportation between remote atomic qubits and efficient entanglement generation via classical feed-forward. The techniques that are being developed will lay the basis for future large-scale realizations of linear optical QIP with atoms and photons.