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Introduction

During the beginning of the last century the long open problem of blackbody radiation was finally explained by Max Planck. Back then no one could foresee that this apparently little problem of classical science would open up a whole new world in theoretical physics. We have come a long way in our understanding of the quantum world and yet there is still so much that we do not understand about what truly happens before a measurement is performed [1].

Even though we are still ignorant to some aspects of quantum physics, what we know of it has helped us immensely through the development of new technologies that have had major impacts on mankind, such as electronics and optoelectronics [2,3]. However, all these developments employed semi-classical approaches in the sense that electrons and photons were still treated mostly macroscopically. With the development of Quantum Information Theory (QIT) [4,5,6] applications were created with the requirement that quantum states are handled individually, such as quantum cryptography [7], quantum teleportation [8] and quantum computation [9].

QIT takes many of its concepts from Classical Information Theory (CIT) [10] with the main difference that instead of discrete classical states (distinct voltage levels, for instance) quantum states are used. Many possible quantum states can be used for QIT, such as the polarization state of a photon [5], or the spin of an electron [11]. Within binary systems in CIT the two possible states that information can be represented in are called bits, and in QIT qubits become the analogue. At first sight this may not seem like a huge difference, however upon closer inspection we notice that, due to quantum theory, the two states may be in a coherent superposition. Furthermore, depending on how the measurement of the states are performed, deterministic or probabilistic results are obtained. These are fundamental principles for QIT.

The focus of this thesis is on quantum communications and, as such, we are interested only in the photon as our quantum information carrier due to its naturally low decoherence probability during its time of flight [7] Several experiments which have been done to solve some of the experimental issues in quantum communications within optical fibers are discussed. These experiments include single-photon transmission using an entangled photon-pair source (idler measured locally, signal transmitted through the fiber) with a classical reference timing channel with a 0.8 nm separation from the quantum channel within the same 27 km of standard single-mode optical fiber. There is also the first experimental demonstration of the decoy state protocol with a heralded single-photon source, an analysis of the impact for quantum communications of spontaneous Raman induced noise, generated from classical channels in optical fibers, a protocol to generate truly random numbers for variable rate Quantum Key Distribution (QKD) systems that also dismisses the usage of quantum random number generators, and finally, the first experimental demonstration of polarization encoded QKD in optical fibers with real-time continuous birrefringence compensation. All these experiments demonstrate improvements to experimental quantum communications in optical fibers, with a slight bias towards polarization coding.

This thesis is organized as follows: Chapter II gives a brief introduction to quantum communications for the beginners in the field, chapter III deals with the two experiments performed in Anders Karlsson's group during the author's stay at KTH in Stockholm, while chapter IV deals with Raman noise measurements and the random number protocol. Finally Chapter V discusses the polarization encoded QKD experiment performed together with the Group of Applied Physics of the University of Geneva led by Nicolas Gisin. Chapter VI provides the conclusions and future perspectives.