# Detectors for space electronics based on the quantum dots and wells

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**Abstract**

One of the promising areas of research applicable in astrophysics is the study of the properties of quantum dots (QDs) and quantum wells (QWs) in the IR region of the spectrum. The IR region of the spectrum contains a huge amount of astronomical information. Devices based on GaAs/AlGaAs QWs and Ge/Si QDs can serve as detectors and sources of IR radiation. In the current work, the photoluminescence, absorption, and transmission spectra of these nanoheterostructures were obtained in the near, mid, and far IR ranges using Fourier spectroscopy. Thus, the studied optical properties of QWs and QDs make it possible to use these structures in astrophysics as sources and detectors of IR radiation.

***Keywords:*** *quantum wells, quantum dots, detectors, radiation sources, photoluminescence, absorption, transmission*

## 1. Introduction and samples

The study of the properties of quantum dots (QDs) and quantum wells (QWs) is one of the promising areas of research aimed at completely different applications: from electronics and astrophysicists to medicine and energetics. Study and creation of such structures and devices based on them is an important and urgent task.

The infrared (IR) region of the spectrum, covering wavelengths from 1 µm to 1 mm, contains a huge amount of astronomical information (Richards & McCreight (2005)). Infrared equipment measure the dominant radiative energy transfer mechanisms in the universe and provide understanding of formation and structure of planets, stars, galaxies and galaxy clusters, and measure the geometry, structure and content of the early universe.

Detectors and sources of far-IR radiation can be devices that use transitions of charge carriers between energy levels associated with shallow impurities in semiconductors. Far-IR radiation devices based on intracenter impurity transitions in doped quantum wells (QWs) are more attractive than devices based on bulk materials, since changing the nanostructure parameters can change the operating spectral range (Masselink et al. (1986)). In turn, acceptor-doped QWs have a number of advantages over n-type structures (Waugh & Dolling (1963)).

It is also possible to realize photodetectors or sources with optical pumping based on the properties of QDs associated with intraband transitions of charge carriers (Bimberg & Pohl (2011)). QD-based photodetectors have a number of advantages and features compared to the same QW detectors, for example: the ability to use the normal incidence of radiation, what contributes to the creation of matrix photodetectors (Rappaport et al. (2000)), high surface density, long lifetime of nonequilibrium charge carriers, compatibility with silicon electronics, which promotes the implementation of silicon-based integrated electronic devices (Krasilnik et al. (2011)).

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## 2. Experimental results

Our research was devoted to investigate the features of the photoluminescence, photoconductivity, and absorption spectra of GaAs/AlGaAs QWs doped with beryllium were studied, which are in good agreement with theoretical calculations of the energies of optical transitions of charge carriers in the structure. The ionization energy of acceptors in a QW was also experimentally determined in various ways, its value corresponds to the theoretical calculation of the energy spectrum of the investigated structure.

Similarly, during the research of the features of Ge/Si QDs, we obtained the spectra of equilibrium and photoinduced absorption and photoluminescence (PL), as well as the temperature dependence of photoinduced absorption. Several samples with different boron impurity concentrations were studied. Atomic force microscopy (AFM) photo of sample with QDs is presented in Fig. 1 on the left.

The PL spectra show two peaks, which are explained by direct and indirect interband transitions of charge carriers in QDs in real space (see Fig. 1 on the right). The peak associated with indirect transitions have a blue shift with increasing pump power, due to band bending at the Si/Ge heterointerface (see Fig. 2 on the left). As the temperature rises, a decrease in the PL intensity is observed. The peak associated with direct electron-hole recombination falls off a little faster due to the intense temperature depopulation of electronic states localized directly in the QD.

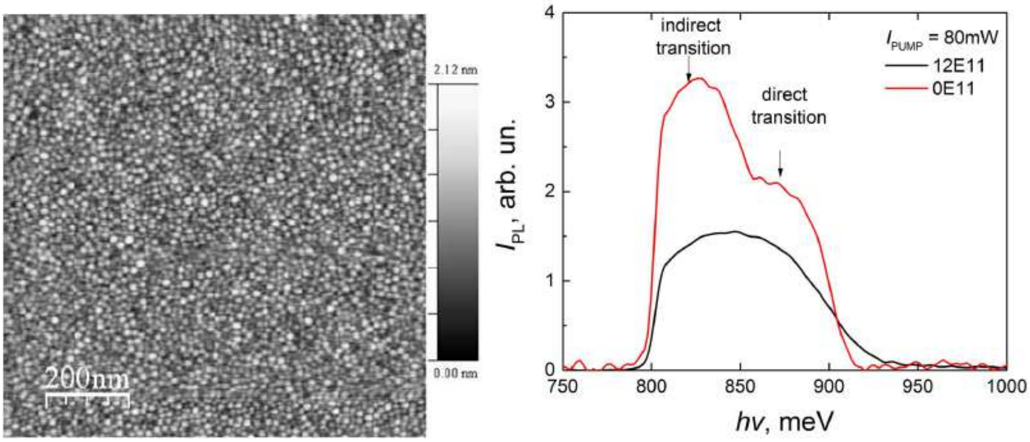


Figure 1. AFM image of Ge/Si QDs (on the left). PL spectra for different impurity concentration (on the right).

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The spectra of photoinduced transmission at the same pump power and different impurity concentrations show peaks associated with transitions from the ground (a) and excited (c) states to the continuous spectrum, as well as intersublevel transitions (b). The intensity of peak "a" increases with an increase in the number of carriers in the ground sublevel of the valence band, so that peak "c" is lost (see Fig. 2. on the left).

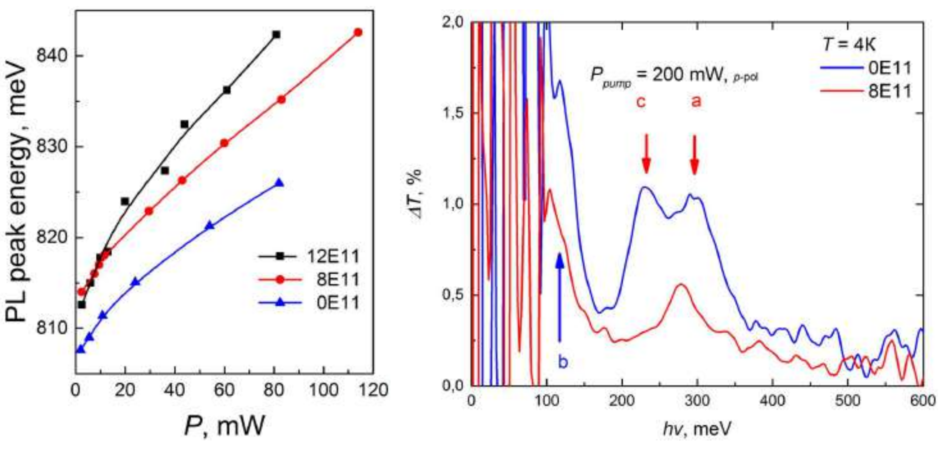


Figure 2. Dependence of the PL peak on the pump power (on the left). Photoinduced absorption spectra at the same pumping and different impurity concentration (on the right).

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# 3. Summary

Thus, in this work, we studied the optical properties of $p$-GaAs/AlGaAs QWs and Ge/Si QDs. The optical and electro-optical properties of acceptors in QWs have not been studied in detail yet due to the complex structure of the valence band and the energy spectrum of impurity states. In addition, such $p$-type nanostructures have prospects for development due to a number of advantages, as well as due to cheaper production and compactness compared to bulk materials and $n$-type. At the same time, QD structures have a wide range of applications. Devices based on Ge/Si QWs have a number of advantages over devices based on QDs. Moreover, the obtained spectra of photoinduced absorption in the far IR frequency range confirm the generalized Kohn theorem for QDs and require further study.

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