Unconventional quantum systems may lead to novel optical devices

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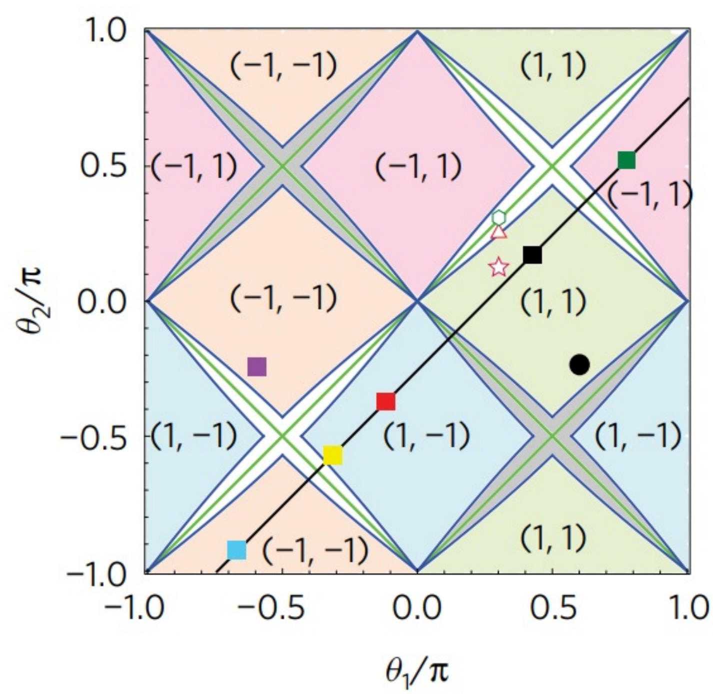

This phase diagram shows the topological numbers that characterize the Floquet topological properties observed in PT-symmetric quantum walks. The different phases are separated by white and gray regions with broken PT symmetry, where the eigenenergies are complex. Credit: Xiao et al. ©2017 *Nature Physics*

(Phys.org)—Physicists have experimentally demonstrated an optical system based on an unconventional class of quantum mechanical systems that could lead to the development of new quantum optical devices. The system is called a "PT-symmetric quantum walk," since it consists of single photons that occupy a superposition of states, called quantum walks, that obey parity-time (PT) symmetry—the property in which a system's coordinates in space and time can have their signs reversed without inherently changing the system.

The physicists, led by Peng Xue at Southeast University in Nanjing, have published a paper on the PT-symmetric quantum walks in a recent issue of *Nature Physics*.

"We present an experimental work tying together three concepts—-non-unitary quantum walks at a single-photon level, PT symmetry, and topological edge states originating from Floquet topological phases," Xue told *Phys.org*. "Each of these three concepts has attracted much attention in the past years in the scientific community. The interplay of these elements in our experimental system will no doubt give rise to rich physics."

The new results build on discoveries made over the past 20 years regarding a new class of quantum systems called non-Hermitian Hamiltonians that deviate from conventional quantum systems. In general, the Hamiltonian of a quantum system, which is a measure of its total energy, must have eigenvalues that are real rather than complex numbers, where the eigenvalues are associated with the physical properties of the quantum system. For many decades, it was thought that Hamiltonians must be mathematically described using Hermitian operators, since Hermitians always have real eigenvalues.

Although being Hermitian is sufficient for a Hamiltonian to have real eigenvalues, in 1998 physicists discovered that Hamiltonians can be non-Hermitian and still have real eigenvalues, as long as they obey PT symmetry. This discovery opened up a whole new class of quantum systems for physicists to explore. Currently, the study of PT-symmetric non-Hermitian systems is an area of active research that holds promise for a variety of applications, particularly in the field of optics.

The new study contributes to this research by demonstrating single-photon PT-symmetric quantum walks. Previously, physicists have theoretically investigated these systems, but the new study marks the first experimental demonstration due to the challenges involved in amplifying single photons.

"A PT-symmetric quantum walk is a non-unitary extension of the unitary quantum walk, which is in turn a quantum mechanical version of the classical random walk," Xue explained. "Just as PT-symmetric non-Hermitian Hamiltonians broaden the horizon of conventional quantum mechanics, a PT-symmetric quantum walk represents a new kind of quantum walk with unique features that are quite different from those of a unitary quantum walk."

This demonstration, in turn, led the researchers to experimentally demonstrate exotic properties called Floquet topological properties in PT-symmetric quantum walks for the first time. The scientists observed that Floquet topological edge states arise between regions with different bulk topological properties, suggesting that these systems contain intriguing quantum phenomena awaiting further exploration. Floquet topological properties are characterized by a pair of topological numbers, and controlling these properties may lead to the development of new quantum optical devices.

"I think our work may lead to a new generation of synthetic PT-symmetric systems," Xue said. "In PT-symmetric classical systems, recent progress may lead to applications in optical switching, modulation, sensors, wireless power transfer, and so on. While our experiment demonstrates Floquet topological states (a special topological matter with time-periodic drives) driven by PT-symmetric quantum dynamics, it provides a new platform where the interplay of PT-symmetric quantum dynamics and topological properties not only offer a quantum mechanical version of PT-symmetric systems, but may also lead to potential applications in quantum information, quantum computation, and quantum sensing."

More information: L. Xiao et al. "Observation of topological edge states in parity–time-symmetric quantum walks." *Nature Physics*. DOI: 10.1038/nphys4204