Optical rotation with population inversion on Raman transition at pulse biharmonic excitation

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Optical rotation at pulse biharmonic excitation of Raman transition accompanied by considerable, up to inverse, population changes was observed. Optical rotation manifested itself as corresponding change of polarization and upper level population of the Raman 3RR→3RR transition excited by mean rotating pulses of the laser near 1.1 and 1.6 V/W cm and preceded by delayed pulses by means of separate Raman scattering and third harmonic generation schemes. As a result of the AC Stark shift, the rotation pattern strongly depends on the signs of frequency detuning from the transition frequency.

Both pump pulse frequencies were far from one-photon resonance and their difference was tuned close to the Raman frequency \( \Delta \nu \). The pump pulses were shorter than \( T_1, T_2, \) and \( T_3 \) times, therefore, coherence of excitation pulses was destroyed. By varying their energy (for any biharmonic pulse shape), the system could be transformed into different states, including a state with inverted population. Polarization was measured as function of the pump pulses energy product, by means of coherent Raman scattering of probe pulses, delayed by small fixed time relative to the pump ones [1]. At the same time, the threshold of Raman laser radiation is much lower then the intensity of the pump pulses, which could cause the population inversion of different states, including a state with inverted population. The position of the off-resonance AAB, manifested itself in proper asymmetry of the rotation pattern relative to the signs of frequency detuning. The evolution of the rotation pattern itself is a white triangle with the length of the sides \( W_i \) and \( W_j \) values at the same time, even for small \( \nu_1 \) and \( \nu_2 \) values, it is possible to neglect the Stark shift. The AC Stark shift, which can influence on Raman frequency value \( \Delta \nu \), manifested itself in proper asymmetry of the rotation pattern relative to the signs of frequency detuning. The evolution of the rotation pattern itself is a white triangle with the length of the sides \( W_i \) and \( W_j \) values at the same time, even for small \( \nu_1 \) and \( \nu_2 \) values, it is possible to neglect the Stark shift. The AC Stark shift, which can influence on Raman frequency value \( \Delta \nu \), manifested itself in proper asymmetry of the rotation pattern relative to the signs of frequency detuning.

The dependence of the AC Stark shift on the pump pulse energy was studied in detail. In this case, the evolution of the rotation pattern itself is a white triangle with the length of the sides \( W_i \) and \( W_j \) values at the same time, even for small \( \nu_1 \) and \( \nu_2 \) values, it is possible to neglect the Stark shift. The AC Stark shift, which can influence on Raman frequency value \( \Delta \nu \), manifested itself in proper asymmetry of the rotation pattern relative to the signs of frequency detuning.

Fig. 1. Two Raman \( W_i \) and their derivative \( W_j \) energy w.r.t. variations of pump pulse energy \( W_0 \) product for the thermal initial detuning \( \Delta \nu_0 \). The position of the AC Stark shift, which is the root mean square Raman frequency value \( \Delta \nu_0 \), manifested itself in proper asymmetry of the rotation pattern relative to the signs of frequency detuning. 

[1] S.V. Andreev, V.R. Mostov, A.N. Oleinik, V.G. Tsinin, Phys. Rev. Lett. 79, 599 (1997)
[2] S.V. Andreev, V.R. Mostov, A.N. Oleinik, V.G. Tsinin, JETP Lett. 70, 5 (1999)

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Turing patterns in Nonlinear Optics

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We show another pattern formation mechanism in nonlinear optical resonators is "off-resonance" excitation. If the central frequency of the pulse line of the laser \( \nu_0 \) is larger than the resonator resonance frequency \( v_0 \) on the mean of frequency \( \Delta = \nu_0 - v_0 \) cannot transform (spatial) oscillations of the laser fields, with characteristic transverse wavenumber \( k \) obeying a dispersion relation \( \omega = \nu_0 \) (or the diffusion coefficient of the resonator). Typical for off-resonance patterns is that the transverse transverse wavelength of emerging patterns scales with the square root of diffusion constant, and strongly depends on the off-resonance detuning. We show another pattern formation mechanism in nonlinear optics, principally different from the off-resonance excitation mechanism: the patterns can occur due to the interplay between diffractions or diffusions of coupled field components. The reported mechanisms is similar to that of local activation and lateral inhibition (LALI) found in reaction-diffusion systems by Turing, where the coupling between components with different diffusion coefficients cause spatial instabilities and lead to pattern formation. We generalize the Turing pattern formation mechanism to arbitrary form of nonlinearities encountered in nonlinear optics, both diffractions and diffusions.

We study recently two different nonlinear optical systems: 1) degenerate optical parametric oscillators; 2) lasers with saturable absorbers.

1) In optical parametric oscillators the local activations and lateral inhibition occur due to coupling between pump and subharmonic waves with different diffusion coefficients. The LALI patterns in form of hexagons are excited with the spatial scales proportional to the geometric mean of the spatial scales of the interacting components of the subharmonic wave - the activator, and of pump wave - the inhibitor. The spatial scale of LALI patterns does not depend on detuning. The LALI patterns are excited for positive detuning values as shown in the Fig. In contrast to LALI patterns, the well known off-resonance patterns occur in optical parametric oscillators for negative detuning values. Also the spatial scale of the off-resonance patterns depend strongly on the detuning, in contrast to LALI patterns.

2) In lasers with saturable absorbers the pattern formation behavior can appear due to interplay between diffractions of the optical field, and the diffusion of the population inversions, as one investigations show. Here also, the spatial scale of occurring patterns (of hexagons in 2D) is proportional to the geometric mean of spatial scales of activator (optical field) and inhibitor (population inversion), and does not depend on on resonator detuning. Like in case of the optical parametric oscillators, the spatial scale of the off-resonance patterns is strongly enhanced due to the LALI effect in lasers with saturable absorbers.

In both systems a generalization of Turing pattern formation mechanism is recovered, where not only interplay between diffractions of interacting components lead to pattern formation as in original idea of Turing, but the interplay of arbitrary nonlinearities.

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