

## HW #4 (For practice only. You don't have to turn it in.)

1. Use the parameters in Appendix K of Chuang's book (Table on next page), calculate the conduction, heavy-hole, and light-hole band energies for  $\text{In}_{1-x}\text{Ga}_x\text{As}/\text{In}_{0.52}\text{Al}_{0.48}\text{As}$  quantum well structures where the barrier  $\text{In}_{0.52}\text{Al}_{0.48}\text{As}$  is lattice-matched to InP substrate, for  $x = 0.7$  (tensile strained)?

Note: Use linear interpolation for the material parameters of  $\text{In}_{1-x}\text{Ga}_x\text{As}$ . For example,

$$C_{11}(\text{In}_{1-x}\text{Ga}_x\text{As}) = x \cdot C_{11}(\text{GaAs}) + (1-x) \cdot C_{11}(\text{InAs})$$

2. Using infinite potential well model, and assume all quantum wells are 10 nm thick, find the electron-heavy hole ( $E_{e1} - E_{HH1}$ ) and electron-light hole ( $E_{e1} - E_{LH1}$ ) transition energies for the for  $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$  (same composition as Prob. 1) quantum well.
3. Find the in-plane effective masses of the heavy and light holes for the quantum well in Problem 2. What is the *ratio* of the *peak optical gain* obtainable for  $E_{hh1}^{e1}$  and  $E_{lh1}^{e1}$  in this quantum well?

**Table K.2 Important Band Structure Parameters<sup>a-f</sup>**  
for GaAs, AlAs, InAs, InP, and GaP

Parameters	Materials				
	GaAs	AlAs	InAs	InP	GaP
$a_0$ (Å)	5.6533	5.6600	6.0584	5.8688	5.4505
$E_g$ (eV)					
0 K	1.519	3.13	0.42	1.424	2.90
		2.229*			2.35*
300 K	1.424	3.03	0.354	1.344	2.78
		2.168*			2.27*
$\Delta$ (eV)	0.34	0.28	0.38	0.11	0.08
$E_{v,av}$ (eV)	-6.92	-7.49	-6.67	-7.04	-7.40
Optical matrix	25.7	21.1	22.2	20.7	22.2
parameter $E_p$ (eV)	(25.0) <sup>f</sup>			(16.7) <sup>f</sup>	
Deformation potentials (eV)					
$a_c$ (eV)	-7.17	-5.64	-5.08	-5.04	-7.14
$a_v$ (eV)	1.16	2.47	1.00	1.27	1.70
$a = a_c - a_v$ (eV)	-8.33	-8.11	-6.08	-6.31	-8.83
$b$ (eV)	-1.7	-1.5	-1.8	-1.7	-1.8
$d$ (eV)	-4.55	-3.4	-3.6	-5.6	-4.5
$C_{11}$ ( $10^{11}$ dyne/cm <sup>2</sup> )	11.879	12.5	8.329	10.11	14.05
$C_{12}$ ( $10^{11}$ dyne/cm <sup>2</sup> )	5.376	5.34	4.526	5.61	6.203
$C_{44}$ ( $10^{11}$ dyne/cm <sup>2</sup> )	5.94	5.42	3.96	4.56	7.033
Effective masses					
$m_e^*/m_0$	0.067	0.15	0.023	0.077	0.25
$m_{hh}^*/m_0$	0.50	0.79	0.40	0.60	0.67
$m_{lh}^*/m_0$	0.087	0.15	0.026	0.12	0.17
$m_{hh,z}/m_0 = \frac{1}{\gamma_1 - 2\gamma_2}$	0.333	0.478	0.263	0.606	0.326
$m_{lh,z}/m_0 = \frac{1}{\gamma_1 + 2\gamma_2}$	0.094	0.208	0.027	0.121	0.199
$\gamma_1$	6.8 (6.85)	3.45	20.4	4.95	4.05
$\gamma_2$	1.9 (2.1)	0.68	8.3	1.65	0.49