Entanglement generated from chirality

With partial support from the National Natural Science Foundation of China, the research teams led by Wang DaWei (王大伟) and Wang HaoHua from Zhejiang University, in collaboration with Zhu XiaoBo from the University of Science and Technology of China and Zheng DongNing from the Institute of Physics, Chinese Academy of Sciences, demonstrated the interplay between chirality and quantum entanglement, which was published in *Nature Physics* (http://doi.org/10.1038/s41567-018-0400-9).

In Einstein's words, entanglement is the "spooky action at a distance", where the measurement of one particle instantaneously determines the quantum state of another remote particle. Not only has it initiated a longtime debate on the completeness of quantum mechanics, but also it has intrigued the fundamentally secure quantum communication. The generation of an increasingly large number of entangled quantum bits (qubits) is central for quantum computation, quantum simulation, quantum metrology and foundational studies of nonlocality and quantum-to-classical transition.

In this study, the authors realized the entanglement of qubits through chirality. An object or a system has chirality if it is distinguishable from its mirror image. Look at our left and right hands, although they are mirror images to each other, there is no way to transform one hand to the other without disintegrating and rebuilding it. French scientist Pasteur discovered the chirality of molecules when he measured the variation of the polarization of light passing through a solution of tartaric acid. Molecules with different chirality are usually called left-handed or right-handed. However, according to quantum mechanics, chiral states cannot be non-degenerate eigenstates of a parity-conserving Hamiltonian. This is in contradiction to the existence of chiral molecules—a fact known as the Hund paradox. The origin of molecular and biological chirality is conjectured to be related to parity-breaking interactions or environmental decoherence, but a quantum superposition of two chiral molecular states with distinctive optical activities has never been observed. To make progress in answering these questions, it is important to construct an artificial quantum system that breaks the parity symmetry and that can be prepared in a superposition of two chiral states.

Wang DaWei and Wang HaoHua's group synthesized the parity-breaking antisymmetric spin exchange interaction (ASI) in an all-to-all connected superconducting circuit containing five superconducting qubits. They showed various chiral spin dynamics in three-, four- and five-spin clusters with tunable configurations of ASI. Furthermore, they demonstrated a three-spin chiral logic gate and entangled up to five qubits in Greenberger-Horne-Zeilinger (GHZ) states, the maximally entangled state of the many-body system. This research provides a new way to generate entanglement, helps to understand the origin of molecular chirality, and is promising in quantum simulation of magnetism with ASI.

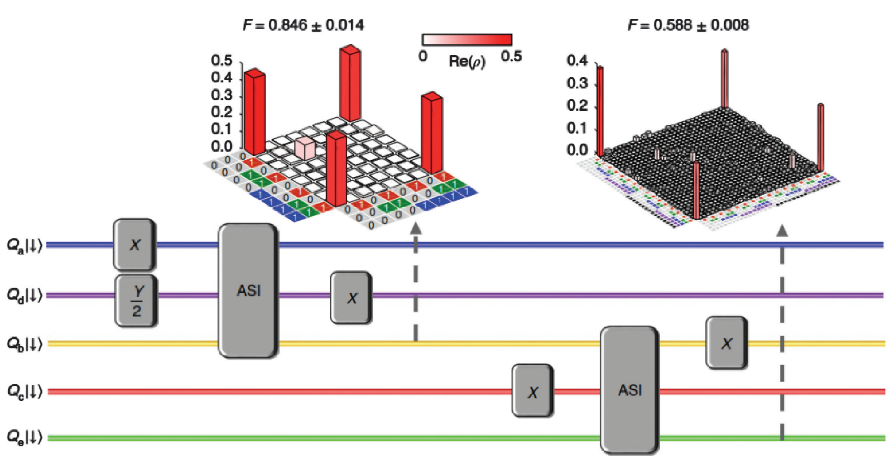

Figure Quantum circuits of generating GHZ states and their fidelities.