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Manipulation and reconstruction of high-dimensional states

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The capability to control and manipulate high dimensional quantum states has become relevant in several fields ranging from the probing of fundamentals of quantum mechanics to the development of safer encryption algorithms. Various engineering techniques of high dimensional quantum states have been proposed, but they strongly depend on the experimental platform and do not provide a general scheme. Here, we experimentally demonstrate an engineering protocol based on the Quantum Walk (QW) dynamic encoding the walker state in the orbital angular momentum (OAM) degree of freedom and the coin state in the spin angular momentum (SAM). The QW dynamic allows the implementation of a platform-independent scheme to engineer qudit states encoded in the walker system. Each step of the 5-steps QW is composed of a set of wave-plates that manipulate the coin state and a peculiar device, the q-plate, that can conditionally change the OAM according to the polarization. Consequently, the walker dynamics are controlled by a suitable choice of step-dependent coin operators. Moreover, decode the information stored in the OAM states is challenging experimentally and theoretically. Indeed, the platforms proposed envisage additional instruments, such as interferometry and spatial filtering, that introduce damaging noise and loss. In this regard, we characterized structured beams where the helicoidal wavefront is coupled with a not uniform distribution of the polarization on the transverse plane (Vector Vortex Beam), by using both supervised and unsupervised machine learning techniques. In particular, we obtained optimal results characterizing 15 experimental classes using both Convolutional Neural Network or Support Vector Machine supported by Principal Component Analysis (PCA). The regression task is addressed too, leveraging PCA to reconstruct a specific class of Vector Vortex Beams.

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