Enhancing the transition oscillator strength in type II quantum wells for application in interband cascade lasers

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Applications related to the detection of hazardous and environmentally-relevant gasses drive the growing demands with respect to all the sensor system components, requiring cheap and compact laser sources. This can be well fulfilled by semiconductor lasers, where one of the efficient solutions is interband cascade laser (ICL[1-3]). Such devices have already been proven to emit at some wavelengths of the mid-infrared (even beyond 10 μm), i.e. in ranges characteristic for maximal absorption of many gasses, and shown to offer continuous-wave single-mode operation at room temperature between 3 and 5 μm, and additionally significantly lower power consumption [2] than the more common quantum cascade lasers. However, ICLs still need further developments regarding especially the demanded performances at longer wavelengths, broad bandwidth or widely tunable devices, where for all of which the fundamental type II optical transition in their active region is one of the limiting factors.

There have been investigated, both experimentally and theoretically, several modifications in the active region of the ICLs. The considered type II quantum wells are based on InAs/(Ga,In)(As,Sb) materials combinations, forming a broken gap system, confining electrons and holes in spatially separate layers, typically grown on either GaSb or InAs substrates. These studies were aimed at maximizing the optical transition oscillator strength (OS) via tailoring the electronic structure, the related strain and wave function engineering. The OS is the most critical parameter of the type II system because it can allow for compensating the intrinsic losses while extending the emission wavelength or the gain bandwidth.

A combination of two spectroscopic techniques was utilized, emission-like (photoluminescence) and absorption-like (modulated reflectivity), supported by the energy level calculations employing multiband k•p modeling. It was demonstrated, that addition of arsenic into the commonly used ternary layer of GaInSb for the holes confinement can significantly enhance the transition OS, while decreasing the overall strain and keeping still the type II design [4,5]. Moreover, it was also shown, that use of a triple type II quantum well structure (or its further multiplication) instead of a typically used double well "W-design" allows for simultaneous red shift of the transition energy and increase of the oscillator strength [6].

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