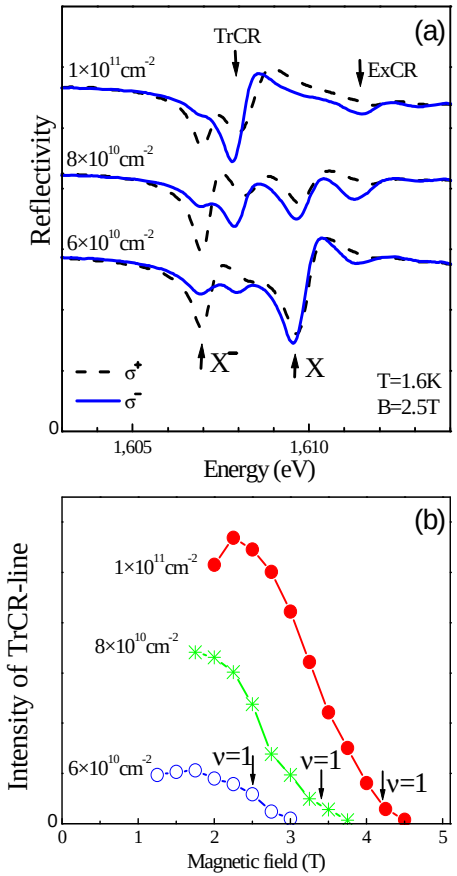
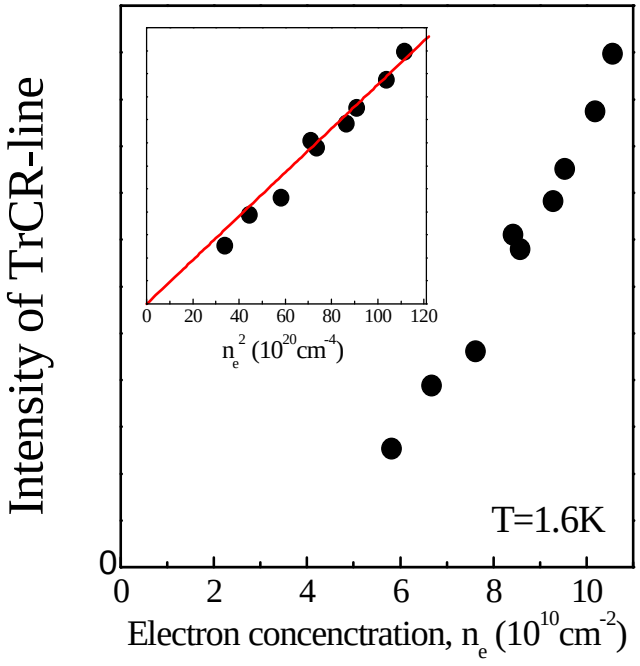
Line of the TrCR is observable at filling factors > 1. The intensity of the TrCR line is proportional to the second power of the 2DEG density

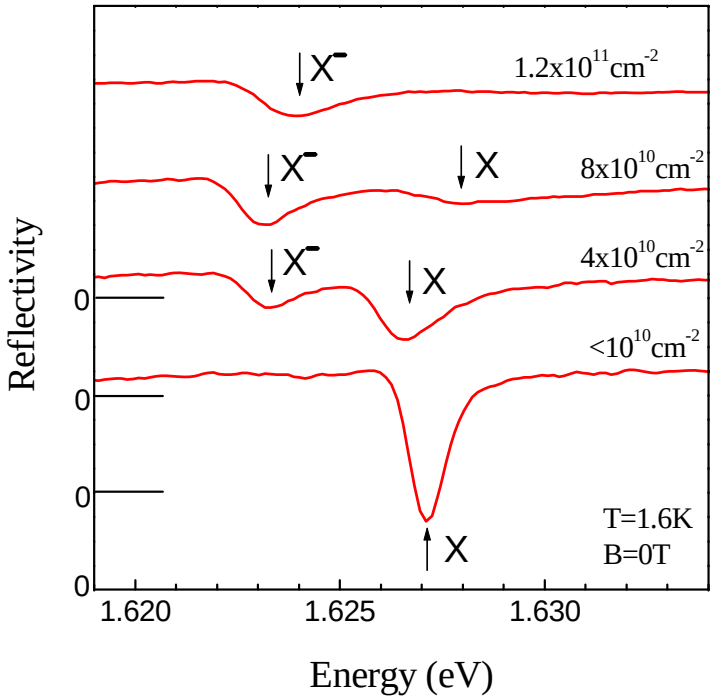


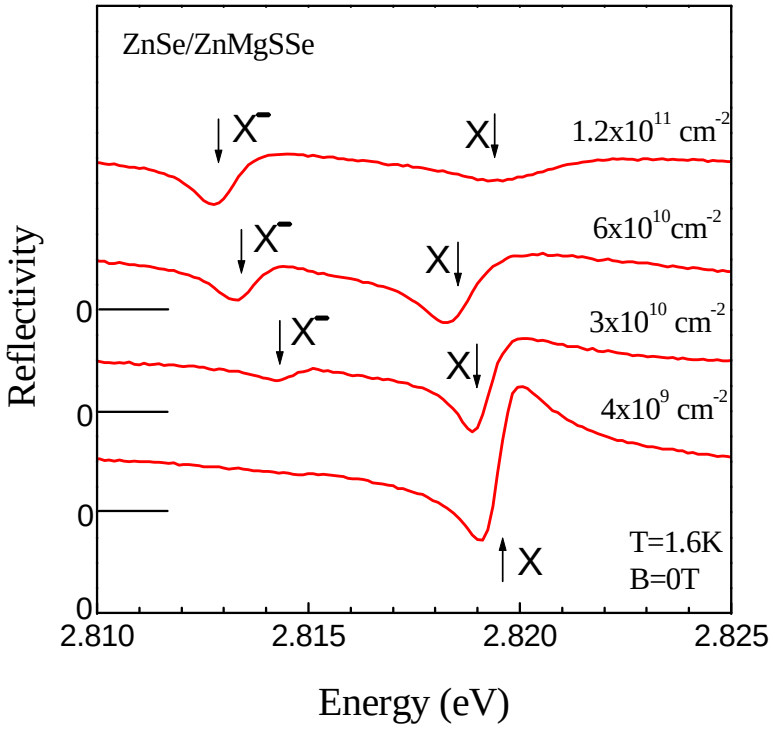
Surprising Trion stability against free electron screening

Экситон исчезает из спектра при относительно малых концентрациях электронов, а трион остается

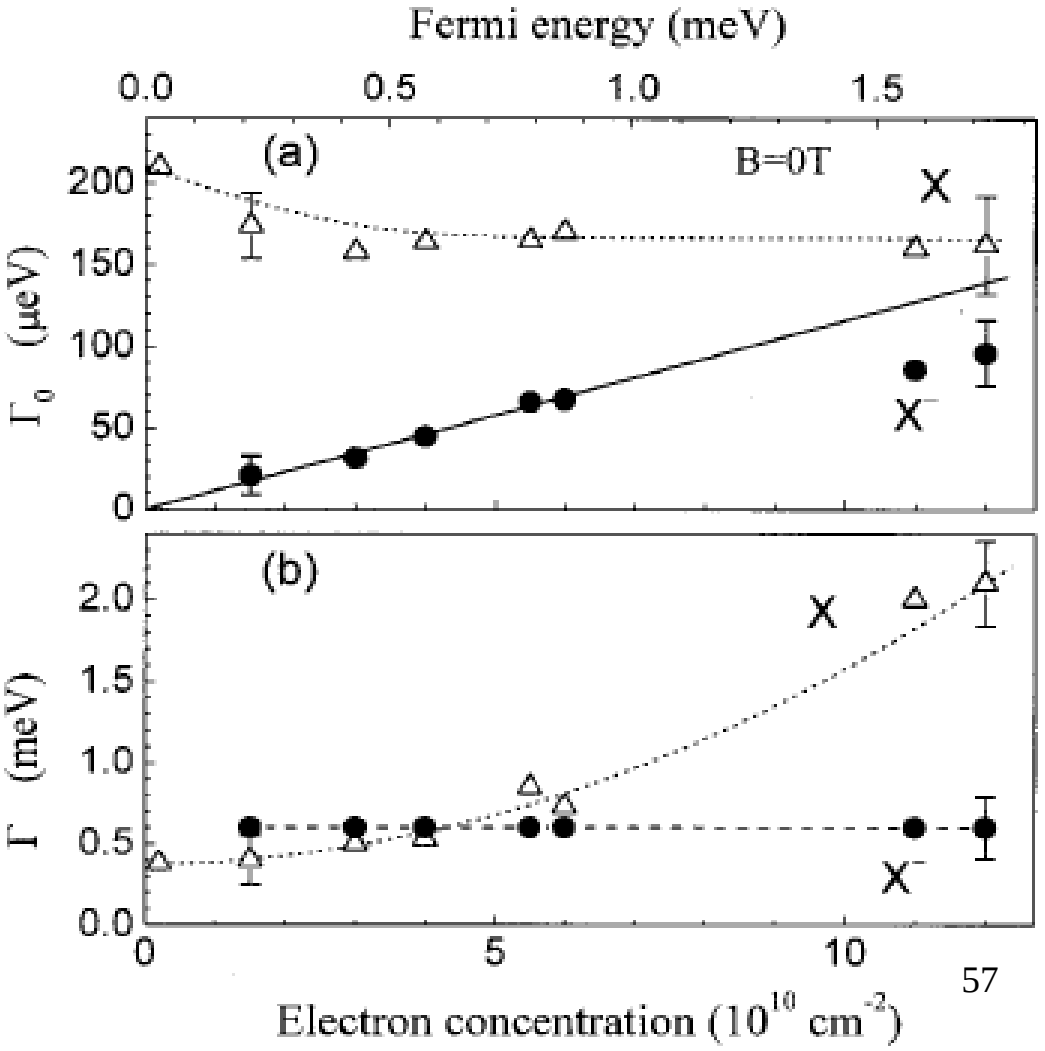
CdTe/CdMgTe 80A




ZnSe/ZnMgSSe 80A

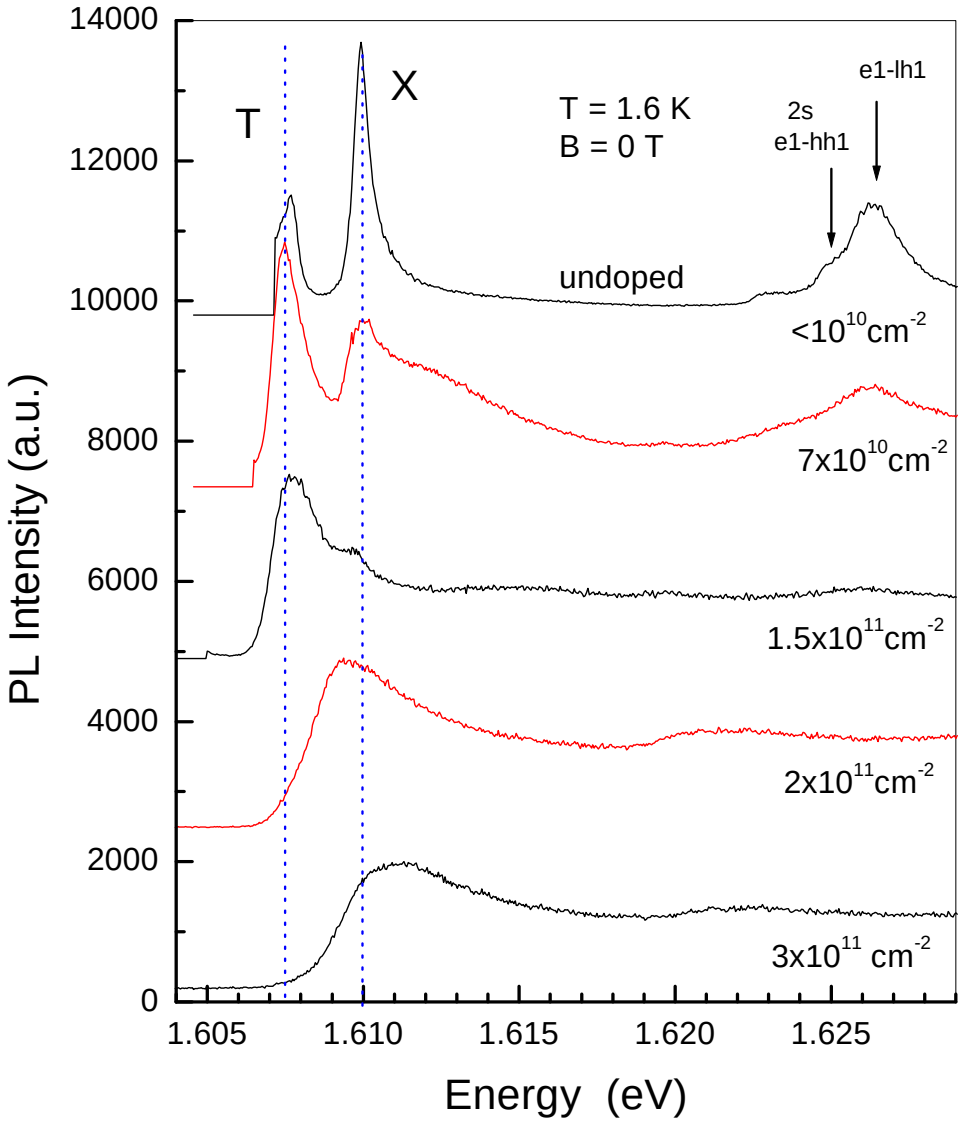


Сила осциллятора экситона не зависит от плотности 2DEG

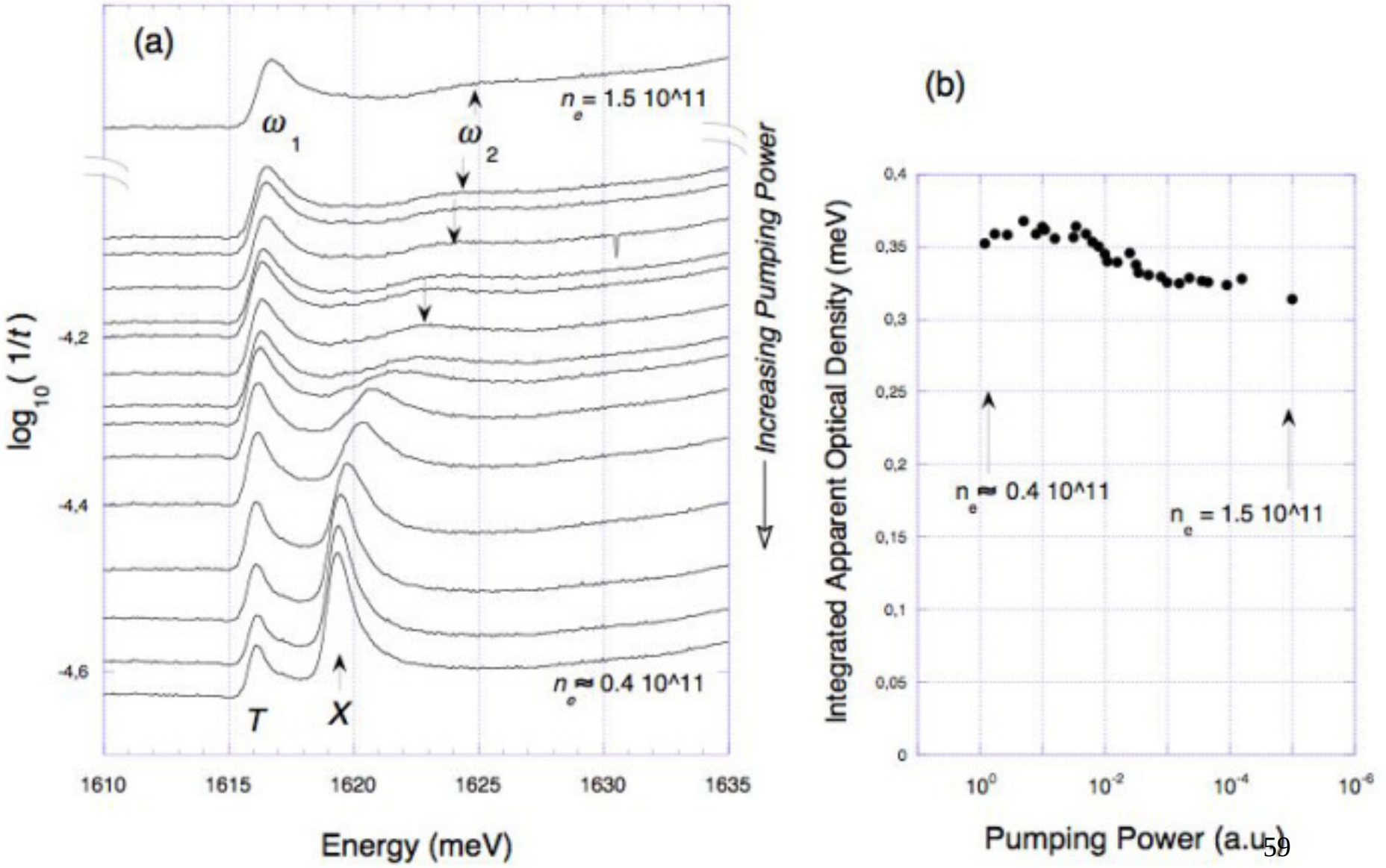



Затухание экситона растет с ростом плотности

# Спектры поглощения (PLE) как функция концентрации



*Optical density of CdMnTe QW m1120 in zero field at 2K*



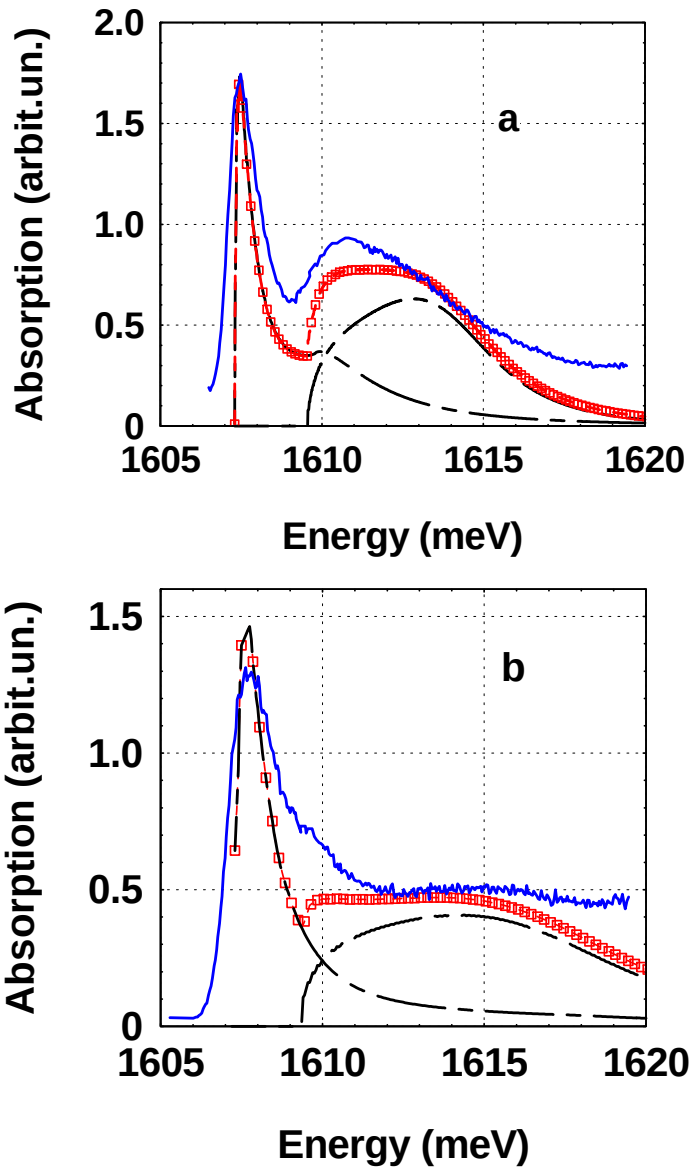


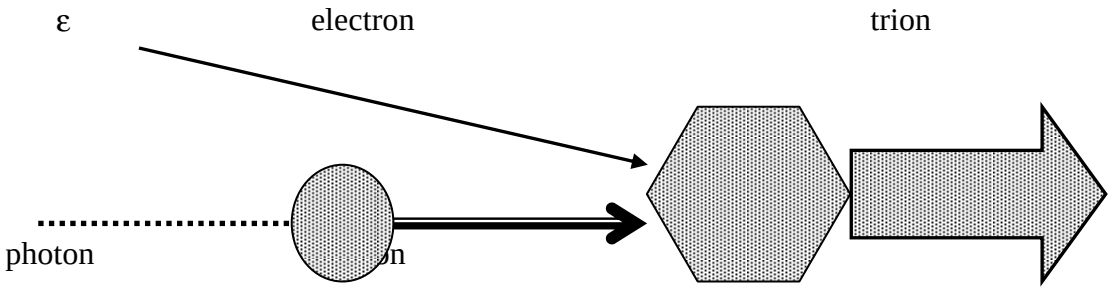

Figure 5: Absorption spectra of CdTe/CdMgTe quantum wells at different densities of free electrons. Solid lines are experimental spectra, symbols present results of calculation at $E_F = 2.5$ meV (upper panel) and $E_F = 10$ meV (lower panel), respectively. Dashed lines are contributions of trion and exciton.

Trion Zeeman splitting as a function of the electron density

The value of the exciton and trion Zeeman splitting?

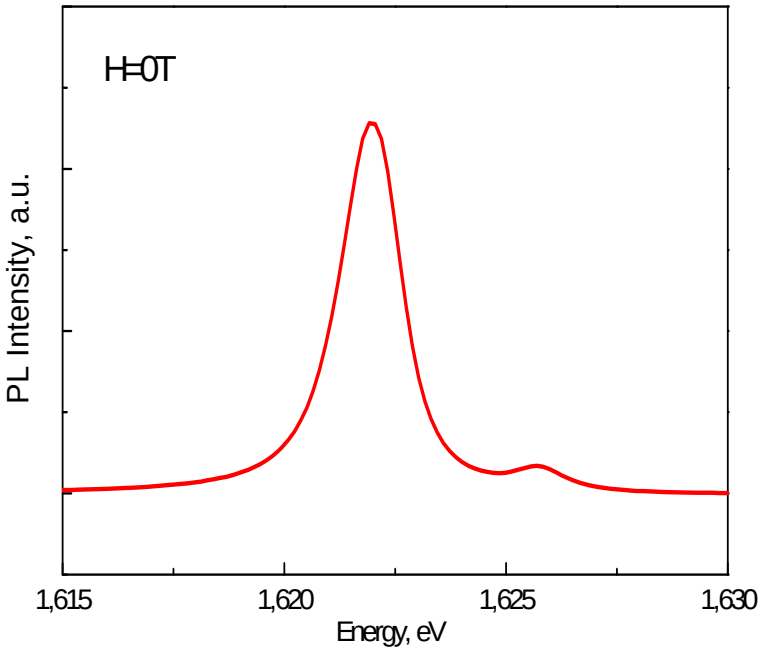
$$e_{init} + ph \rightarrow Tr = (Ex + e_{fin})$$

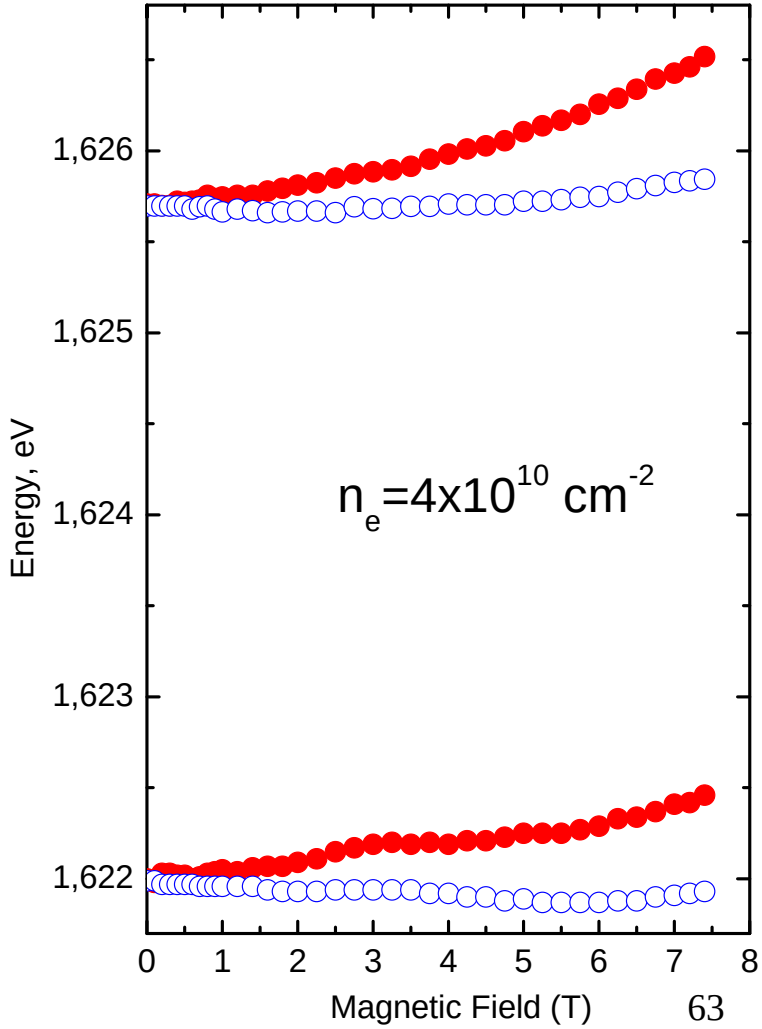
Because the initial and the final state of the electron are the same (the same spin and the same Landau level) we should see only the exciton Zeeman splitting on exciton and on trion line



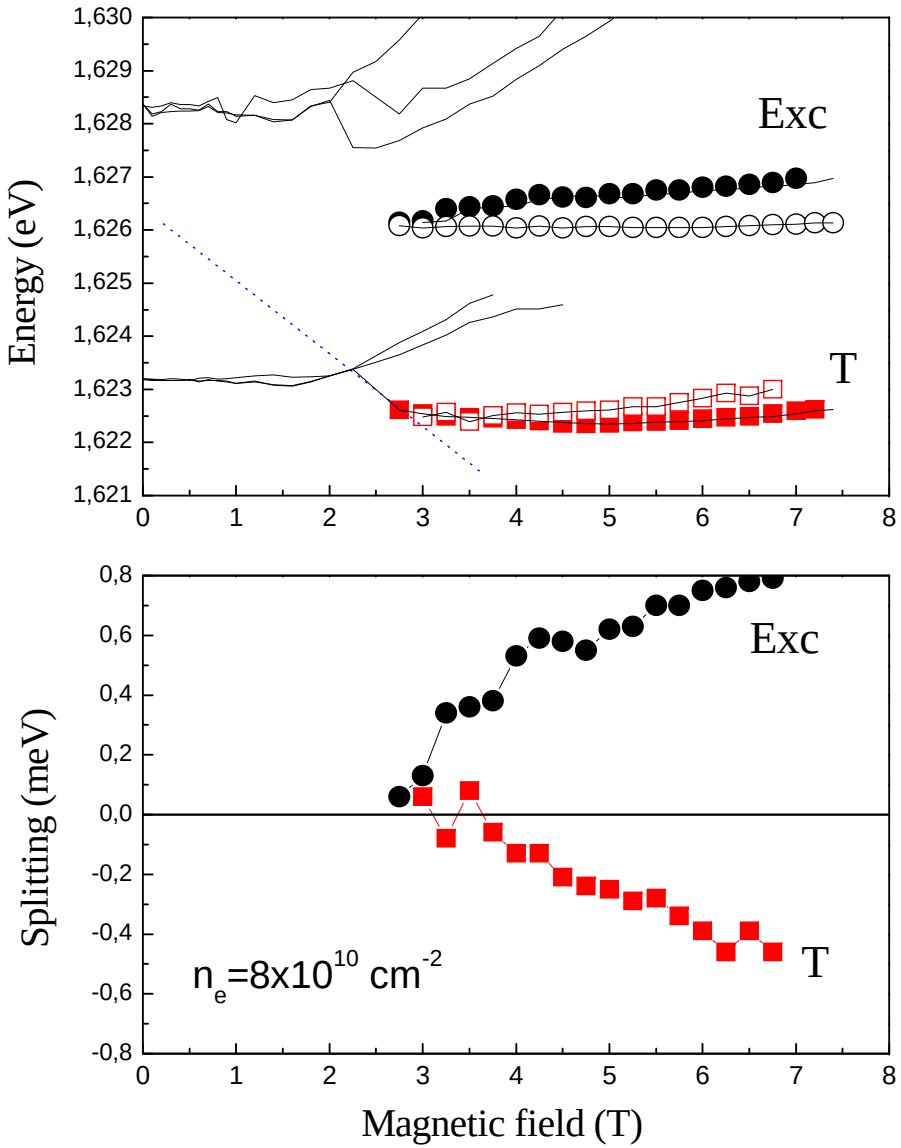
# Photoluminescence

In PL the exciton and trion Zeeman splitting are equal



# Exciton and trion Zeeman splitting at high electron concentrations



This is possible only in the case if the initial and final spin state of the electron are not the same – we need spin-flip

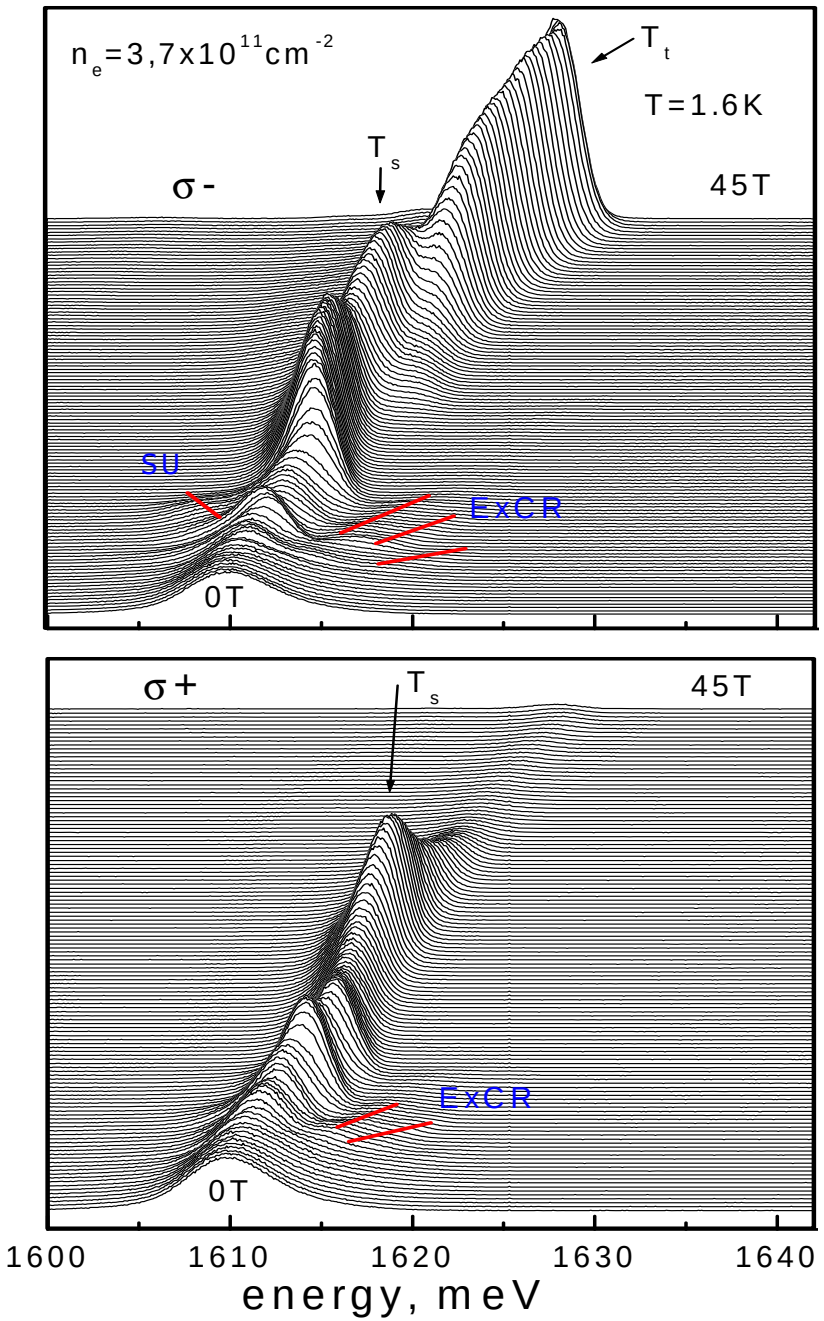
For spin-flip we need spin-orbital interaction. This can be the triplet-singlet splitting of the trion

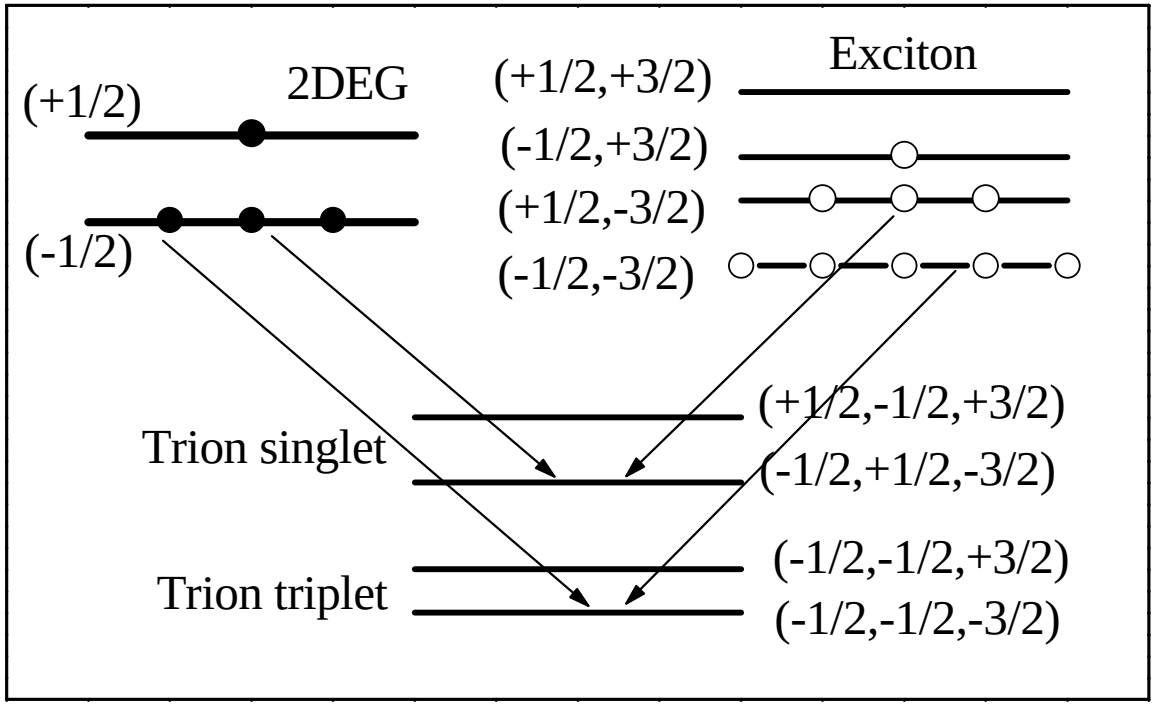
In the initial state the photon creates virtual state of the triplet trion. Because of very fast spin-flip of one of the electrons in the final state we have the singlet trion (already real). This is the process reversal to the ExCR

An incident photon creates a virtual trion in the triplet state. This trion produces a spin-flip with one of the electrons on the first Landau level. As a result, in the final state, we get a trion in the singlet state plus an electron on the second Landau level with opposite spin.

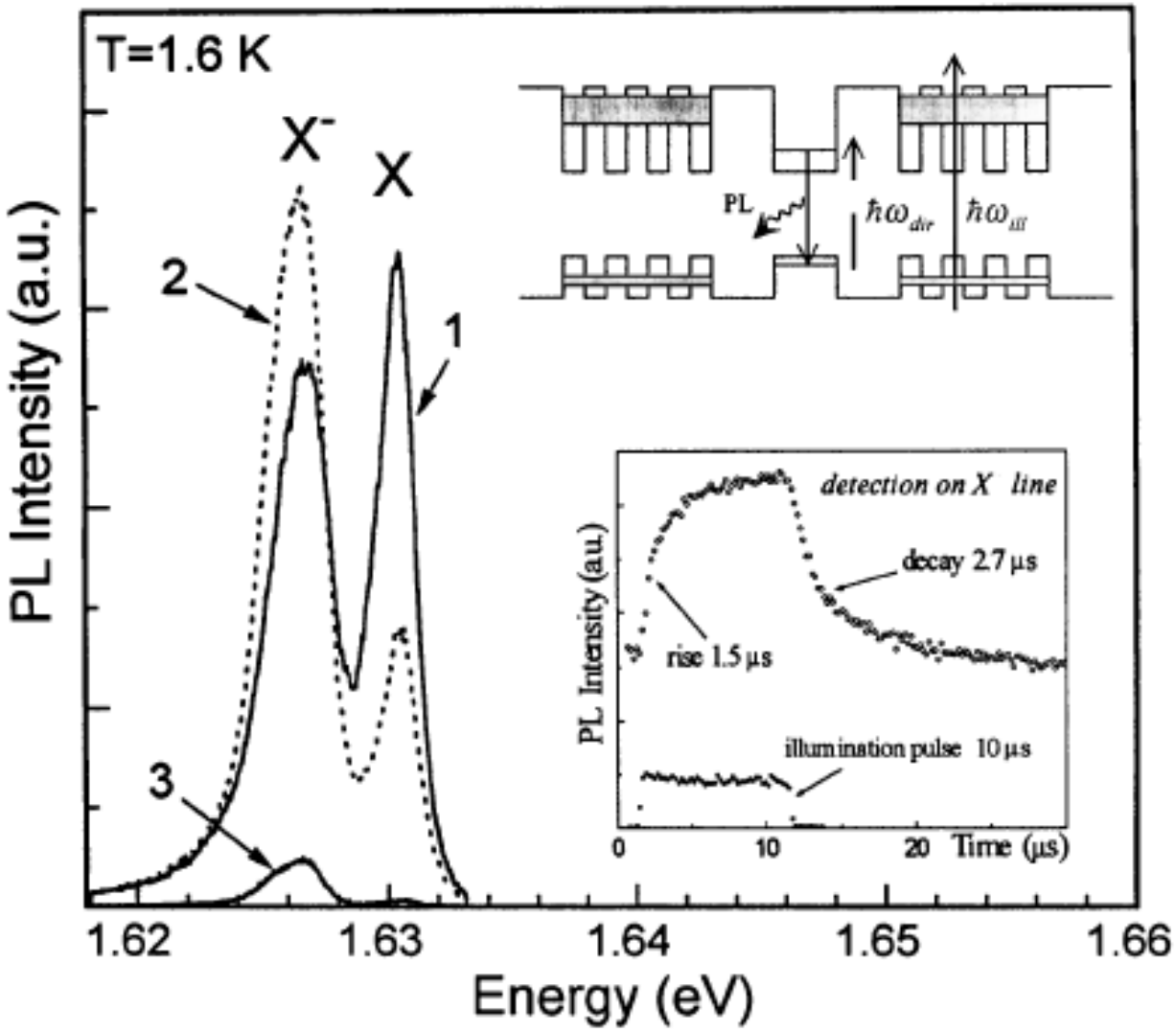
This reaction looks

$$e_1^{\uparrow} + e_2^{\uparrow} + ph \rightarrow Tr^{t} + e_1^{\uparrow} \rightarrow Tr^{s} + e_2^{\downarrow}$$


$n_e=3,7x10^{11}cm^{-2}$
$T_t$
T=1.6K
$T_s$
σ-
45T
SU
ExCR
0T
σ+
$T_s$
45T
ExCR
0T
1600
1610
1620
1630
1640
energy, meV

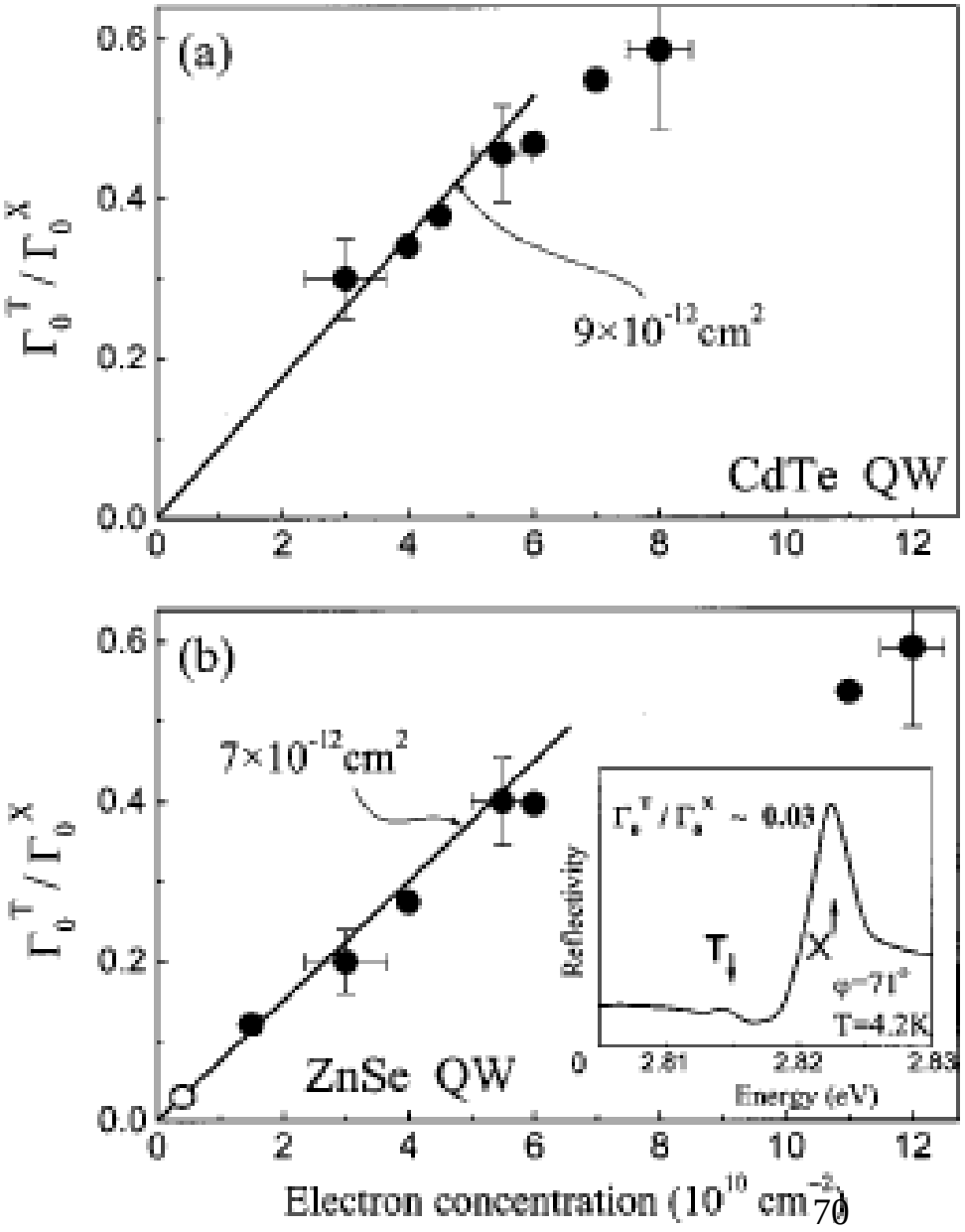

2DEG
(+1/2)
(-1/2)
Exciton
(+1/2,+3/2)
(-1/2,+3/2)
(+1/2,-3/2)
(-1/2,-3/2)
Trion singlet
(+1/2,-1/2,+3/2)
(-1/2,+1/2,-3/2)
Trion triplet
(-1/2,-1/2,+3/2)
(-1/2,-1/2,-3/2)

Трионы можно наблюдать и в нелегированных структурах



Сила осциллятора экситона приходящаяся на элементарную ячейку равна силе осциллятора триона на один электрон, также Как для связанных экситонов

$$\frac{\Gamma_0^T}{\Gamma_0^X} = Cn_e$$



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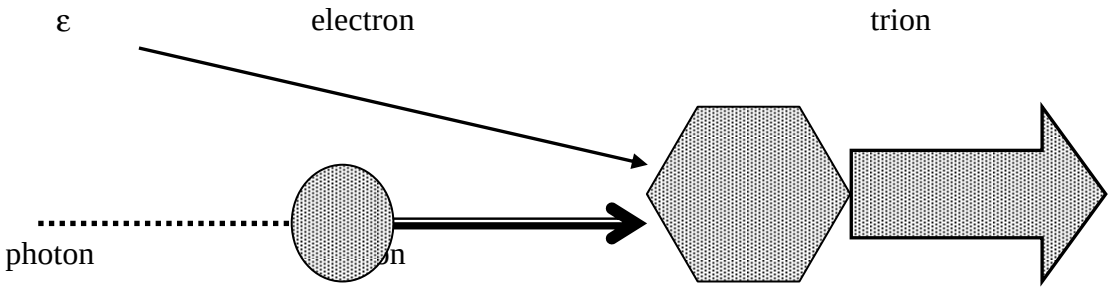
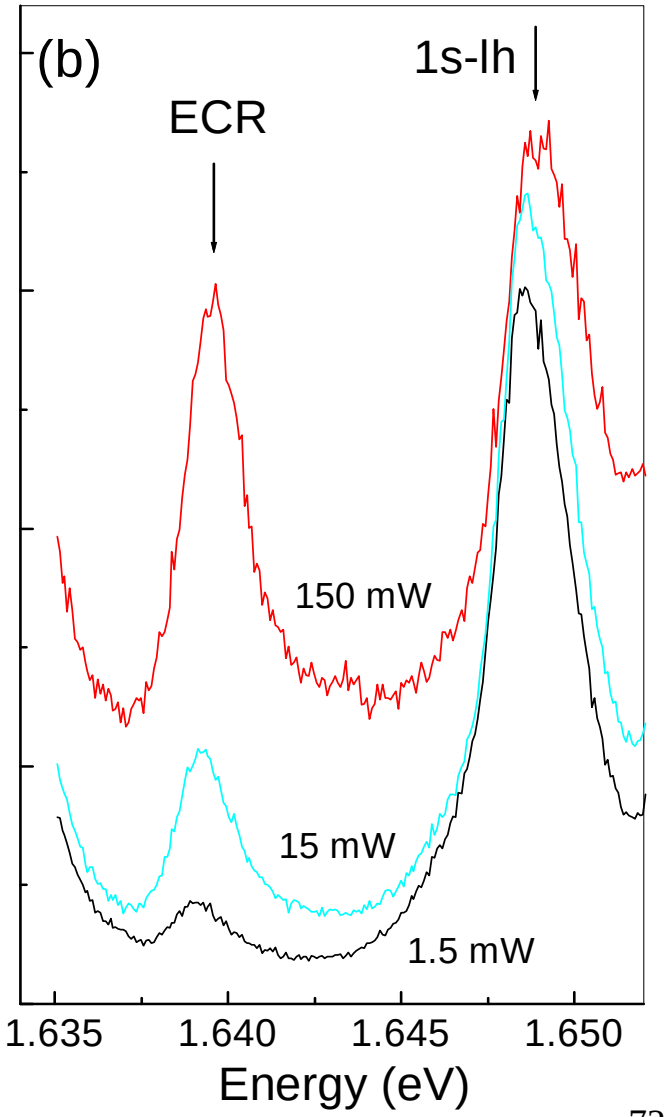
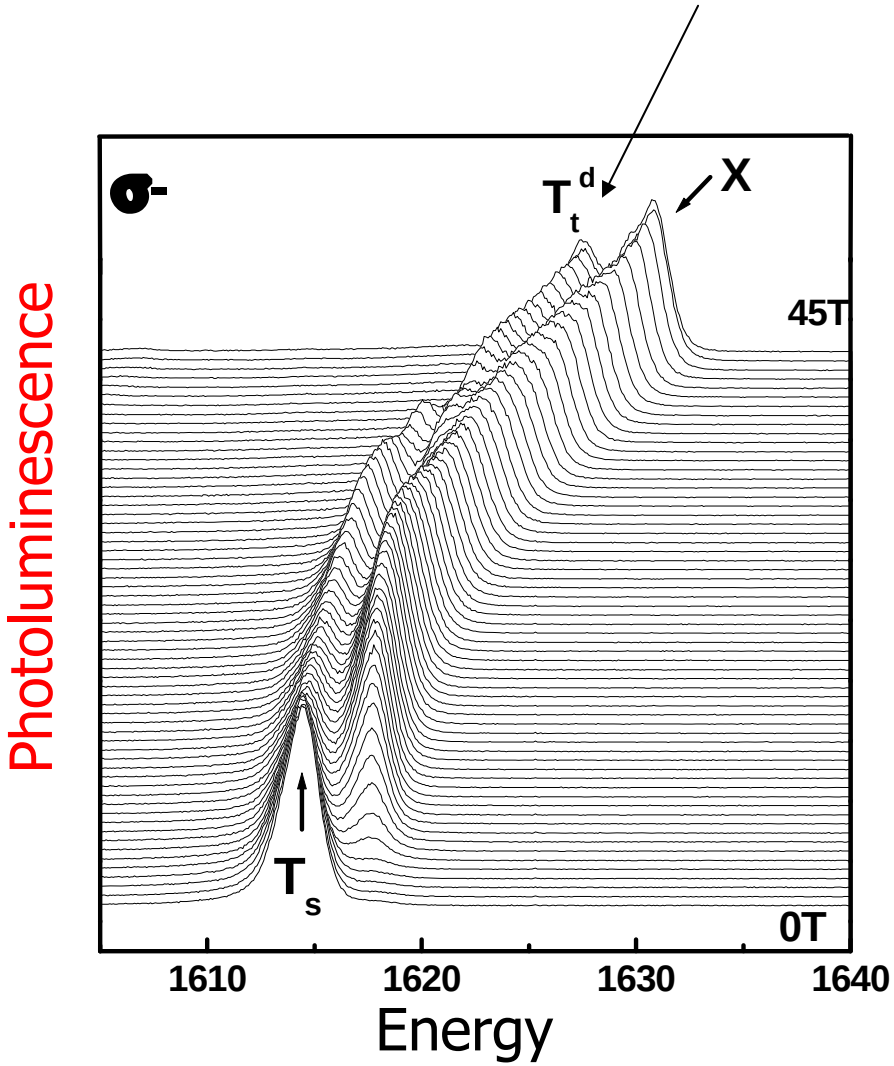
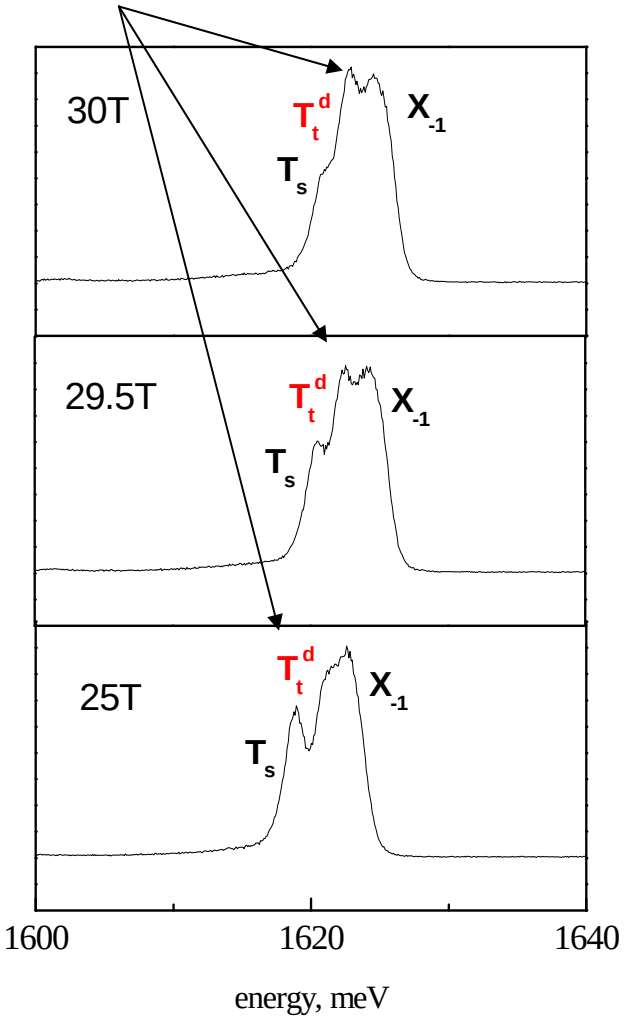


Еще сильнее эффект подсветки проявляется в спектрах PLE на линии ExCR



# Triplet trion in high magnetic fields



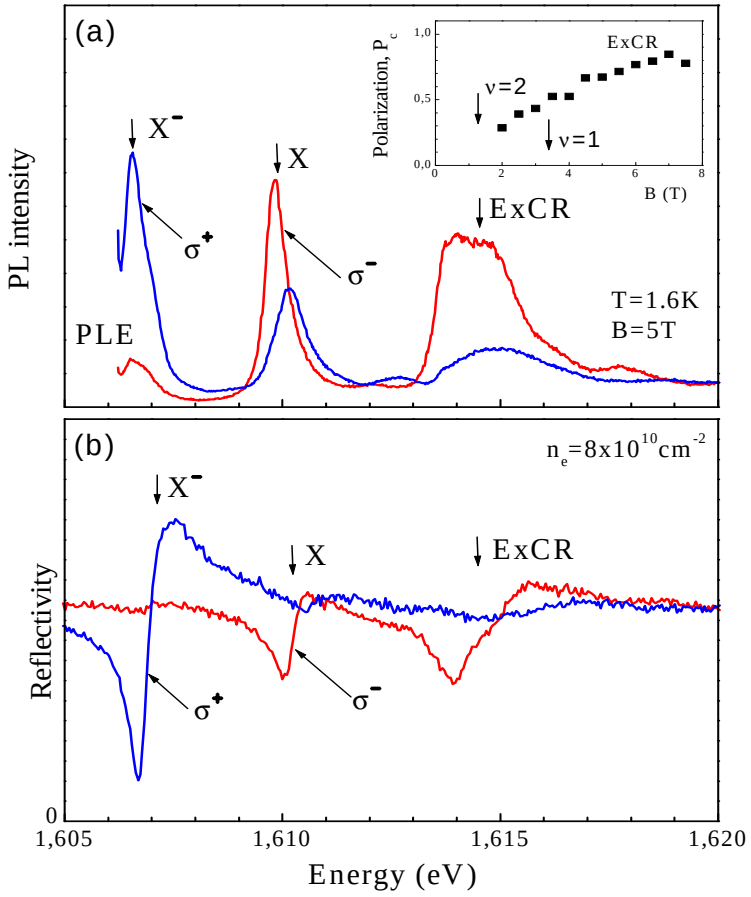



We can neglect the trion binding energy because $E_{ex}^{b} >> \hbar\omega_c >> E_{Tr}^{b}$

$$e + ph \Rightarrow Ex + e^{*}$$

$$\frac{1}{2}\hbar\omega_e^c + \hbar\omega = E_{exc} + \frac{3}{2}\hbar\omega_e^c$$

The intensity of the ExCR absorption line is comparable with the intensity of the exciton line



# ТРИОНЫ В КВАНТОВЫХ ЯМАХ

КОЧЕРЕШКО В.П.

***Trions at low electron density limit***

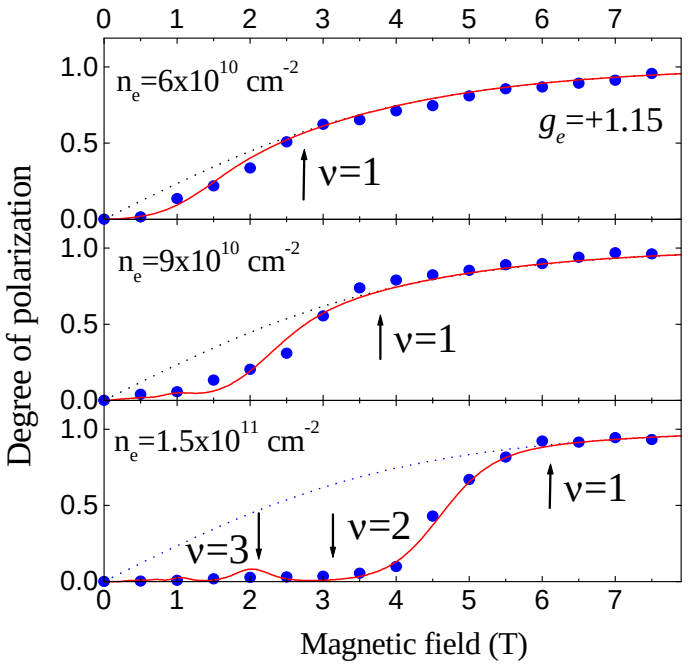
- **1. Charged exciton-electron complexes (trions)**
- **2. Singlet and triplet trion states**
- **3. Modulation doped QWs**
- **4. Trions in optical spectra**
- **5. Action of magnetic fields on the trions**

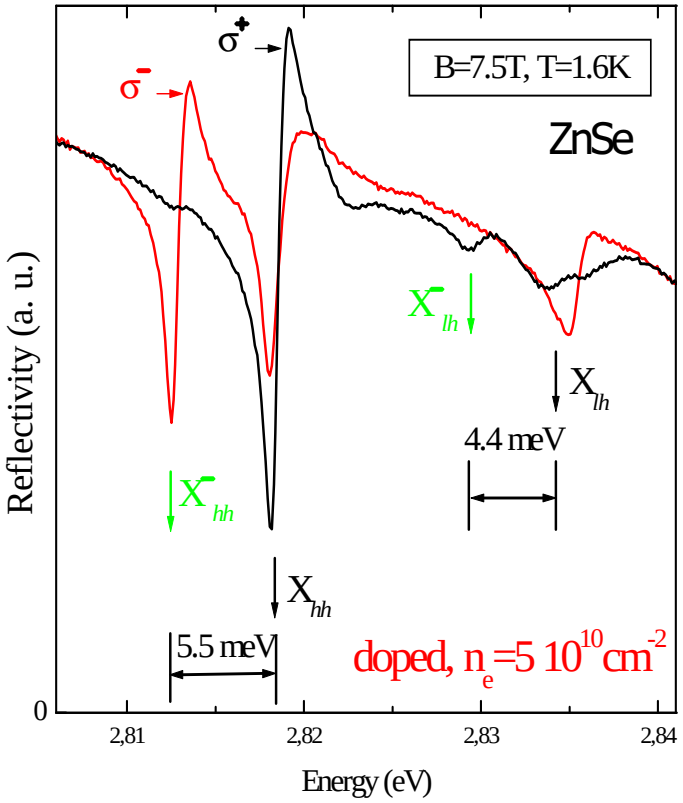
***Trions at high electron density limit***

- **6. Combined exciton cyclotron resonance**
- **7. Combined trion cyclotron resonance**
- **8. Combined exciton electron processes in PL spectra**
- **9. Trion Zeeman splitting**

Спин зависимое экситон – электронное рассеяние

# Singlet trion in magnetic fields

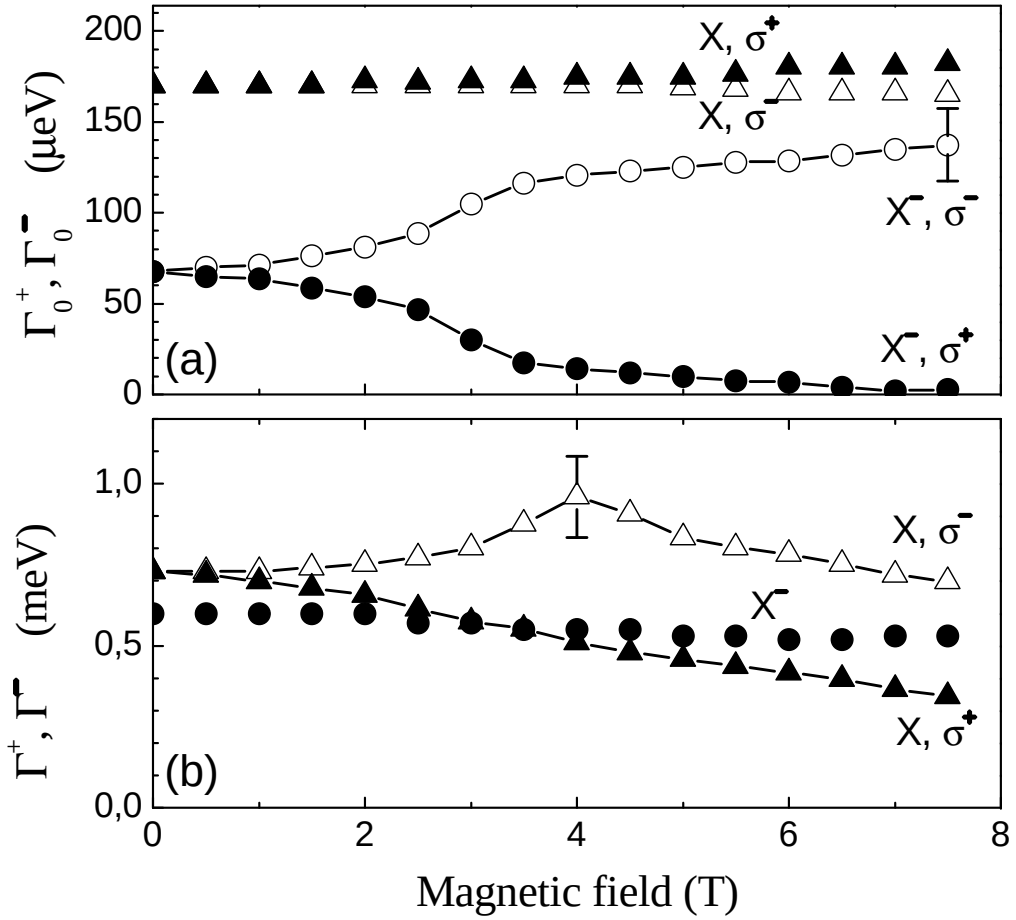



The circular polarization of the trion absorption (reflectivity line ) in magnetic fields can be used to determine electron concentration by pure optical method

$X^-_{hh}$ and $X^-_{lh}$ resonances appear in opposite circular polarizations

# Изменение экситонных и трионных параметров в магнитном поле



# Спин зависимое рассеяние экситонов