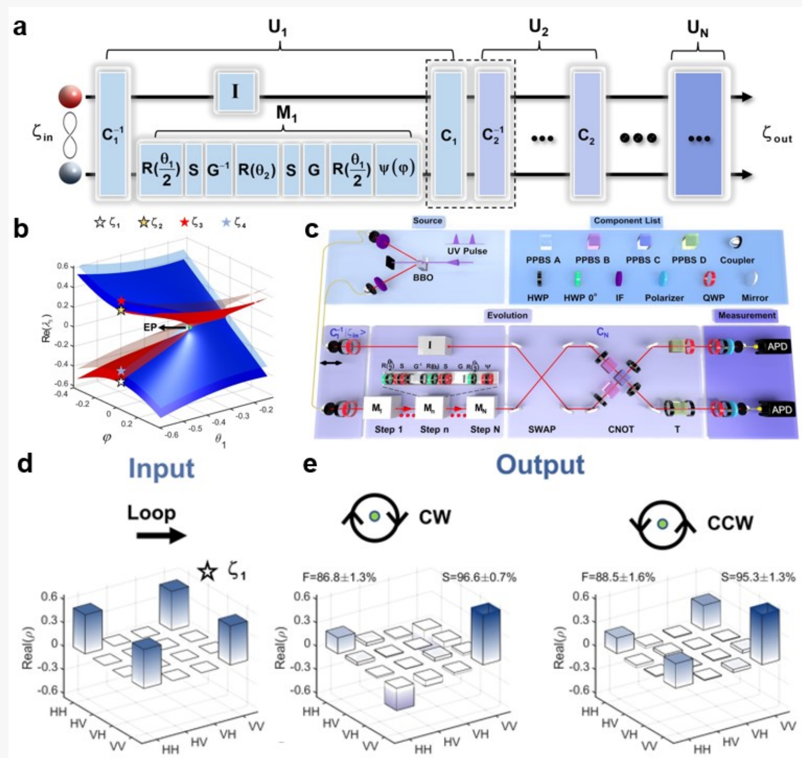
Topologically protected entanglement switching around exceptional points

USA, September 2, 2024 /EINPresswire.com/ -- The robust operation of quantum entanglement states is crucial in quantum information, and computation. However, it is a great challenge to complete such a task because of decoherence and disorder. Towards this goal, scientists in China designed quadruple degeneracy exceptional points to realize robust operation of quantum entanglement states, and realized a chiral switch for entangled states. This work opens up a new way for the application of non-Hermitian physics in quantum information.



a, the schematic of the quantum walk evolution operator. b, Riemann energy surface for evolution operator Ui. c, experimental setup. d and e, experimental results of the chiral entanglement switching with encircling an EP.

Quantum entanglement as the heart of quantum mechanics highlights the non-separability and nonlocality, which has been created experimentally in various physical systems. However, it is susceptible to influences of environment, which often appears decoherence. How to perform robust entanglement operations is crucial for applications in quantum information. Recent investigations have shown that the combination of topology and quantum states can bring hope to solve such a problem, but the fidelities of entangled states become very low without any efficient design of these topologically protected operations.

In a new paper (doi: https://doi.org/10.1038/s41377-024-01514-1) published in Light Science & Applications, a team of scientists, led by Professor Xiangdong Zhang from Key Laboratory of Advanced Optoelectronic Quantum Architecture and Measurements of Ministry of Education, Beijing Key Laboratory of Nanophotonics & Ultrafine Optoelectronic Systems, School of Physics, Beijing Institute of Technology, Beijing, China, and co-workers have developed effective scheme to realize robust operation of quantum entanglement states with high fidelity by designing quadruple degeneracy exceptional points (EPs). Based on this design, the asymmetric conversion between the four entangled states has been realized by encircling the EP, which indicates the realization of a chirality switch for entangled states. The output entangled state in the conversion is determined by the direction of circling the EP, and the conversion efficiency is very high. More interestingly, such a switch for entangled states is topologically protected. Even the disorder is introduced into the encircled path, the fidelities for output entangled states with disorder also do not change much compared to the case without disorder. This means the chiral switching of the entangled states does indeed exhibit robustness against disorder in the path parameters. At the end, they have experimentally realized the above theoretical scheme by constructing the non-Hermitian quantum walk platform, and demonstrated the robustness of this chiral switch for entangled states. The reported design will open new avenues for future quantum information, computing, and communications.

The scheme to realize robust operation of quantum entanglement states with high fidelity strongly depends on the design of quadruple degeneracy EPs. Because the designed Riemann energy surfaces with degeneracy EPs have the same eigenstates as the entangled states, asymmetric conversion between the entangled states can be realized by encircling the EP. Such manipulation for the entangled states is topologically protected due to the topological properties of the Riemann surface structure. These scientists summarize the principle of their design:

“We design a topologically protected entanglement switching around EPs for three purposes in one: (1) to realize the full topological switch between all entangled Bell states; (2) to simplify the design of various parameters for the transformation between different entangled states; and (3) to find a way to be easily implemented in various real systems.”

“Since the fidelities for all entangled states undergoing the switch are larger than 84%, it indicates the output states are very close to the ideal entangled states, and robustness to the disorder” they added.

“The presented method can be used to efficiently switch between different quantum entangled states but also help people manipulate quantum information in the real world. This breakthrough could open a new venue for future distant quantum information transfer, robust quantum computation, and any other quantum technologies.” the scientists forecast.

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