Current leakage suppression in two-well structural THz-QCLs by using asymmetric design

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Great efforts have been contributed since the THz-QCLs first realized, its operating temperature, however, is still far away from room-temperature. It is quite significant to further reveal the quantum transport in cascaded MQWs as exactly as possible and find new Schemes to increase the devices operating temperature, at least, to be up to the thermoelectric cooling 230K. Three-wells with resonant tunneling at injecting and extracting process and LO phonon depopulation has been achieved the highest operating temperature of 199.5K[1]. In this paper, we study the two-wells structure: first, we discuss the regular two-wells ($GaAs/Al_{0.33}Ga_{0.67}As$) and then propose an improved design based on it. It can be defined as asymmetric two-wells($Al_xGa_{1-x}As/AlGaAs$), where x is small to avoid serious alloy scattering induced. Non-equilibrium green's function method is used and it need to be noted that electron-electron interaction is included. (Detailed information of models and calculation procedure will be presented on site). Fig.1 shows the band structures of those two schemes with/without high-energy excited states. E, U, L mean the extracting, upper lasing and lower lasing levels, respectively. From the optical gain under operating bias (50mV/period) in fig.2, for regular two-wells at high temperature (here, 210K), no positive optical gain at the designed lasing frequency can be obtained when high-energy states are included where it will be higher than 20cm-1 if only levels E, U, L are considered. It gives a strong evidence that electron escaped through high-energy levels, especially the leakage channel between injecting E and the 2nd excited states from the next period, is too strong in case of the regular two-wells scheme if full energy range is introduced. In asymmetric two-wells, the deep and narrow lower lasing well weakens those channels by lifting up the excited states from this well. The optical gain is almost no change no matter the high-energy levels considered or not. At 210K, gain of 45cm-1 is achieved even the threshold current is also quite small (∽700A/cm^2) and also the lasing dynamic range is much larger (700→1305A/cm^2). The corresponding values of the world record designs are 1060A/cm^2 and 1060→1200A/cm^2, respectively. Electron-electron interactions included, and even at 260K, it is still larger than the mirror and waveguide loss(∽20cm^{-1}). (The growth results will be presented at the site)

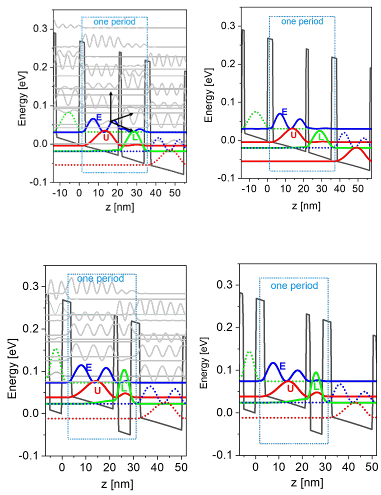

Fig.1 Band structures of the regular two-wells (*a,b*) and asymmetric two-wells(*c,d*) under operating bias at 50mV/period. The *a* and *c* figs are with high-energy levels and *b*, *d* figs are NOT with high-energy levels.

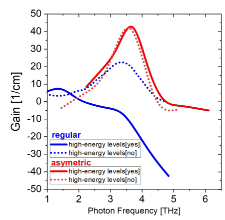

Fig.2 Optical gain of those two schemes with/without high-energy levels at lattice temperature of 210K.

References

[1] S. Fathololoumi,et.al, Optics Express (2012)3866.