About significant enhancement of optical phase conjugate wave formed via dynamic holographic techniques

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Four-wave mixing (FWM) in dynamic holography is a well-recognazed method to producing waves with optical phase conjugation (OPC) (see, e.g., [1]). Areas of application of OPC-mirrors include: autofocusing of radiation, photolithography, lidars, control of the spatio-temporal structure of wavefronts in optical communication, the creation of bistable optical devices and optical computers, amplification of images. However, the practical use of FWM for these applications has been restricted by the rather weak intensity observed for the backward OPC signal.

The dynamical system for FWM includes the coupled-wave equations together with a governing equation describing the time evolution of the the amplitude of the dynamic grating related to the photo-induced refractive index change. Such a system is strongly nonlinear, where the amplitude of the dynamic grating can be regarded as a coupling function for the interacting waves. Moreover, the stability analysis of this system shows that the OPC-wave gain depends significantly on the boundary conditions for the input wave intensities. It turned out that just at optimal ratios of intensities, yielding significant amplification of the OPC-wave (in the region of 10 - 1000 times), the system exhibits unstable behavior. So it would seem that this mode is not achievable in dynamic holographic techniques.

In our approach, we have shown that the entire nonlinear system can be reduced to a single governing equation of type of complex Ginzburg-Landau equation (CGLE) [2,3]. Then dissipative solitons of different kinds can be formed in such a system. In the present work, we reduce the original set to a system that describes the evolution of the envelope of the amplitude of the dynamical grating, denoted by $\mathbf{\Phi}(t,z)$:

$$\frac{\partial^2 \mathbf{\Phi}}{\partial t\, \partial z} + \frac{1}{\tau}\frac{\partial \mathbf{\Phi}}{\partial z} - 2\gamma_{_N} \mathbf{\Phi} G = 0; \qquad \frac{\partial G}{\partial z} = -\frac{1}{\tau\gamma_{_N}}\mathbf{\Phi}\mathbf{\Phi}^* - \frac{1}{2\gamma_{_N}}\left[\mathbf{\Phi}^*\frac{\partial \mathbf{\Phi}}{\partial t} + \mathbf{\Phi}\frac{\partial \mathbf{\Phi}^*}{\partial t}\right] \tag{1}$$

where $G(t,z)$ is a real fucntion describing the net gain in energy transfer between interacting waves. Second, we obtained that this system reduces to a CGLE-type equation by applying a multiscale expansion:

$$i\,\frac{\partial \mathbf{U}}{\partial \eta} - a\,\frac{\partial^2 \mathbf{U}}{\partial \zeta^2} - a\,|\mathbf{U}|^2\mathbf{U} = (q^2 a - i\beta)\,\mathbf{U} \tag{2}$$

Our goal is to identify the conditions for the occurrence of extreme events and/or rogue-waves in such a system, as has been found in many other nonlinear systems (see, e.g., the review [4]). Under these dynamic regimes, it is possible to achieve significant OPC-wave enhancements in real time.

References

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