Comment on "Directed Beam of Excitons Produced by Stimulated Scattering"

In a recent Letter [1] Mysyrowicz, Benson, and Fortin have demonstrated an amplification of directed ballistic beam of excitons in Cu_2O at 2 K, created by a 10 ns pulse surface excitation as in Ref. [2]. The authors claim that the amplification is due to the stimulated scattering of additional cw-pumped excitons into the ballistic excitons, which are in a superfluid Bose condensed state. The authors propose a new conception of "excitoner," i.e., radiationless counterpart of a laser.

However, direct estimates show that such excitoner interpretation [1] is far from reality. If the exciton pulse, detected without the cw irradiations, is due to the exciton condensate, the exciton density in the ballistic packet has to exceed the Bose Einstein critical density at 2 K, $n_c \approx 8.7 \times 10^{16}$ cm^{-3}. The total number of excitons in the "superfluid ballistic exciton packet" should be larger than $N_{\min} = n_c A S \tau_{\mathrm{bal}} \approx 4 \times 10^{13}$, where $A \approx 1$ mm^2 is the detector area, and $\tau_{\mathrm{bal}} \approx 0.1$ μs and $S = 4.5 \times 10^5$ cm/s are the duration and ballistic velocity of the detected pulse, respectively. The cw irradiation may increase the amount of excitons, reaching the detector, at least by twice (see, e.g., Fig. 1(b) in [1]). Thus, more than 10^{13} excitons should exist in the sample due to the cw irradiation, in order to agree with the excitoner picture. On the other hand, the total number of cw excitons, excited in the sample through the $d = 1$ mm diaphragm by $I_{\mathrm{cw}} = 4$ W/cm^2 beam with $\hbar\omega_{\mathrm{cw}} = 2.049$ eV, is controlled either by the exciton lifetime, τ, or the diffusive time, l^2/D (where $l \approx 1$ mm is the sample size and D is the diffusion constant), depending on what is smaller. It cannot exceed

$$N_{\max} = \min\left\{\tau, \frac{l^2}{D}\right\} \frac{I_{\mathrm{cw}}}{\hbar\omega_{\mathrm{cw}}} \frac{\pi d^2}{4} \approx 2 \times 10^{10} - 3 \times 10^{11},$$

where $\tau \approx 10^{-6} - 10^{-3}$ s and $D \approx 600$ cm^2/s [2,3]. This number is at least by 100 times smaller than needed for the excitoner interpretation.

We have developed [4] the alternative "phonon wind" interpretation of the ballistic exciton transport in Cu_2O, which attributes the latter to the nonequilibrium phonon induced drag without assuming the exciton superfluidity. The new experiments [1] can also be quantitatively explained within this picture. The ballistic phonons, generated near the sample surface during the relaxation of pulse-generated excitons, drag toward the detector not only their "parent" excitons, but the cw excitons as well. In Fig. 1 we show the calculated evolution of the exciton flux on the back side of a 2.2 mm thick sample, for two different pulse intensities, $I_p = 0.063$ and 2 MW/cm^2 [Figs. 1(a) and 1(b)], without (solid lines) and under cw excitation trough 150 and 250 μm slits (dotted and dashed curves, respectively), with $I_{\mathrm{cw}} = (0, 0.5, \ldots 2.5)\eta$ kW/cm^2, where $\eta \approx 10^{-3}$ is the relative part of pulse-generated excitons, reaching the back surface. Figure 1 reproduces correctly the experimental results of [1].

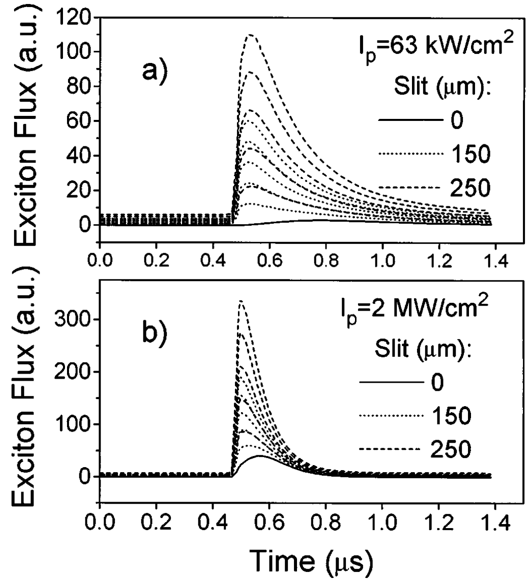

FIG. 1. Exciton flux at the back surface of a 2.2 mm sample vs time after a 10 ns pulse excitation, calculated within the phonon wind model (see text).

The "gain" coefficient as defined in [1] becomes very large within the phonon wind model below the threshold, when the pulse-generated excitons do not reach the detector ballistically. But the phonons still reach the detector and push toward it the cw excitons. This explains the experimental data at lower I_p (see Fig. 4 in [1]). The excitoner explanation of this fact is excluded, because without the condensate there should be no stimulated scattering.

In conclusion, the experiments [1] should be attributed to the nonequilibrium phonons rather than to the stimulated scattering into a superfluid exciton packet.

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