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Observable negative diffusion in two-component systems with exchange

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Recent experimental results for the diffusion of excitons in low-dimensional semiconductors show negative diffusion of excitons at intermediate time scales [1,2]. In the experiments the initial laser pulse produces excitons which eventually recombine and emit light. Along the process they could be trapped for a period of time. In the trapped state the excitons cannot recombine and, thus, are invisible for the measurements. Only the density of the free excitons can be estimated from the intensity of the recombination. In this contribution we show that if one observes a single component in two-component systems with exchange (such as free and trapped excitons) one could register narrowing of the distribution of particles which corresponds to the negative diffusion. We propose two models which explain the phenomenon, a simulation lattice-based model and an analytical model based on a system of reaction-diffusion equations. Both of these models belong to the class of mobile-immobile models which are also used in geophysics context [3,4,5]. The analysis shows that the observed effect is primarily caused by the initial capture and subsequent delayed release of free excitons in the vicinity of the original excitation site. Although the density of trapped excitons cannot be directly measured, the signal from the free excitons reflects the delayed release of these non-diffusing particles. As a result, at intermediate times the exciton density profile appears narrower and the mean-squared displacement decreases, which may be interpreted as a negative diffusion. The increase in intensity of recombination and binary reactions enhance the effect. While our work focusses on semiconductors the observable negative diffusion should be a general phenomenon for the multicomponent systems with components/states having very different diffusion coefficients and long trapping in a slower state.

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