DOCTORAL DISSERTATION ABSTRACT

Generating and processing quantum states of light with atoms

This PhD thesis focuses on the development of multimode quantum memory based on cold rubidium-87 atoms. Two main developments of the memory system are considered and presented in two parts of the thesis, respectively. The presentation of the scientific results (II and III) is preceded by an introductory part including a literature review, a theoretical introduction and a description of the most important parts of the experimental setup.

In the II part, I present the application of a quantum memory setup for the multiplexed generation of polarization entangled photon pairs. Chapter 4 provides a theoretical introduction to the problem of generating photon pairs in the memory and converting their EPR state to a polarization Bell states. Chapter 5 presents a characterization of the generated Bell states distributed among many angular modes. Experimental investigation includes noise level measurements, analysis of the visibility of interference in the Bell measurement and calculation of number of modes as well as measurement of the memory lifetime. Chapter 6 describes the demonstration of a phase-sensitive ghost imaging protocol employing the Bell state generator described in the previous two chapters. The presented ghost imaging scheme that incorporates a quantum memory instead of a delay line is the first demonstration of its kind previously absent in the literature.

Part III focuses on the implementation of a gradient echo memory protocol (GEM) with built-in processing capabilities. Presentation of the experimental results is preceded by a theoretical introduction describing the GEM protocol in chapter 7. Chapter 8 describes the implementation of the temporal imaging scheme in the GEM setup. The chapter includes a demonstration of a narrowband spectrometer based on the temporal Fourier transform implemented inside the memory. Chapter 9 extends this method to allow a super-resolution measurement of the frequency separation between two spectral lines. Demonstration of the protocol is preceded by a detailed discussion of the super-resolution problem in the context of information theory of measurement and estimation. The last chapter of this part (chapter 10) describes a method for three-dimensional imaging of atomic coherence stored in the memory. The presented results pave the way towards volumetric imaging of electromagnetic fields.

The (last) part IV consists of a brief summary of the presented results and identifies possible ways for the development of the memory system described in this dissertation.