

Robust certification of high-dimensional quantum communication

Some Sankar Bhattacharya

Javier Fernández Cano, Albert Rico, David Viedma, Adam Vallés, Verónica Ahufinger, Anna Sanpera

Física Teòrica: Informació i Fenòmens Quàntics, Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

Optics group, Physics Department, Facultat de Ciències, Edifici C, Universitat Autònoma de Barcelona, E-08193 Bellaterra (Barcelona), Spain (Century Gothic 10)

somesankar.bhattacharya@uab.cat

Abstract

Certifying the quantum properties of remote systems is crucial both for deepening our understanding of quantum physics and for enabling future technological applications. Most standard approaches to certifying quantumness, such as Bell nonlocality, contextuality, or quantum steering, require pre-shared resources like randomness or entanglement. Crucially, quantum behaviour can also be certified within prepare-and-measure scenarios, provided one assumes that the devices operate within a bounded Hilbert-space dimension. Among such approaches, schemes that do not rely on measurement incompatibility are particularly promising (1, 2), as they require even fewer resources. Here, we propose, design, and experimentally implement a protocol that certifies quantumness between two distant parties without the need for pre-shared resources or measurement incompatibility. The experiments are carried out using the orbital angular momentum degrees of freedom of single photons, chosen for providing increased dimensionality that is scalable. We demonstrate the robustness of the protocol through rank-stability analysis of the observed correlations, which enables the certification of non-classicality even in the presence of noise. Our results pave the way

for the certification of near-term quantum devices in noisy scenarios where distant parties have access to only a few state preparations, a single quantum measurement, and limited operational dimensions.

References

- [1] Z. Ma, M. Rambach, K. Goswami, S. S. Bhattacharya, M. Banik, and J. Romero, "Randomness-free test of nonclassicality: A proof of concept," *Phys. Rev. Lett.* 131, 130201 (2023).
- [2] T. Heinosaari, O. Kerppo, L. Leppäjärvi, and M. Plávala, "Simple information-processing tasks with unbounded quantum advantage," *Phys. Rev. A* 109, 032627 (2024).

Figures

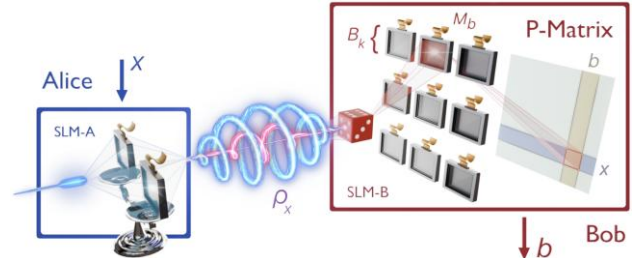


Figure 1: Scheme of the communication protocol.

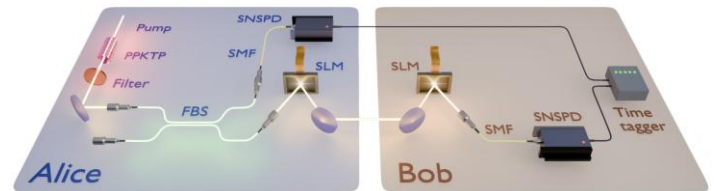


Figure 2: Simplified scheme of the setup. PPKTP: periodically poled potassium titanyl phosphate; SPDC: spontaneous parametric down-conversion; FBS: fibre beam splitter; SLM: spatial light modulator; SMF: single-mode fibre; SNSPD: superconducting nanowire single-photon detector.