

PHOTOCONDUCTIVITY
OF GaSe UNDER HIGH INTENSITY EXCITATION

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An investigation is presented of the photoconductivity in layered GaSe crystals in the exciton resonance region under high intensity optical excitation. The disappearance of the exciton peak in the photoconductivity and transmission spectra is ascribed to a process involving exciton-exciton interaction. The electron-hole pair density is about $3 \times 10^{19} \text{cm}^{-3}$ which exceeds the exciton density necessary for the Mott transition in GaSe.

In this note we present the preliminary experimental results of photoconductivity in GaSe crystals in the exciton resonance region at high optical excitation.

As an excitation source, a Rhodamine 6G dye laser pumped by the output of a N_2 -laser, tuned through the region 594-643 nm with a spectral width of 0.04 nm, a pulse power of 120 kW at a repetition frequency of 10 Hz and a pulse width of 1 ns was used.

The layered GaSe samples investigated were grown by the Bridgman method. The cleaved samples had thicknesses about 10-30 μm with high quality surfaces. Ohmic contacts to the samples were made using In. The mobility and concentration of the charge carriers, measured by conventional methods at room temperature, were about $20 \text{ cm}^2/\text{Vs}$ and $1 \times 10^{14} \text{ cm}^{-3}$, respectively. The incident light being perpendicular to the layer surfaces (parallel to c-axis) was focused into a spot of 0.1 mm diameter. The applied field direction was perpendicular to the c-axis of the crystal. The output signals were detected by a recorder through a storage oscilloscope.

The results for the excitation spectra of photoconductivity are given in Fig. 1. At the lowest excitation the well-known exciton peak is observed at 2.00 eV (curve 1) [1-5]. By increasing the laser intensity, the exciton peak is raised first (curve 2), then begins to diminish (curve 3) and disappears completely at higher intensities (curve 4). The transmission spectrum of GaSe measured under the same experimental conditions is also indicative of a bleaching of exciton absorption at higher excitations. This is illustrated in the inset of Fig. 1.

Dependence of the photoconductivity on the excitation power in the case of resonant excitation of excitons is shown in Fig. 2. It is clear from the figure that, photoconductivity is changed from a linear to a sublinear dependency over a rather extended region of intensities. By increasing the laser intensity further, the photocurrent starts to decrease.

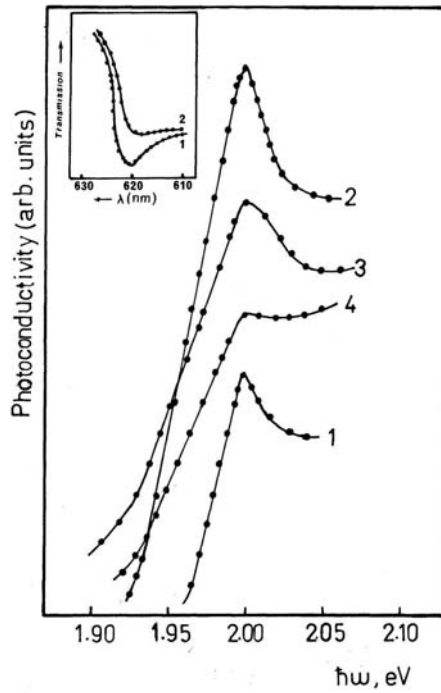


Fig.1. Photoconductivity spectra of GaSe (300 K) at various excitation powers (in MW/cm^2): 1-0.3; 2-1; 3-5; 4-12; The inset shows transmission spectra for two levels of excitation (in MW/cm^2): 1-0.1; 2-12;

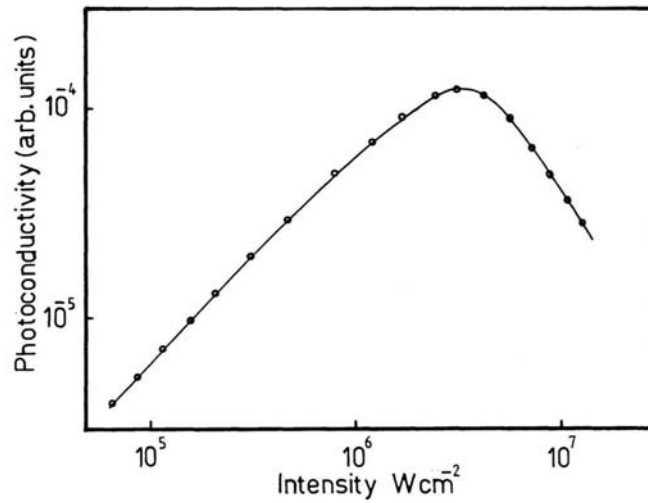


Fig.2. Dependence of the photoconductivity on the excitation power in the case of resonant excitation of excitons ($\hbar\nu = 2.00 \text{ eV}$).

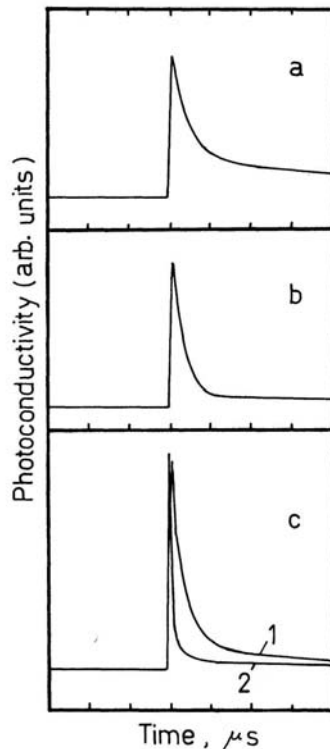


Fig.3. Relaxation curves of photoconductivity at various excitation powers (in MW/cm²): a- 0.3; b-3.9 (time per division 0.5μs), c-6 (curve 1), 12 (curve 2) (time per division 0.2μs).

The relaxation curves of photoconductivity as a function of the excitation show certain peculiarities (Fig.3.). At low excitation (~ 1.5 MW/cm²), the decay time consists of fast and slow components (Fig.3, a). The fast component is of the order of $\sim 3 \times 10^{-7}$ s which does not change upto 3 MW/cm², while the slow component is of the order of a few microseconds. By increasing the intensity, the density of charge carriers contributing to the slow component decreases with respect to that of the fast component (Fig.3, b). When the excitation power exceeds ~ 3 MW/cm², the time duration of the fast component becomes small ~ 10 ns (Fig.3,c).

The above characteristics exhibited by GaSe samples may be explained by the process of exciton - exciton interaction leading to a complete breakdown of excitons [6-10]. In fact, at low excitation levels, in the case of resonant excitation of excitons, only a small number of excitons having mutually weak interactions is created in GaSe. By increasing the laser intensity, the exciton density is raised leading in turn to a rise in photoconductivity. When the concentration of excitons reaches a critical value, strong interactions take place between them. This process limits the concentration of excitons and therefore causes the photocurrent not to rise. The density of the absorbed photons at 4 MW/cm² averaged over the sample thickness in our experiment reached $\sim 3 \times 10^{19}$ cm⁻³ which exceeds the exciton density necessary for the Mott transition in GaSe [2].

Analysis of the kinetics of the equations of photoconductivity for CdS show that, at low excitations photoconductivity changes linearly with the excitation intensity, but at high excitations when exciton-exciton interaction becomes dominant, the linear dependency is changed into a sublinear one [11, 12]. Our experimental results concerning the photoconductivity in GaSe are in good agreement with the results of V.D.Egorov et al. [12] for excitations upto 3 MW/cm², but for higher excitations the photoconductivity starts to decrease (see Fig.2). The decrease in photoconductivity at higher excitation levels (> 4 MW/cm²) may be due not only to the diminishing of the exciton absorption (due to an exciton-exciton interaction process), but also to the diminishing of the recombinaton life time of electron-hole pairs (due to the other processes such as two-photon absorption or free-carrier absorption [13]).

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YÜKSƏK OPTİK HƏYƏCANLAŞMADA GaSe KRİSTALLARININ FOTOKƏÇİRİCİLİYİ

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XÜLASƏ

Layvari GaSe kristallarının fotokeçiriciliyi yüksək optik həyəcanlaşmada eksiton rezonansı oblastında təcrübi olaraq tədqiq edilmişdir. Fotokeçiriciliyin və buraxma əmsalının spektrlərində eksiton udulmasının aradan getməsi eksiton-eksiton qarşılıqlı təsiri ilə izah olunur. Elektron-deşik cütünün konsentrasiyası ($3 \times 10^{19} \text{ sm}^{-3}$) GaSe kristallarında Mott keçidi üçün tələb olunan eksitonların konsentrasiyasından ($\sim 10^{17} \text{ sm}^{-3}$) iki tərtib çoxdur.

**ФОТОПРОВОДИМОСТЬ GaSe
ПРИ ВЫСОКИХ УРОВНЯХ ОПТИЧЕСКОГО ВОЗБУЖДЕНИЯ**

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РЕЗЮМЕ

В слоистых кристаллах GaSe экспериментально исследована фотопроводимость в области экситонного резонанса при высоких уровнях оптического возбуждения. Исчезновение экситонного пика в спектрах поглощения и фотопроводимости кристаллов GaSe объясняется процессом экситон-экситонного взаимодействия. Плотность электронно-дырочных пар, генерированных в GaSe под действием лазерного излучения ($3 \times 10^{19} \text{ см}^{-3}$) на два порядка превышает плотность экситонов, необходимую для моттовского перехода в этих кристаллах ($\sim 10^{17} \text{ см}^{-3}$).