Entanglement of three quantum memories via interference of three single photons

With support by the National Key R&D Program of China, Anhui Initiative in Quantum Information Technologies, National Natural Science Foundation of China, and Chinese Academy of Sciences, the research team led by Prof. Pan JianWei and Prof. Bao XiaoHui (包小辉) at the University of Science and Technology of China reports the generation and verification of entanglement of three remote quantum memories via three-photon interference. This work was published in *Nature Photonics* on 21 January 2019.

Quantum network involving entanglement of multiple remote quantum memories has significant applications in multi-party quantum communication, distributed quantum computing, distributed quantum precision measurement, etc. As a photon can act as a flying qubit for long-distance transmission, it suits well for connecting different quantum memories. Thus generating photon-memory entanglement with high brightness and fidelity is of significant importance.

Pan's team makes use of cold atomic ensembles for quantum memory harnessing its superiority in terms of retrieval efficiency and storage lifetime. They place the atomic ensembles inside a ring cavity to enhance the photon-atom interaction and use the cavity itself as a filter. Besides. They also use a high-order mode for the cavity-locking beam to reduce its leakage into the single-photon channels. By taking above means, the photon-memory entanglement can be generated efficiently.

Based on the efficient source of entanglement, three pairs of photon-memory entanglement are generated separately, then the three flying photons are sent together for interference (Figure). After interference, by making projective measurements on photons 1′, 2′, 3′ and detecting their coincidence, Greenberger-Horne-Zeilinger (GHZ) state of three atomic ensembles can be created. As a result, the entangled state fidelity is 0.709 ± 0.026, exceeding the bound of 0.5 by 8 standard deviations, proving the existence of GHZ state among three quantum memories, which is the largest entangled state of remote quantum memories reported so far and paves the way towards building long-distance quantum networks.

In the near future, it is expected the photon-atom entanglement will be generated deterministically by harnessing Rydberg blockade, the memory lifetime will be extended to second regime by using optical lattice, and the wavelength will be shifted to telecom, which together will enable the creation of heralded multi-node entanglement over a long distance with a high rate.

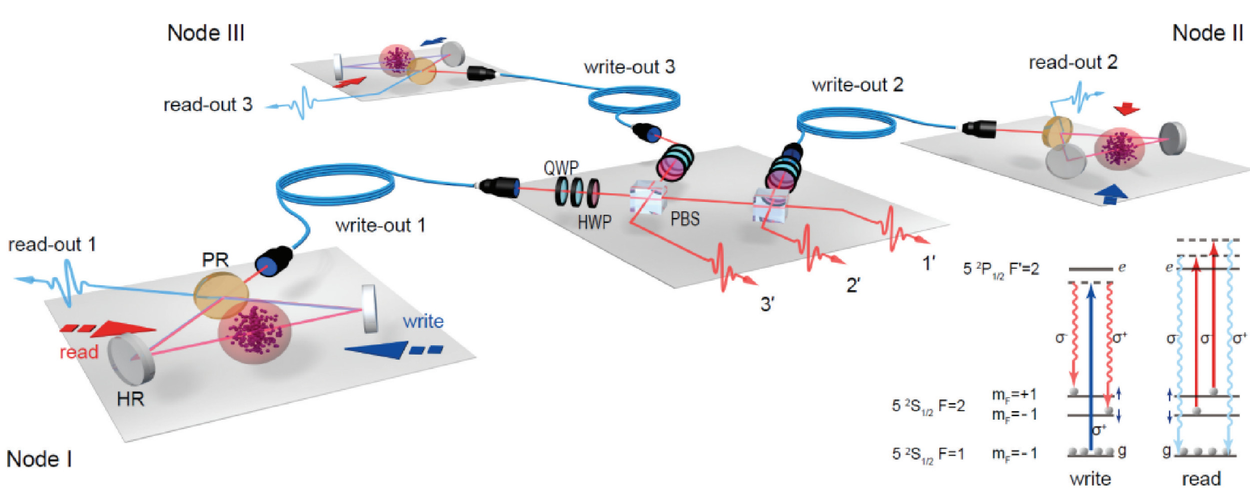

Figure Experimental layout.