Characterizing entanglement dimensionality with covariances and randomized measurements

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High-dimensional entanglement has been identified as an important resource in quantum information processing, and also as a main obstacle for simulating quantum systems. Its certification is often difficult, and most widely used methods for experiments are based on fidelity measurements with respect to highly entangled states. Here, instead, we consider covariances of collective observables, as in the well-known Covariance Matrix Criterion (CMC). In the first part of the talk, I will present a generalization of the CMC for determining the Schmidt number of a bipartite system [1]. In the second part, I show an inequality that is invariant under local changes of su(d) bases and can be used to find regions in the space of moments of randomized correlations that allow to distinguish states with different entanglement-dimensionalities [2]. In particular, we find analytical boundary curves for the different entanglement dimensionalities in the space of second- and fourth-order moments of randomized correlations for all dimensions d of a bipartite system. Finally, I will show how our method works in practice by presenting an experimental certification of three-dimensional entanglement in a five-dimensional two-photon state using 800 Haar-random measurements implemented via a 10-plane programmable light converter (cf. Fig. 1) [3]. We further demonstrate the robustness of this approach against random rotations, certifying high-dimensional entanglement despite arbitrary phase randomization of the optical modes. This method, which requires no common reference frame between parties, opens the door for high-dimensional entanglement distribution through long-range random links.

References

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[3] O. Lib, S. Liu, R. Shekel, Q. He, M. Huber, Y. Bromberg and G. Vitagliano, Phys. Rev. Lett. 134, 210202 (2025)

Figures

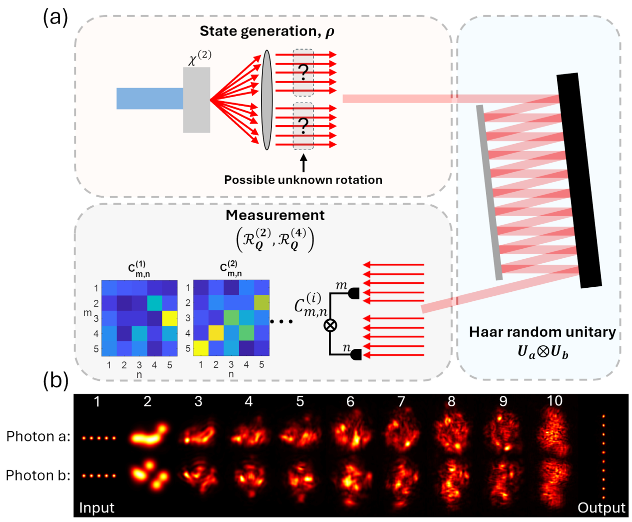

Figure 1: Sketch of the photonic experiment