Correspondence

Correction to "Reduction of Lasing Threshold Current Density by the Lowering of Valence Band Effective Mass"

E. YABLONOVITCH AND E. O. KANE

The authors would like to note the following in regards to their recently published paper.[1]

In $k \cdot p$ perturbation theory, the wave functions are regarded as traveling waves with k acting as the wave-vector. Some care has to be exercised in the application of $k \cdot p$ perturbation theory to quantum wells and superlattices. A deep quantum well forces the wave vector k_z in the direction perpendicular to the well to assume the quantized values

$$k_z = \pm\left(\frac{l\pi}{d}\right)$$

where l is the quantum index and d is the thickness of the well. The wave function in the well will be a coherent superposition of forward and backward going waves. It will therefore have a different symmetry from the freely propagating waves in the absence of quantum confinement. The effect of this additional symmetry is to cause one of the off-diagonal terms in the $k \cdot p$ Hamiltonian to vanish identically. This off-diagonal term is usually written as $k_x k_z N/\sqrt{3}$ in the notation of [2]. Its linear dependence on k_z shows explicitly that it will vanish for a standing wave. Therefore $k \cdot p$ perturbation theory results can be carried directly over to the quantum well case *provided* that such terms are dropped. The only band structure term which is affected by this change is $C^2 = (N^2/3) - 3B^2$, again in the notation of [2]. The matrix element involving N vanishes and C^2 becomes equal to $-3B^2$. This simplifies [1, eq. (7)] which becomes $\pm T = \mp B/2$. Now [1, eq. (6)] becomes:

$$E = A(l\pi/d)^2 \pm \{B(l\pi/d)^2 - b(e_{xx} - e_{zz})\} + (A \mp B/2)k_\parallel^2.$$

Provided that $k_\parallel^2 << (l\pi/d)^2$ the strain does not influence the effective mass! The highest lying valence band will have a heavy mass in the z direction, but will be light, $m_\parallel = -(A + B/2)^{-1}$ in the x-y plane. Using the values for A and B from [1, table I], $m_\parallel = 0.057m_e$ which is very close to the conduction band mass $m_c = 0.045m_e$. The conclusions for reduced laser threshold current density are now even more favorable than before. The valence band mass is almost as low as the conduction band mass and no strain is really required, which should be a significant practical impetus for such lasers.

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[1] E. Yablonovitch and E. O. Kane, *J. Lightwave Technol.*, vol. LT-4, no. 5, pp. 504–506, May 1986.

References

[1] E. Yablonovitch and E. O. Kane, "Reduction of lasing threshold current density by the lowering of valence band effective mass," *J. Lightwave Technol.*, vol. LT-4, no. 5, pp. 504–506, May 1986.

[2] E. O. Kane, in *Handbook on Semiconductors*, vol. 1, T. S. Moss and W. Paul, Eds. North-Holland, 1982, ch. 4A.