Experimental classical optical analogues of open quantum systems: Quantum discord, violation of the Leggett-Garg inequality, and decoherence enhanced tunneling

Wenlei Zhang, Jacob M. Leamer, Ravi K. Saripalli, Nicholas J. Savino, Ryan T. Glasser, and Denys I. Bondar

Tulane University, Department of Physics & Engineering Physics, 2001 Percival Stern Hall, New Orleans, USA

State of incoherent classical light is described by a coherency matrix. In our research we utilize a known mathematical equivalency between the coherency matrix and the density matrix of a quantum system to import concepts from the theory of open quantum systems to classical optics in order to uncover surprising new physics.

We, for the first time, experimentally realize complete kinematic state controllability of an open single-qubit by Kraus maps and construct all-optical input-agnostic polarization transformer (AI-APT), which transforms all input states of polarization to a particular state that can be polarized or partially polarized [1]. The output state of polarization and intensity depends solely on setup parameters, and not on the input state, thereby the AI-APT functions differently from simple polarizers and polarization rotators.

Quantum discord has been shown to be a resource for quantum advantage in addition to quantum entanglement. We present an experimental realization of an analogue of quantum discord using classical light [2]. Such a classical analogue may provide further insight in understanding and development of quantum information technologies making use of discord.

Evanescent waves are classical optical analogue of quantum tunnelling. Evanescent waves are inhomogeneous electromagnetic waves resulting from the continuity of the electric field under the conditions of total internal reflection. We experimentally and theoretically show that transmittances of the evanescent waves can be control by visibility (i.e., the degree of coherence) of the incident light [3]. This predicts a new quantum tunneling phenomenon, where incoherence of the initial state can be used to enhance the tunneling rate.

Contradicting a widespread expectation, we experimentally demonstrate *the violation of the Leggett-Garg inequality in a classical optical system* using only the polarization degree of freedom of a laser beam [3]. Our results show maximal violations of the Leggett-Garg inequality.

[1] W. Zhang et al. arXiv:2103.05398.

[2] Jacob M. Leamer et al. arXiv:2205.00088.

[3] Nicholas J Savino et al.arXiv:2205.00087.

[4] W. Zhang et al. Phys. Rev. A 104 (2021) 043711.