

Increasing of AlGaAs/GaAs quantum well robustness to resonant excitation by lowering Al concentration in barriers

I A Solovev, V G Davydov, Yu V Kapitonov, P Yu Shapochkin, Yu P Efimov, V A Lovcjus, S A Eliseev, V V Petrov and V V Ovsyankin

St. Petersburg state university, Ulyanovskaya 1, Petrodvorets, St. Petersburg, 198504, Russia

E-mail: Solivan2007@yandex.ru

Abstract. The robustness of AlGaAs/GaAs quantum well to strong resonant excitation is studied. It was found that lowering Al concentration in barriers to 3% does not influence the measured radiative linewidth of exciton resonance in the sample at low intensities. At the same time parasitic broadening of the resonance by an additional resonant illumination is strongly suppressed as compared to the quantum well with 30% of Al in barriers.

1. Introduction

III–V semiconductor heterostructures with quantum wells (QW) are very attractive for research because of theoretical possibility to use them as an all-optical logic element[1] due to the strong resonant interaction of excitons in QW with light. We have demonstrated that the molecular beam epitaxy technique (MBE) allows one to produce high-quality samples with the inhomogeneous broadening comparable to the radiative linewidth of excitonic resonance for both $\text{In}_{0.02}\text{Ga}_{0.98}\text{As}/\text{GaAs}$ [2] and $\text{GaAs}/\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ [3] QWs.

There are limitations of direct use of $\text{GaAs}/\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ structures in optical information processing due to the reversible bleaching which manifests itself as an additional broadening of exciton's spectral line under strong resonant excitation. This effect accumulates with characteristic times in microseconds scale and longer, and eventually vanishes after termination of the resonant illumination.

In this work we have shown that the bleaching effect can be reduced through lowering aluminum concentration in barriers from 30% to 3% while maintaining the same spectral quality of the sample.

2. Experimental

The sample T670 is grown by MBE technique. It contains a 14 nm GaAs QW between $\text{Al}_{0.03}\text{Ga}_{0.97}\text{As}$ barriers.

We use the reflection spectroscopy to investigate coherent optical properties of excitons with heavy holes (HH-exciton). The p -polarized probe light is incident on the sample surface at the Brewster's angle[2, 3] in order to eliminate nonresonant reflection off the surface (Fig. 1).



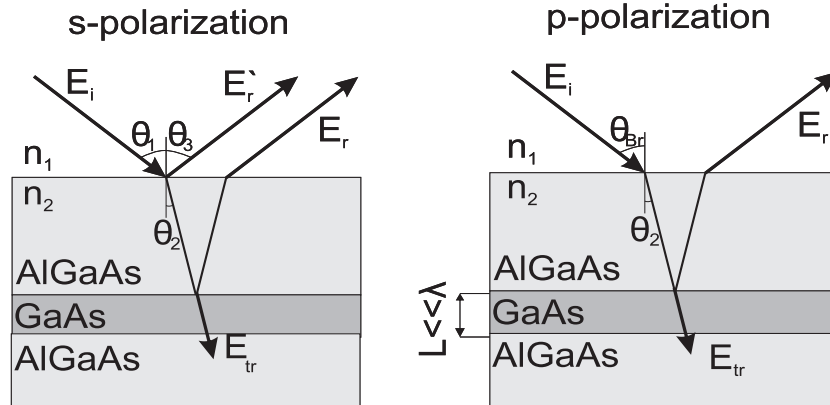


Figure 1. The scheme of propagation polarized light through a sample.

In this case the reflection spectrum could be described by the Lorentzian:

$$K_R(\omega) = \frac{\Gamma_R^2}{(\omega - \omega_0)^2 + (\Gamma_R + \Gamma_{NR})^2}, \quad (1)$$

where ω_0 is the resonant frequency, Γ_R is the radiative linewidth, Γ_{NR} denotes all nonradiative broadening of various kinds combined together and K_R is the experimentally determined absolute reflection coefficient.

Sample temperature was 8K. Probe intensity was weak enough to guarantee the linear response. Spectra were recorded using femtosecond Ti:sapphire laser as a spectrally broad source of probe light and 0.5 m spectrograph with multichannel CCD-detector.

In order to study the bleaching effect we use an additional CW monochromatic semiconductor laser which was carefully tuned to the HH-exciton resonance frequency. Fig. 2a illustrates the dependence of the resonant reflection (RR) spectra $K_R(\omega)$ on the pump intensity I_{pump} . It should be noted that there is no significant shift of spectral line, so thermal broadening is negligible (fig. 3). By quantitative fitting the spectra with Eq. (1) (modified by addition of a weak nonresonant background) we obtain both quantities Γ_R and Γ_{NR} .

3. Discussion

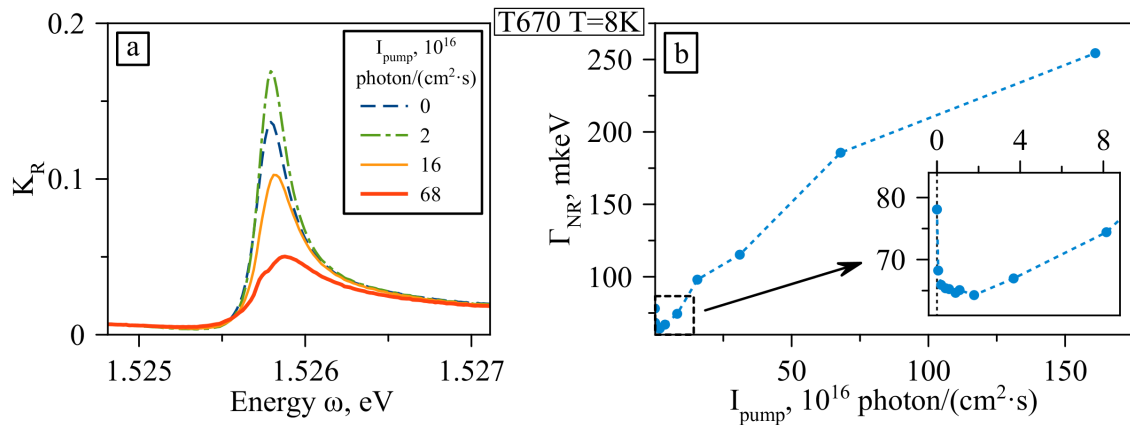


Figure 2. Reflection spectra of the T670 sample at different intensities of the resonant pump (a) and dependence of the nonradiative linewidth on that intensity (b).

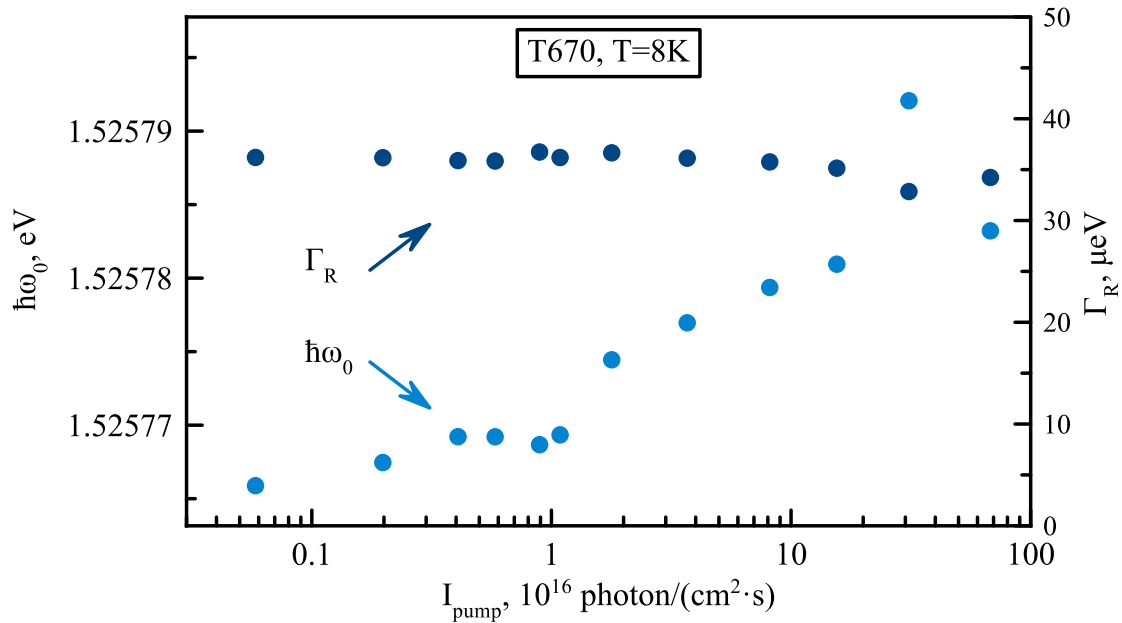


Figure 3. Dependence of the spectral position of excitonic resonance $\hbar\omega_0$ and radiative width Γ_R on the pump intensity I_{pump} .

It has been experimentally established that radiative width remains constant in wide range of pump intensity and equals $36 \pm 3 \mu\text{eV}$ (Fig. 3). This value is similar to the Γ_R obtained for the sample E296 which has been investigated in a previous work[2] and contains a 13 nm GaAs QW between $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ barriers. Observed ratio $\Gamma_{NR}/\Gamma_R = 0.46$ in linear limit $I_{\text{pump}} \rightarrow 0$ proves the high quality of the sample T670 (for comparison: in the sample E296 the ratio Γ_{NR}/Γ_R is approximately the same).

However considerable nonradiative broadening appears only for rather strong pump intensities approaching 10^{18} photons/ cm^2s which are two orders of magnitude higher than that in E296 sample (Fig. 2b).

We attribute such behavior to the weaker effects of free charge carriers in this system, which are believed to cause strong scattering of the excitons and thus deteriorating their optical resonance.

An indirect proof of this fact is the absence of noticeable spectral features at energies slightly lower than the HH-exciton resonance that correspond to the creation of bounded charged excitons (trions) by excitation of an exciton in the vicinity of the free charge carrier. This trion lines were readily observed in E296 sample. Nevertheless we couldn't totally rule out charge effects from consideration due to the observed small decrease of Γ_{NR} at low pump intensities (see inset Fig. 2b) due to the charge sign reversal, which is typical for photovoltaic phenomena in GaAs quantum wells[4].

4. Conclusion

We have investigated resonant reflection spectra from QW with additional resonant pumping. Quantitative analysis demonstrate that lowering Al concentration in barriers to 3% lets us to decrease the bleaching effect, while spectroscopic quality of the sample being as high as that of classical sample with 30% aluminum.

Acknowledgments

The reported study was partially supported by RFBR, research project No 15-52-12016 nmio_a. This work was carried out on the equipment of the SPbU Resource Center “Nanophotonics” (<http://photon.spbu.ru>)

References

- [1] Gerlovin I Ya, Ovsyankin V V, Stroganov B V and Zapasskii V S 2000, *Nanotechnology* **11**, 383–6.
- [2] Poltavtsev S V, Efimov Yu P, Dolgikh Yu K, Eliseev S A, Petrov V V and Ovsyankin V V 2014 *Solid State Communications* **199**, 47–51.
- [3] Poltavtsev S V and Stroganov B V 2010, *Physics of the Solid State* **52**, 1899–905.
- [4] Glasberg Sh, Finkelstein G, Shtrikman H and Bar-Joseph I 1998 *Phys. Rev. B* **59**, R10425–8.