Optimization of the Experimental Generation and Measurement of High Dimensional Light States

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The engineering of high-dimensional quantum states (*qudit*) is a pivotal task in quantum information applications, since exploiting such states it is possible to increase the amount of information exchanged between parties and to enhance the security of cryptographic schemes. In photonic implementations, qudits can be encoded using the Orbital Angular Momentum (OAM) of photons. This is an internal and infinite-dimensional degree of freedom of light with several applications both in classical and quantum optics. However, to fully exploit the potential of OAM, reliable generation and measurement platforms are needed.
In our works [1,2], we present approaches for optimize the generation and for reliably detect OAM states. In both cases, we used the photonic implementation of a quantum walk (see Fig. 1) which has been proved capable of generate arbitrary OAM qudits [3].
In particular, in the generation stage [1] we adopted a black-box algorithm to optimize the production of OAM states both in classical and quantum regime, automatically accounting in this way for experimental imperfections. Instead, in the measurement phase [2], we performed a machine learning-based regression task for the reconstruction of the coefficients of the state under analysis, combining a dimensional reduction algorithm and a linear regressor. The high value of the fidelities, obtained averaging over several states, showcases the performance of both the approaches and indicates how they represent powerful tools for the implementation of quantum information protocols.

References

[1] A. Suprano *et al.*, Advanced Photonics, 6 (2021), Vol. 3 066002
[2] D. Zia *et al.*, preprint arXiv:2206.09873 (2022)
[3] T. Giordani *et al.*, Physical Review Letters, 2 (2019) Vol. 122 020503

Figures

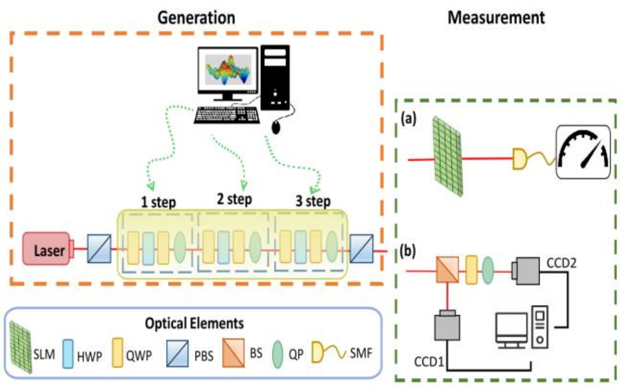

Figure 1: Experimental setup, (a) generation optimization and (b) machine learning-based measurement. SLM = Spatil Light Modulator, HWP = half-wave plate, QWP = quarter-wave plate, PBS = Polarizing Beam Splitter, BS = Beam Splitter, CCD = Charge Coupled Device, SMF = Single Mode Fiber.