Dr. Valeria Saggio

Photonic experiments on few-copy entanglement detection and quantum reinforcement learning

Supervisor: Prof. Philip Walther

Abstract:

In the past few years, quantum technologies have been experiencing rapid progress. The generation of quantum systems with an increasingly large number of entangled qubits, the fabrication of complex integrated processors for computation and simulation, and the development of impressive machine learning protocols that can even outperform some human skills, are only a few examples confirming broad technological progress. While this field keeps moving forward, the crucial question arises of how to effectively and practically use these new tools. For example, while entanglement verification is now a straightforward tasks in small quantum systems, the practical ability to generate increasingly large entangled states does not imply that their verification remains an easy task. Similarly, while intelligent machines solving increasingly complex tasks can be created, the question remains of how fast such machines can learn to fulfill their goals. In the course of this thesis, I will focus on these two examples and present two novel techniques that might prove essential for growing quantum applications in these fields.

First, I will present a novel protocol that verifies the presence of entanglement in quantum systems by using only a significantly reduced number of detection events. This technique aims at minimizing the experimental requirements for entanglement detection and thus constitutes a significant advantage compared to previously implemented protocols. For this reason, it proves particularly useful when large-scale quantum systems are considered. In this thesis, I will present the theoretical framework and its validation on an experimental six-qubit photonic cluster state, demonstrating that only about a hundred detection events suffice to verify entanglement with at least 99% confidence in the system.

Second, I will show the experimental verification of a machine learning protocol where quantum mechanics aids in speeding up the learning process. In fact, one of the crucial questions for practical applications is how fast machines can learn to successfully accomplish certain tasks. Previously implemented protocols had already investigated the use of quantum mechanics in machine learning algorithms and successfully shown that machine learning proves amenable to quantum enhancements. However, a reduction in the learning time was never experimentally demonstrated. I will show how to achieve such a speed-up and present the experimental implementation realized on an integrated nanophotonic processor interfaced with single photons at telecom wavelengths.