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Realizing non-Hermitian dynamics via non-unitary photonic with structured light

In recent years, non-Hermitian photonics collected significant attention as a rising field in optics due to the emergence of numerous physical concepts and novel effects. Unlike systems described by a Hermitian Hamiltonian, where the Hermitian conjugate ensures system closure to the environment and energy conservation, a non-Hermitian system characterized by complex eigenvalues enables the description of open systems and facilitates understanding of how a system can interact with the environment. Here, we propose an innovative approach for simulating non-Hermitian dynamics by realizing a non-unitary photonic quantum walk based on a light beam propagating in free space and manipulated via step operators acting jointly on its polarization and transverse momentum. Within this framework, we use the latter degrees of freedom to encode the coin and walker systems, respectively, typically characterizing coined quantum walks. To induce spin-rotation, we utilize a uniform liquid-crystal (LC) plate and an LC dichroic polarization grating to obtain a spin-dependent non-unitary translation operation on the walker. Through the combination of liquid crystals and absorbing dyes, we can manipulate both polarization and light amplitude, effectively recreating a dispersive system. This development yields a compact and versatile platform that significantly expands the scope of photonic simulations in studying quantum dynamics. It, also, introduces a new dimension for manipulating topological states, enabling the observation of phenomena such as those related to non-Hermitian topological phases.

Primary author(s) : Mrs. SAVARESE, PAOLA

Presenter(s) : Mrs. SAVARESE, PAOLA