Modulational Instability, Switching Waves, Bistability and Dissipative Solitons at Resonance Excitation of Molecular J-aggregates

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Abstract: It was studied analytically and numerically the excitation of modulation instability and dissipative solitons, and also bistability phenomena in molecular j-aggregates at resonance optical pumping. Three-particle molecular interactions connected with exciton-exciton annihilation in chains were taken into account. Modulation instability boundaries both in the bistability region and outside it were determined. The investigation of various soliton types was carried out.

Keywords: modulation instability, bistability, dissipative solitons, j-aggregates

Oriented J-aggregates of cyanine’s dyes have strong optical nonlinearities at subpicosecond relaxation times. Therefore such nanostructures hold much promise for diverse applications. In particular the bistability for single j-aggregates was predicted in [1, 2]. Further the dissipative solitons (DSs) in these structures were also predicted in [3, 4].

In the present work the analytical and numerical study of modulation instability (MI) and also of DSs in single molecular j-aggregates was carried out, the three-particle interactions between molecules being taken into account. The investigation of MI was performed in linear approximation for the stationary states of homogeneous regimes in infinite chains consisting of three-level molecules (see [5]). The boundaries of stability and instability regions were determined. The relation between these boundaries and bistability boundaries was studied. It was shown that stationary states of homogeneous regimes on the upper branch of bistable dependence upon pump field amplitude are always stable, and on the middle branch they are, as usual, unstable. There are the unstable states corresponding to the lower branch of bistability also (Fig. 1).

Predicted stable and unstable stationary states were investigated by numerical simulation for finite molecular chains of large lengths. Good agreement between results of the linear theory and simulations for central regions of finite chains was obtained. It was found, that in the final stage of degradation of unstable states on lower bistability branch the transition to the upper stable branch is achieved with counter switching waves, travelling from ends of chain to its center.

The possibility of a single DS formation has been demonstrated also. The domain of soliton parameters, where such formation is possible, have been analyzed.

![Fig. 1. Instability region (dashed domain) corresponding to stationary states of the second level population relating to the lower bistability branch. 1 - boundaries of bistability region. α is the constant of exciton-exciton annihilation, Ω is the Rabi frequency.](image)

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