

Photonic quantum walks with four-dimensional coins

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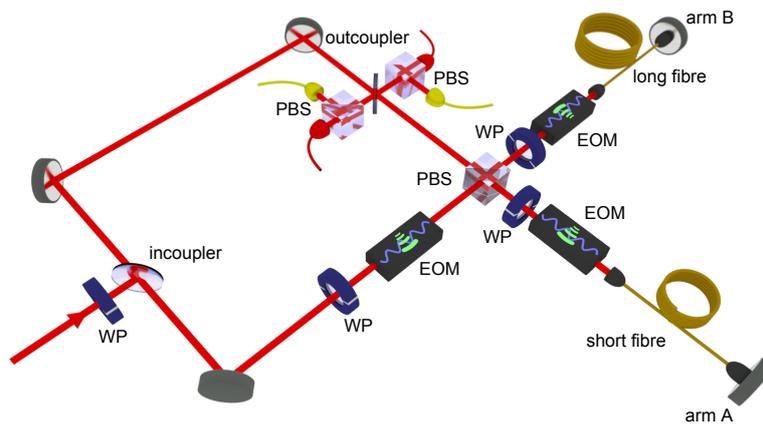
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Abstract

Discrete time quantum walks, realized in time-multiplexed architectures, are an essential tool to experimentally study quantum transport phenomena. We have implemented the well-established time-multiplexing scheme in a Michelson interferometer loop, in contrast to the standard Mach-Zehnder setup [1,2]. By exploiting the two different traveling directions in the loop in addition to the two possible polarizations of the walker, we devise a four dimensional coin space for a one dimensional quantum walk.



The dimensionality of the internal coin space of discrete-time quantum walks has a strong impact on the complexity and richness of the dynamics of quantum walkers. While two-dimensional coin operators are sufficient to define a certain range of dynamics on complex graphs, higher dimensional coins are necessary to unleash the full potential of discrete-time quantum walks. Here we present an experimental realization of a discrete-time quantum walk on a line graph that, instead of two-dimensional, exhibits a four-dimensional coin space. Making use of the extra degree of freedom we observe multiple ballistic propagation speeds specific to higher dimensional coin operators. By implementing a scalable technique, we demonstrate quantum walks on circles of various sizes, as well as on an example of a Husimi cactus graph. Our theoretical analysis shows that the platform supports implementations of quantum walks with arbitrary 4×4 unitary coin operations, and usual quantum walks on a line with various periodic and twisted boundary conditions.

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- [2] A. Schreiber, A. Gábris, P. P. Rohde, K. Laiho, M. Štefaňák, V. Potoček, C. Hamilton, I. Jex, and Ch. Silberhorn, *A 2D Quantum Walk Simulation of Two-Particle Dynamics*, Science **336**, 55 (2012).
- [3] L. Lorz, E. Meyer-Scott, T. Nitsche, V. Potoček, A. Gábris, S. Barkhofen, I. Jex, Ch. Silberhorn, *A photonic quantum walk with a four-dimensional coin*, arXiv:1809.00591 [quant-ph]