Dynamic quantum phase transitions in quantum walks

With the support by the National Natural Science Foundation of China, the research team led by Prof. Xue Peng (薛鹏) at Beijing Computational Science Research Center, reported an experiment on simulating dynamic quantum phase transitions in photonic quantum walks, which was published in *Physical Review Letters* (2019, 122: 020501).

Topological phases feature a wealth of fascinating properties governed by the geometry of their ground state wave functions at equilibrium, but topological phenomena also manifest as non-equilibrium quantum dynamics in driven-dissipative and Floquet systems, as well as in quench processes. The study of phase transitions lies at the core of the description of equilibrium states of matter. Besides conventional continuous phase transitions that are signalled by symmetry breaking, topological phase transitions, characterized by the change of topology in their ground-state wavefunctions, have attracted much attention since the discovery of quantum Hall effects.

Prof. Xue's group and their collaborators report the first experimental study of dynamic quantum phase transitions using discrete-time quantum walks of single photons. They simulate many-body quench dynamics between distinct Floquet topological phases using photonic quantum-walk dynamics, and experimentally characterize dynamic quantum phase transitions and the underlying dynamic topological order parameters through interference-based measurements. Their experiment directly confirms the relation between dynamic quantum phase transitions and dynamic topological order parameters in quench dynamics of topological systems. This experiment opens up the avenue of investigating dynamics quantum phase transitions and related dynamic topological phenomena using quantum walk dynamics, whose flexible control paves the way for future studies in novel contexts such as engineered non-unitary dynamics, with decoherence, or in higher dimensions.

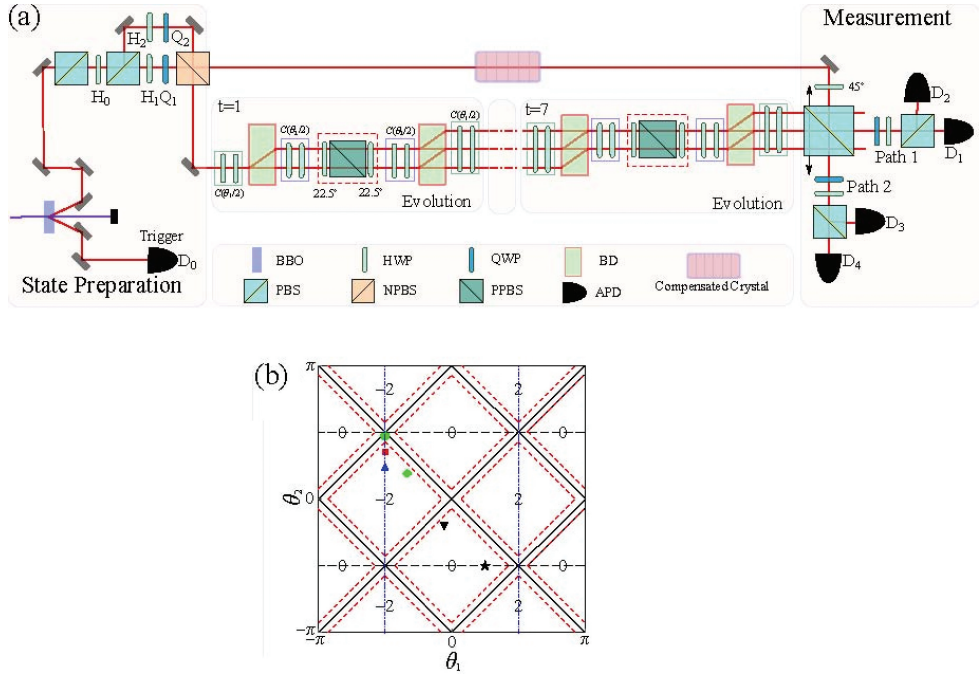

Figure (a) Experimental setup for the simulation of dynamic quantum phase transitions using quantum walks. Pairs of single photons are generated via type-I spontaneous parametric down conversion. Coin rotations and conditional translations are realized by two half-wave plates (HWPs) and a beam displacer (BD), respectively. For non-unitary quantum walks, a sandwich-type HWP-PPBS-HWP setup is inserted to introduce the partial measurement. Avalanche photodiodes (APDs) detect the signal and herald-ing photons. (b) Phase diagram for quantum walks.