

Long-range distribution of multiphoton entanglement

Monika E. Mycroft¹, Adam Buraczewski¹, Stefanie Barz^{2,3}, and Magdalena Stobińska¹

¹ Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warsaw, Poland

² Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany

³ Center for Integrated Quantum Science and Technology, University of Stuttgart, IQST, 70569 Stuttgart, Germany

Abstract

We propose a long-distance quantum communications protocol based on multiphoton bipartite entanglement and photon-number-resolving detection, which shows remarkable robustness to high transmission losses and offers near-maximally entangled states in realistic implementations.

Distribution of photonic entanglement is a key element in building secure long-distance quantum communications networks [1], but becomes easily corrupted by losses in the transmitting channels. Amplification of quantum signals is impossible [2], therefore alternative remedies are on high demand, e.g. quantum repeaters [3] or satellite quantum communications [4]. However, their resource-efficient, verifiable and well suited to the existing quantum-photonics technology implementation remains an open problem.

In Ref. [5] we present a protocol (Fig. 1a) that uses multiphoton bipartite entanglement and photon-number-resolving detection to establish entanglement distribution. We need two sources of two-mode squeezed vacuum from which the idler modes are sent towards a satellite carrying an entangling Bell measurement station. Because of the primary photon-number correlations between the signal and idler modes in each source, the two signal modes from Alice and Bob become entangled after the measurement. The amount of shared entanglement is uniquely parametrised by the measurement outcomes, k and $S-k$, and is close to maximal.

We computed the logarithmic negativity of the output state in realistic scenarios (Fig. 1b). Our protocol shows robustness to arbitrarily high symmetric losses in the idler modes. However, a reasonable imbalance lowers the entanglement negativity only by a small amount. We also prove that losses scale down the efficiency of the protocol, but not its quality, which was considered exclusive to single-photon technology. In contrast, losses in the signal modes spoil the created entanglement but these can be overcome in a delayed-choice scheme.

A Bell test on the whole ensemble of the prepared states can be performed without sampling them. The detection loophole is closed with highly efficient detectors paving the way to a genuine loophole-free Bell test [6].

To summarise, we propose an alternative to the existing solutions in the field of long-distance quantum communications. Our setup exhibits robustness to arbitrarily high transmission losses, ability of choosing local dimension of the generated entangled state and the possibility of performing a loophole-free Bell test.

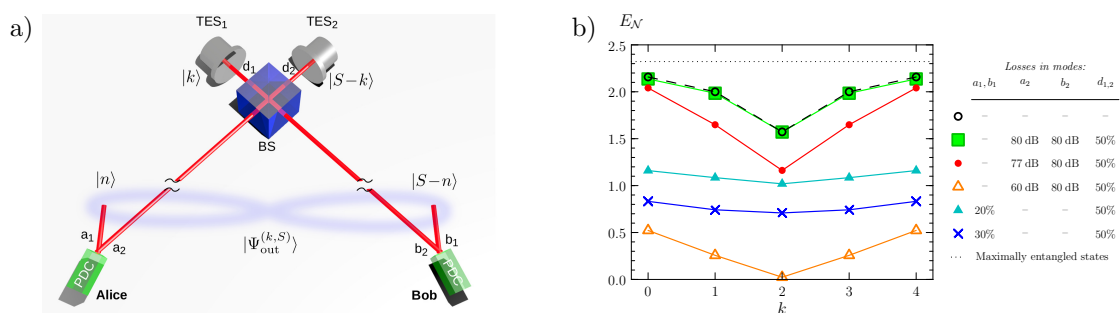


Figure 1: a) Setup. b) Logarithmic negativity as a function of detector readouts. $d_{1,2}$ denote detection efficiency.

- [1] N. Gisin and R. Thew, *Quantum communication*, Nat. Photonics **1**, 165 (2007).
- [2] W. K. Wootters and W. H. Zurek, *A single quantum cannot be cloned*, Nature **299**, 802 (1982).
- [3] N. Sangouard *et al.*, *Quantum repeaters based on atomic ensembles and linear optics*, Rev. Mod. Phys. **83**, 33 (2011).
- [4] J. Yin *et al.*, *Satellite-based entanglement distribution over 1200 kilometers*, Science **356**, 1140 (2017).
- [5] M. E. Mycroft *et al.*, *Long-range distribution of multiphoton entanglement*, arXiv:1812.10935 (2018).
- [6] A. Peres, *Bell inequalities with postselection*, Boston Stud. Philos. Sci. **194**, 191 (Kluwer, 1997).