

Autor: Radosław Chrapkiewicz

Tytuł pracy doktorskiej:

"Generation and characterization of spatially structured few-photon states of light"

## ABSTRACT

The present doctoral dissertation discusses the results of research on the characterization of spatial structure and statistical properties of few-photon states of light generated i.a. with the use of a new source based on multimode atomic memory. The dissertation comprises nine chapters grouped into the following parts: a literature and theoretical introduction, and three main parts providing the experimental results.

Part I discusses the characteristics of a scientific complementary metal-oxide semiconductor camera supplied with an image intensifier (I-sCMOS) constructed by our group. We provide theoretical models of saturation of photon-number-resolving detectors which relate qualitatively to our camera. We perform experimental tomography of the I-sCMOS camera and use its results for high-fidelity reconstruction of the original statistics of the impinging light.

In Part II we present an atomic memory setup in warm rubidium vapors where the write-in and readout occur due to collective Raman scattering. The memory is able to store information about the spatial structure of light. We describe the experimental setup thoroughly, with particular attention to the filtering system. We characterize multimode Raman scattering and investigate the storage performance of the memory which is limited by diffusional decoherence. We demonstrate spatial correlations between delayed Stokes and anti-Stokes photons. Using the I-sCMOS camera together with an advanced filtering system we observe spatial correlations down to single atomic excitations per memory mode.

In Part III we discuss the use of the I-sCMOS camera to observe the Hong-Ou-Mandel two-photon interference phenomenon with spatial resolution. We study the influence of finite spatial distinguishability of photons on the interference results, which leads us to measurements of the local spatial structure of a single photon.

We observe and examine closely the following relatively unexplored phenomena. In Part I we investigate seemingly nonclassical effects in measurements of photon counts statistics on the camera. In Part II we are the first ones to show multimode Raman scattering in atomic memories. Finally, in Part III we describe the first observation of the Hong-Ou-Mandel effect with spatial resolution which is studied further in terms of finite spatial distinguishability of the interfering photons.

In this thesis, we present the following novel experimental methodology. We use a new-type of I-sCMOS camera. We implement and perform the reconstruction of photon statistics based on tomographic characterization of the detector. We also build an efficient filtering system for photons in atomic memory and create an accurate method of measuring diffusion coefficients in atomic memory. We present our own methods of spatial characterization of the properties of light. Eventually, we introduce an entirely novel method: holographic measurement of the phase structure of a single photon using i.a. a specially developed phase reconstruction algorithm.

The presented results fall within the scope of contemporary research in quantum optics and have a number of possible applications, as discussed in the final remarks section.

