Research Interests
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My research interests are directed toward analyzing the nonclassical states of light, mainly the quadrature- and polarization- squeezed light, and light with sub-Poissonian photon statistics. In this broadly defined range of subjects the focus is mostly on the generation and control of the squeezed states of light by self- and cross-phase modulation. Such an interest can be justified from both a fundamental scientific point of view, and its applications. Respect to the quantum optics it is known that squeezed states of light play an important role in high precision measurements. It is also expected the squeezed states of light can be widely used in a new series of experiments designed for gravitational wave detection in the nearest future.

Here are some of the intriguing topics on which I focused my attention in the last couple of years and that are still in my attention:

a) **Generation of quadrature-squeezed light by self-phase modulation of ultrashort light pulses in nonlinear media with electronic Kerr nonlinearity**

The process of self-phase modulation of ultrashort light pulses in nonlinear Kerr medium can be efficiently employed to generate so called ”quadrature - squeezed” light. This procedure has some distinct advantages in comparison with other schemes for generating quadrature-squeezed light. There are two directions of theoretical investigations of the self-phase modulation of ultrashort light pulses in Kerr media. In one direction of investigations it is considered that the intensities of ultrashort light pulses are higher and their relative fluctuations are small. This approach makes use of the assumption that the nonlinear response of the Kerr medium is instantaneous. During the last 15 years this assumption was widely used when the quadrature - squeezed light formation in nonlinear media was investigated. This approach is applicable when it is considered that the light is monochromatic and the Kerr effect is basically due to the Raman oscillators. There are some deficiencies in this approach from both theoretical and experimental viewpoints. First, to satisfy commutation relation for the annihilation and creation Bose operators it is necessary to introduce additional noise terms in the interaction Hamiltonian. This addition is required by the preservation of canonical structure of the quantum theory but it made the theoretical treatment of self-phase modulation process very complicated. Second, in the majority of experimental situations the Kerr effect is made in proportion of about 80% by the electronic motion, Raman oscillators being responsible only for 20% of the Kerr effect. This is the typical case of fused silica fibers.

A consistent quantum theory of the self-phase modulation must account for the relaxation behavior of the Kerr nonlinearity. In this sense, the relaxation time must be considered of a finite magnitude. Thus, the starting point of a consistent quantum theory must account on the fact that the Kerr effect is made basically by the electronic motion. Such a consistent quantum theory which accounts for the finite relaxation time of the nonlinearity has been developed through the author’s efforts. The theory developed is based on the momentum operator which
accounts for the evolution of the pulse field in space instead of using an interaction Hamiltonian to describe the nonlinear process. The nonlinear response function is contained in the momentum operator such that the momentum operator satisfy the causality principle. The momentum operator has a normally ordered form. The commutation relation of annihilation and creation Bose operators is exactly fulfilled and the addition of noise terms is therefore unnecessary. The algebra of time-dependent Bose operators is developed and successfully used to estimate the correlation functions and the spectra of quadrature components. It is shown that by choosing the linear phase of the initial pulse (or the phase of heterodyne pulse) optimal, one can control the spectra of quantum fluctuations of the quadrature-squeezed component. It is also shown that, by spectral filtration, the quadrature-squeezed pulses with sub-Poissonian statistics can be formed.

The approach developed does not account for the thermal fluctuations which in fact are also present in the Kerr medium, but the predictions of the theory agree in a high degree of accuracy with the experimental results. However, the account for the thermal noise could make the treated situation be very close to the experimental one. The consideration of the thermal noise into the quantum treatment still remains a challenging question.

b) **Spectral control of the quadrature-squeezed light**

It is well known that in the case of two pulse propagation in nonlinear medium, besides self-phase modulation, other quantum effects, such as parametric interaction and cross-phase modulation, can take place. In the case of a large phase mismatch among modes the parametric interaction can be neglected. In this case the main additional effect is the cross-phase modulation. A systematic analysis of the case when the self- and cross-phase modulation effects occur simultaneously has been provided by the author. The theory developed is based on the momentum operators for self-end cross-phase modulation effects which contain a nonlinear response function in their structure. It was shown that controlling both the linear phase difference between pulses and the intensity of one pulse one can efficiently control the spectra of quantum fluctuations of quadrature components of another light pulse. The approach developed has large practical applications and its results could be used in high precision and non-demolition measurements, as well as in the techniques related to the information encoding.

c) **Formation of ultrashort light pulses with sub-Poissonian photon statistics**

Ultrashort light pulses still continue to be in the focus of the investigators. The formation and application of USPs in a nonclassical state make it possible to combine in experiments a high time resolution with a low level of fluctuations. In principle, one can obtain pulsed light fields in a nonclassical state by using the same nonlinear optical interaction as those used in the case of continuous fields. Parametric amplification is a technique that is most extensively used for this purpose nowadays. In the case of the degenerate three-frequency parametric amplification, quadrature-squeezed light is produced. However, this light is found to have super-Poissonian statistics directly at the output of the amplifier, and one needs interferometers to transform it
to be sub-Poissonian. One can obtain light with sub-Poissonian photon statistics with the aid of nonlinear interferometric devices in the presence of self-phase modulation.

If a light pulse with self-phase modulation propagates in a dispersive linear medium (or passes through optical compressors) it can be transformed in a pulse with sub-Poissonian photon statistics. An accurate calculation of this process can be made by using the consistent quantum theory developed for the self-phase modulation of light pulses in a medium with inertial electronic Kerr nonlinearity. The method proposed by the author for the formation of pulses with sub-Poissonian statistics is simple in terms of realization and stable against external random effects (technical fluctuations).

d) **Polarization-squeezed light formation in a nonlinear medium with electronic Kerr nonlinearity**

The polarization-squeezed states of light are investigated intensively in the last couple of years. It is known that the polarization light has large applications in polarimetry, ellipseometry as well as in spintronics. A characterization of this nonclassical state of light is linked with the theory behind the Stokes parameters. Up to now, the theory of Stokes parameters was used to characterize the polarization squeezed state of light only for the case of the monochromatic radiation. The theory of Stokes parameters completed with the algebra of time dependent Bose-operators has been applied successfully by the author for the case of two-pulse propagation in a nonlinear medium with electronic Kerr nonlinearity. The correlation functions of the Stokes parameters were computed for the first time. This allowed the estimation of the spectra of Stokes parameters. It was also established the optimal strategy for their control. It was shown that the spectra of quantum fluctuations of Stokes parameters could be effectively controlled by choosing the linear phase difference between pulses to be optimal at a defined frequency, by varying the intensity of one pulse in comparison with the intensity of another pulse that is considered fixed, as well as by changing one of the nonlinear phase shift per photon for one pulse at the equal intensities of pulses. The methods enumerated above of controlling the spectra of quantum fluctuations of Stokes parameters could be successfully used in experiments to obtain the required level of quantum fluctuations suppression. The results of the developed theory allows one to interpret correctly the results of the experiments that have as a result the polarization - squeezed light formation in the nonlinear media with electronic Kerr nonlinearity.