Crystal orientation dependence of the e1-hh1 fundamental transition in type II W-design quantum well structures

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Semiconductor diode lasers emitting at wavelengths longer than 2-3 μm are of great interest for applications in environmental pollution monitoring, medical diagnostics, infrared countermeasures, laser surgery and gas leakage detection. In this wavelength region, there exist at least several competing concepts of sources of coherent radiation in MIR including common laser diodes base on type I quantum wells (QWs), quantum cascade lasers (QCLs) and interband cascade lasers (ICLs). For the latter ones, it has been proven possible the combination of broad tuning range of the emission, minimized influence of the Auger related carrier losses, and a very low power consumption [1]. However, in order to realize that many parameters of these multilayer structures must be optimized, especially on the side of the active region which is composed of a cascade of type II QWs made of a broken gap materials.

In this work, we discuss a few possibilities of implementing type-II W-design QWs, which allows preserving the large optical matrix elements in spite of indirect in the real space character of the optical transition. We calculate the fundamental electronic structure properties of AlSb/InAs/GaInSb/ InAs/AlSb QWs grown on GaSb substrate [2] on various crystallographic planes taking into account the effect of modifications in the band structure due to strain, crystal orientation and piezoelectric field effects. The calculations are carried out within the eight-band k·p theory. We demonstrate the broad range of spectral tunability via the structure parameters modifications. We find the fundamental e1-hh1 transition energy decreases as the crystal orientation is inclined from (001) toward (110). The absolute values of the internal piezoelectric fields in GaInSb layer are the largest for (111)-QW and zero for the (001)-QW and (110)-QWs. We show that the transition energy e1-hh1 can still be efficiently optimized for wavelengths even beyond 8 μm, if the composition of the separating barrier, which is simultaneously the well for holes, is chosen properly, and for the given range of thicknesses of InAs layers confining electrons for particular orientations of the substrate.

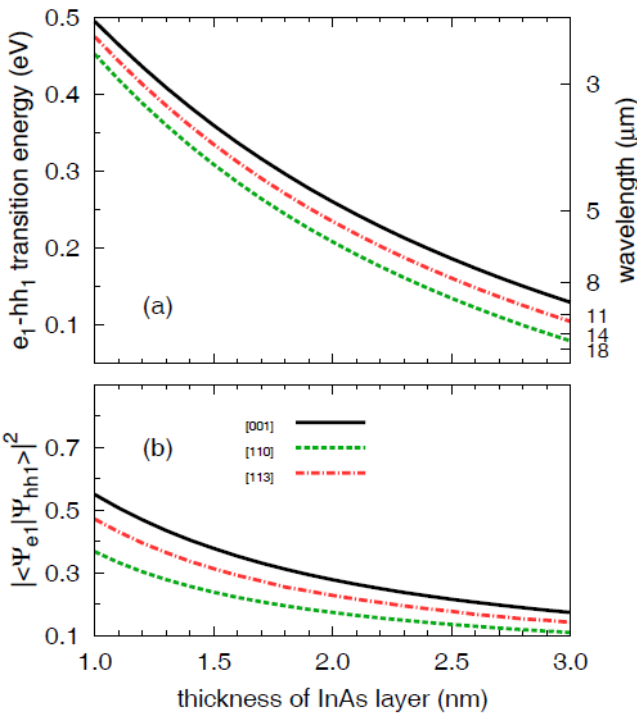

Fig. 1 Effect of thickness of InAs layer on the fundamental e1-hh1 transition energy (a) and on the squared wave functions overlap (b).

[1] I. Vurgaftman, W. W. Bewley, C. L. Canedy, C. S. Kim, M. Kim, C. D. Merritt, J. Abell, J. R. Lindle, J. R. Meyer, Nature Commun. 2, 585 (2011).

[2] K. Ryczko, G. Sęk, J. Misiewicz, Journal of Applied Physics 114, 223519 (2013).