DEPENDENCE OF ELECTRON MOBILITY ON THE ORDER OF ABSORPTION
(ONE-FOUR) IN ZnS AND CdI₂ CRYSTALS.
ABSTRACT

The photoconductivity and electron mobility of ZnS and CdI₂ crystals have been studied (Chapter II and III respectively) using N₂-laser, fundamental and frequency doubled Nd:YAG laser. Extremely low values of the electron mobility (≈10⁻³ cm²/V sec), are however, found to be varying with the order of absorption, in both the cases, when different lasers are used. It is found to be low in case of one-photon absorption and increases with the order of absorption.
4.1 INTRODUCTION

In Chapter II and III we have studied different aspects of the photoconductivity in ZnS and CdI₂ crystals using pulsed laser excitation. Both of these crystals have band gap more than three electron-volts. In both the cases another band is reported at a depth of 0.8 - 0.9 ev, wherefrom one-photon transition is forbidden but two-photon transition is allowed contrary to the argument made by Myl'nikov and Kozyrev in case of ZnS crystal. It has been concluded that N₂-laser excites one-photon absorption in both the cases while multiphoton absorption takes place in case of Nd:YAG, frequency doubled Nd:YAG and Ruby laser excitations. In conformity with the results reported by the earlier investigators, the electron mobility is quite low in most of these cases showing variation with the frequency of the laser used. Since the values obtained during the present course of investigation are several orders of magnitude low in comparison to value reported in the case of cw excitation using xe-arc lamp or mercury lamp. The problem seems to be quite interesting. Due to the coherence the properties of laser radiation are altogether different from xe arc lamp or mercury...
lamp, we can not come to a quick decision while comparing the signals obtained in different cases. Earlier investigators coined a world laser-induced-absorption to explain the extremely low values of the electron mobility in case of ZnS crystal using N₂-laser excitation. Due to this reason, and also because ZnS gives a very strong reflectance as well as photoconductivity signal at N₂-laser frequency we have studied the different aspects of electron mobility in these two cases. The results are reported here.

4.2 EXPERIMENTAL PROCEDURE

The experimental details for electron mobility measurements are the same as described earlier in Chapter II. The schematic diagram of the system has been shown in Fig.2.1. All the measurements are done in the range \(-\tau_l < t < 0\), where \(\tau_l\) is the pulse width of the laser used. Electrical contacts are taken with the help of silver paint in case of CdI₂ and indium coated electrodes with silver paint in case of ZnS crystal. As shown in the figure, in all these cases, light falls perpendicular to the front surface on which the electrodes are attached.
4.3 RESULT AND DISCUSSION

Figure 4.1 shows the electron mobilities in case of CdI$_2$ crystal under N$_2$-laser excitation whereas figure 4.2 and 4.3 represent electron mobilities in CdI$_2$ and ZnS crystals under Nd:YAG and frequency doubled Nd:YAG laser excitations. The value of electron mobility increases with the excitation intensity in all the cases as expected according to the standard relation $\mu = 10^{13} \frac{I}{\nu^2}$ [38]. However, the values of electron mobility obtained in these cases show marked difference. In case of N$_2$-laser excitation the electron mobility is found to be in the range $10^{-3}$ cm$^2$/V sec in both ZnS (Chapter IIB) and CdI$_2$ crystals, while in the case of Nd:YAG laser excitation the maximum values obtained are 33 cm$^2$/V sec and 24.7 cm$^2$/V sec in case of CdI$_2$ and ZnS crystals respectively. In case of frequency doubled Nd:YAG laser shown in figure 4.2 (inset) and figure 4.3 (inset), the mobility lies in between the two. Since the band gaps of CdI$_2$ and ZnS crystals as reported earlier are 3.2 ev and 3.68 ev respectively, we expect one, two, and three photon excitations in case of CdI$_2$ using N$_2$-laser, frequency doubled, and fundamental Nd:YAG lasers respectively, while in case of ZnS, two and four photon excitation is possible using
FIG. 4.1. Increase in mobility of CdI₂ crystal with an increase of intensity at different electric fields using N₂-laser excitation.
FIG. 4.2. Increase in electron mobility of CdI₂ crystal with intensity under (A) Nd: YAG laser and (B) frequency doubled Nd: YAG laser excitation.
FIG. 4.3. Increase in electron mobility of ZnS crystal with intensity under (A) Nd:YAG laser and (B) frequency doubled Nd:YAG laser excitation.
frequency doubled and fundamental Nd:YAG lasers. Extremely small value of the electron mobility in case of $N_2$-laser excitation can be understood to be due to the dominance of surface effect in case of one-photon absorption. With the increase of the order of absorption, the absorption cross-section decreases, so the volume effect starts dominating rather than the surface one. This argument is particularly relevant in the present case due to the geometry of the experimental set up (figure 2.1), where the electrodes are attached on the surface of the crystal on which light is falling. For an alternative arrangement when one electrode is at the front and the other at the back surface greater volume of the sample may be involved even in the case of one-photon absorption. But this can be done only at the cost of the photocurrent, which may become too feeble to be detected.

Excitation by a pulsed laser, which is the case of all the multiphoton absorption using high power lasers, must be understood in a different frame than those of cw excitations involving one-photon absorption using ordinary light sources. Under the condition $\tau_L < \tau_{eL}$ (where $\tau_{eL}$ is the recombination time), the carrier density $N$ is given by the relation $56$
\[ N = \frac{\alpha \bar{E}_{\text{ad}}}{h \nu} \]  

(4.1)

where \( \alpha \) is the absorption coefficient, \( \bar{E}_{\text{ad}} \) is the energy area density and \( h \nu \) is the energy of the photon.

The electron mobility \( \mu \) is given by the relation

\[ \mu = \frac{I_{\text{ph}}}{e \alpha \bar{E} E} \]  

(4.2)

where \( E \) is the applied electric field and \( "a" \) the separation between the two electrodes.

Using equations (4.1) and (4.2), the value of \( \mu \) can be written as

\[ \mu = \frac{I_{\text{ph}} \bar{E}_{\text{ad}}}{e \alpha \bar{E} \times \bar{E}_{\text{ad}}} \]  

(4.3)

In case of laser excitation, \( \bar{E}_{\text{ad}} \) is very large in comparison to the excitation by ordinary light, so \( \mu \) is expected to be quite low. This is sometimes called laser-induced-absorption. This argument goes well so long as the absorption is one-photon and \( \alpha \) relatively high. But in the case of two/multiphoton absorption, larger volume of the optical material is involved due to the low value of absorption coefficients which also reduces \( N \). As a result electron mobility increases due to this reduction of the carrier density \( N \). The large value of \( N \) in case of one-photon absorption also explains the appearance of photocurrent.
in case of ZnS using \( N_2 \)-laser excitation, though there is a strong reflection band at this frequency. As the electrodes are deposited on the front surface of the crystal, a large contribution to the photocurrent is due to the surface rather than the volume of the sample. In the case of spectrophotometers where we use xe-lamp having photon density much smaller than the \( N_2 \)-laser, volume effects dominate over the surface effects and hence the physical processes going on in the two cases are altogether different.

4.4 CONCLUSION

The electron mobility is found to be very low in case of one-photon absorption using pulsed lasers. This is attributed to the high concentration of charge carriers produced at the surface due to the relatively large absorption cross section. With the increase in the order of absorption the absorption cross section decreases, which results into an increase in the value of the electron mobility.

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Observations using Nd:YAG laser made by Dr. R.D. Singh, my supervisor, at I.R.O.E. - CNR and Instituto de Quantistica Electronica, Firenze, Italy during his visit to these laboratories.