SUMMARY OF Ph.D. DISSERTATION

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Title

Study for Squeezed Pulse Generation Using Nonlinear Fiber Optics

Abstract

Generation and control of quantum entanglement are essential to realize practical quantum computing and quantum information processing. In optical quantum information processing, quantum entangled states would be delivered through optical fibers. Therefore, it is ideal if quantum entanglement states are directly generated in optical fibers and the major quantum information protocols are performed in optical fiber platforms.

In this study, strong quantum correlation formed among the frequency modes of femtosecond laser pulses during propagation in an optical fiber is studied in detail and it is revealed that photon-number squeezed pulses and quantum non-demolition measurement can be achieved using ultrafast nonlinear fiber optics. On the other hand, in the practical use of optical fibers, phase noise caused by guided acoustic wave Brillouin scattering (GAWBS) and Raman scattering prevent us from obtaining higher and purer squeezing states. Especially, it is a principal requirement to reduce GAWBS noise to obtain quadrature squeezed pulses, which is more suitable to generate practical quantum entanglement of light. In this study, a novel post-selection scheme is proposed and experimentally demonstrated to improve the purity of squeezed states.

Chapter 1 summarizes optical states necessary to quantum information processing, and introduces the trend of research for squeezed state and quantum entanglement generation in optics. Then, the objective of this study is summarized.

Chapter 2 describes the fundamental theory of quantum optics relating to squeezing with nonlinear optics.

Chapter 3 describes experiment and numerical analysis of photon number squeezed pulse generation with 800-nm femtosecond laser pulses using a photonic crystal fibre and a spectral filtering method. The photon number squeezing of –4.6dB is obtained by preserving the soliton-like long-wavelength component. Numerical model calculations show that quantum correlation is generated between various frequency mode pairs in the broad band laser pulse. Especially, the soliton-like long-wavelength component has strong correlation with various frequency components in the optical pulse.

Chapter 4 describes numerical analysis on photon number correlation between two individual femtosecond laser pulses during fiber propagation, where the long-wavelength component of one pulse superpose the short-wavelength component of the other pulse and they co-propagate for a long distance. As a result, photon number squeezing is obtained when two pulses overlap in frequency domain, whereas strong photon number correlation is formed when two pulses are separated in frequency domain. This strong correlation is applicable for quantum non-demolition measurement.

Chapter 5 describes experiments on quadrature squeezed pulse generation. A quadrature squeezing at –0.7dB is obtained from a Sagnac fibre loop with 1.55 μm femtosecond laser pulses only when the Sagnac loop fibre is refrigerated at 77 K to suppress GAWBS. The phase noise is also decreased by 3dB.

Chapter 6 describes the experiment of squeezed state purification using conditional homodyne detection. When selecting only pulses within a smaller amplitude variance, the purities of the squeezed states are significantly improved. Theoretical analysis supports the experimental results.

Chapter 7 summarizes the results of this research.