Title:	Photonic quantum memory and atom-cavity interactions
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Abstract:	Photons have shown dominance in quantum information processing tasks and long- range quantum communication. Their ability to travel long distances without inter- acting with the external environment makes them excellent flying qubits. However, certain photonic quantum information processing tasks require the faithful storage and retrieval of single photons while preserving their internal states. This requires a quantum memory, a device that can store and retrieve single photons on demand. It is accomplished through controlled and reversible mapping of the photonic state onto the atomic state. Apart from storing single photons, engineering and manipulating the quantum states of light is another key requirement in photonic quantum information pro- cessing. Atom-cavity interactions are prominently used to achieve this goal as it can provide a strong coupling between single atoms and photons. Furthermore, the strong interaction between atoms and photons allows us to implement the quantum gates between atoms and photons which is essential in order to implement quantum information processing tasks. This thesis focuses on the quantum memories and atom-cavity interactions, the two major components of photonic quantum informa- tion processing. In the first part of the thesis, we present a method to store the internal states of photons using the intra-atomic frequency-comb protocol. We show that I-AFC is capable of storing the polarization states and OAM modes efficiently, which can be employed to store the vector-vortex states. Further, we show that a single atom containing a frequency comb coupled to an optical cavity can work as an efficient quantum memory. This provides us with the possibility to realize robust and efficient ivon-chip quantum memory suitable for integrated photonic chips. In the second part, we discuss the complete input-output theory in the context of atom-cavity interactions. It provides a complete description of the interaction of an input pulse prepared in an arbitrary quantum state interacting with a local quantum system. We apply this theory to investigate the photon-subtraction operation using an atom-cavity system. This reveals the multi-modal nature of the output state upon the photon subtraction process and provides a clear picture of the photon- subtraction process.
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