Applications in Quantum Hypothesis Testing

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This Thesis work analyzes different protocols in the context of photonic quantum sensing. Quantum sensing in the optical and photonic domain is a developed field of quantum technologies that aims at improving the measurements beyond the performance of conventional techniques by exploiting quantum states of light. Our work finds its theoretical basis in Quantum Hypothesis Testing (QHT), a field that studies the discrimination among a finite set of hypotheses codified on a quantum state, by performing a measurement on it. While a rich field from a theoretical point of view, QHT counts few experimental realizations, with some notable exceptions, such as the ones related to Quantum Illumination. With the aim to partially fill this gap we present, as original results, a more applicative approach and experimental proof-of-principles to some QHT protocols, that could open interesting perspectives for real applications. The first result is the experimental realization of the Quantum reading (QR) protocol. The original QR proposal showed how quantum-correlated optical states of light can enhance the readout of classical digital data, stored in optical memories (an example are DVDs), when compared to classical sensing benchmarks. We have also demonstrated for the first time a quantum advantage in a QHT protocol applied to the monitoring of production processes, namely the identification of a deviation of the distribution of the end-products from a reference, a protocol that we labeled as Quantum Conformance Test (QCT). We finally discuss the more complex problem of pattern recognition. Pattern recognition is the task aimed at sorting images in predetermined classes, an example being the recognition of handwritten digits. The classification is done by classical processing, ranging from simple algorithms to sophisticated machine learning techniques. Regardless of the classification method, the pattern recognition performance is heavily influenced by the reliability of the images to be classified. In our analysis we demonstrate how, using the quantum sensing techniques discussed in the thesis, one can achieve a notable advantage in the recognition task, sometimes with a great amplification of the pure sensing advantage. We validate our results experimentally showing the scalability of the quantum enhancement with the complexity of the application, not only in theory, but in practical conditions. We show how these results can be achieved using photonic correlated states, that can be routinely produced in laboratories and

photon counting (PC) measurements, performed by commercial detectors. All of the protocols discussed show good resistance to experimental imperfections, notably to optical losses, a limiting factor for most of the quantum schemes. This, in conjunction with the relative simplicity of the experimental approach adopted in the realizations, strongly suggests that the protocols discussed are very promising avenues for near-term technological applications.