# Physicists revealed spontaneous T-symmetry breaking and exceptional points in cavity QED

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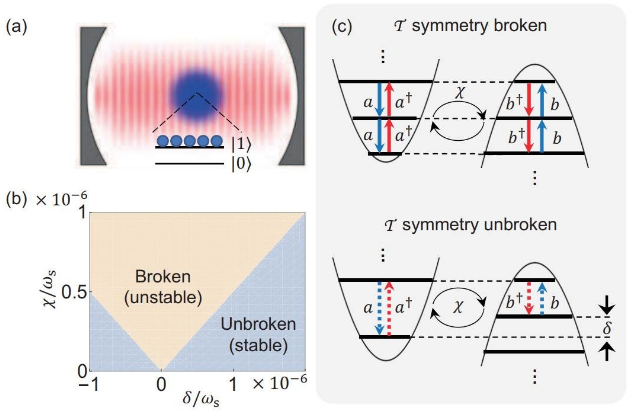
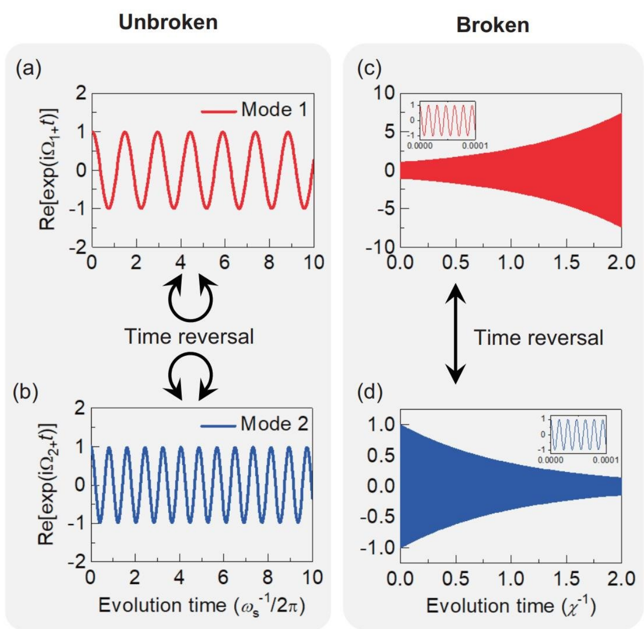



Schematic illustration of the system and the mechanism of T-symmetry breaking. Credit: ©Science China Press

Spontaneous symmetry breaking (SSB) is a physics phenomenon in which a symmetric system produces symmetry-violating states. Recently, extensive study shows that the parity-time symmetry breaking in open systems leads to exceptional points, promising for novel applications leasers and sensing.

In this work, the researchers theoretically demonstrated spontaneous time-reversal symmetry (T-symmetry) breaking in a cavity quantum electrodynamics system. The system is composed of an ensemble of 2-level atoms inside a cavity. The atoms are kept near their highest excited states and act like an oscillator with a negative mass. The researchers utilize the dipole interaction between the atoms and the cavity mode to induce the T-symmetry breaking and to obtain exceptional points (EPs).

"The dipole interaction provides a linear coupling between the collective motion of the atoms and the cavity mode," said Yu-Kun Lu, who is an undergraduate at Peking University. "For small coupling strength, the system undergoes harmonic oscillation, which is invariant under time-reversal operation. When the coupling strength reaches a threshold, the system becomes unstable against the pair-production (annihilation) process, and the excitation number of the cavity mode and the atoms will increase (decrease) with time, thus leading to the spontaneous T-symmetry breaking." The critical point between the T-symmetric and T-symmetry broken phase is proved to be an EP.




Demonstration of T-symmetry breaking in the eigenmode dynamics. Credit: ©Science China Press

"To demonstrate the existence of EP, we showed the dependence of the eigenfrequencies as well as the eigenmode on the cavity-atom detuning, and we found they coalesce at the critical point, and thus proved it to be an EP," said Pai Peng, a former undergraduate in Prof. Xiao's group and now a Ph.D. at Massachusetts Institute of Technology. Moreover, due to the singular topology of the EP, the dynamics in the vicinity of the EP is robust.

"After encircling a whole loop around EP, the final state only depends on the direction of the loop but not its shape, and thus the result is topological protected," said Qi-Tao Cao, a Ph.D. at Peking University.

"EPs used to be studied exclusively in open systems. The demonstration of EP in the present system broadens the understanding of SSB and singularities in physics," said Prof. Xiao. "Apart from its fundamental interest, spontaneous T-symmetry breaking without gain or loss also provides a new platform for various applications, such as sensing and quantum information processing."

**More information:** Yu-Kun Lu et al, Spontaneous T-symmetry breaking and exceptional points in cavity quantum electrodynamics systems, *Science Bulletin* (2018). DOI: 10.1016/j.scib.2018.07.020