Photoluminescence Excitation Spectroscopy of Zero-dimensional Nanostructures at Telecommunication Wavelengths

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The present knowledge on the electronic structure of quantum dots and energy transfer mechanisms (specially on a single dot level) available experimentally through photoluminescence excitation spectroscopy is limited mainly to the quantum dots emitting below 1 μm. Within the near infrared region, telecommunication windows of 1.3 μm and 1.5 μm are of special interest, for they correspond to the most desirable wavelengths in optoelectronic applications. Besides the fundamental information on the electronic structure, photoluminescence excitation spectroscopy can provide additional data, e.g., on the confinement regime in nanostructures or relaxation efficiency, when compared with phonon energies. The relaxation processes can be farther enhanced by the continuum of states below the wetting layer ground state. There is also a very limited knowledge and published reports on the carrier transfer between the wetting layer itself and the nanostructures or on the in-plane energy transfer between quantum dots emitting in this application-relevant spectral range.

The report presents photoluminescence excitation study of zero-dimensional III-V nanostructures with the ground state emission in the spectral region of telecommunication wavelengths. The experiment is based on a microphotoluminescence setup adapted to the tunable excitation laser source with external cavity design. Depending on the wavelength, the external cavity is arranged in Littrow or Littman configurations with additional spectrometer-based laser-line filtering. This solution provides continuous wavelength tuning range of around 100 nm with a single laser diode. In addition, pulsed laser system (based on optical parametric oscillator) is available, providing large-wavelength-step but spectrally wide tuning. This solutions can provide the total excitation spectral range of at least 1000-1600 nm. The study aims at expanding the knowledge on the quantum dot energy structure – in particular, it attempts to provide more detailed insight into the excited states. Additionally, for larger nanostructures (e.g. elongated quantum dots) the energy difference between electronic levels is expected to be relatively low and even comparable with the thermal energy, which is crucial for potential applications, where thermal losses have to be evaluated.

The photoluminescence excitation results are supplemented by standard microphotoluminescence characterization, identifying the emission spectral range of the investigated nanostructures. The obtained results are confronted with the 8-band $k \cdot p$ theory simulations to predict the detailed electronic/excitonic structure versus various morphological and compositional parameters of the system under investigation.

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