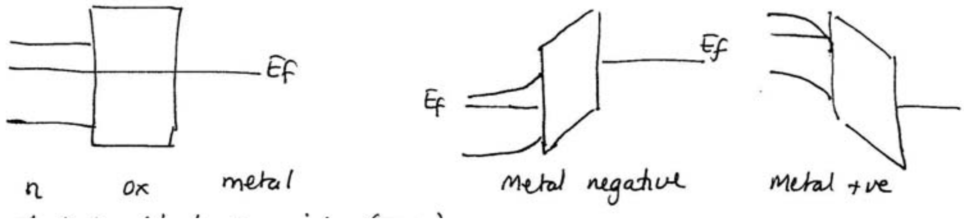
Sample Exam 2 Solutions

Problem 1

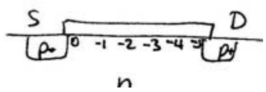
a.



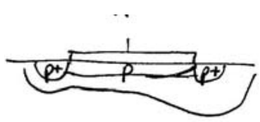
Material masked in black is oxide (SiO_2)
V_G negative: initially electrons depleted from S/C, eventually goes into inversion (becomes p type). Metal gate has depletion of electrons close to interface.
V_G positive: electrons accumulate in S/C and also in metal near interface.

b.

Zero V_g:

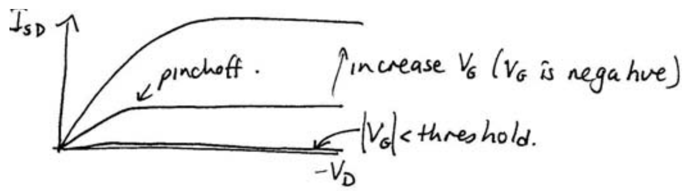


pn junction at D is in large reverse bias, no current flows S-D.
Negative V_g:



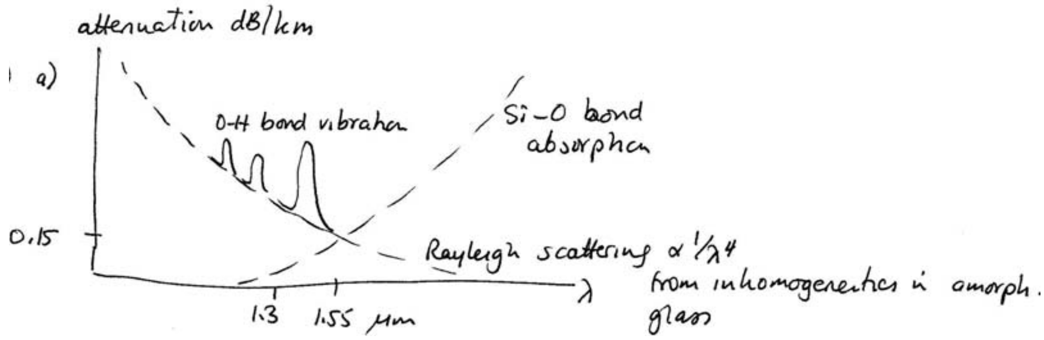
At threshold V_g, n goes into inversion and forms channel. Curren I_{SD} flows, but channel is narrower near D, and eventually pinches off → limits I_{SD}.

Positive V_G: No channel forms, no conduction from S to D.



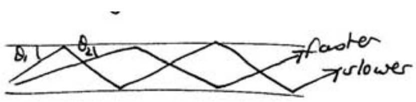
Problem 2

a.



b.

Modal dispersion: Monochromatic modes traveling at different angles travel different distances → pulse spreads out.
Materials disperstion: different color; light travels with different speed because refractive index is function of λ.



Waveguide dispersion: modes of different color travel at different speeds because each color's modes have slightly different propagation angles.
c.

Dispersion irrelevant because light is continuous. However, loss is an issue because need high power output (note: 2 eV = 620 nm light, and silica is quite absorbent at this λ).
d.

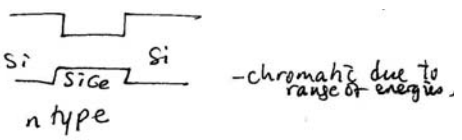
Core (must be direct gap): (Ga,In) P where Ga   50 - 60% or (InAl)As, Al

80%
Cladding: Larger bandgap, eg (GaIn)P, Ga ¿ 60% or (InAl)As, Al ¿ 80% or (AlGa)As or AlAr
Substrate: Lattice match, binary composition: GaAs or even Ge InP (or AlAs)

e.

SiGe laser could produce light from 0.67 - 1.1 eV (1.1 - 2 μm), IR problem is that SiGe is indirect and there are many III-V compounds that could do the job better.

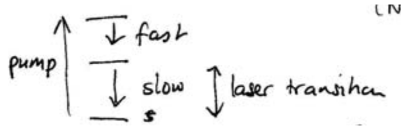
If you use amorphous SiGe, like the solar cell, it could be direct (uncertainty principle). Design as heterostructure since carrier lifetime is short. Light would not be very monochromatic due to range of energies.



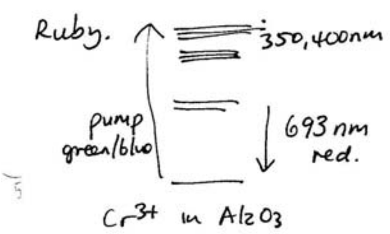
Problem 3

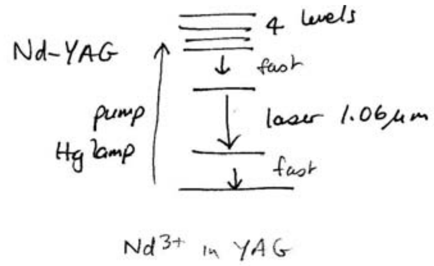
a.

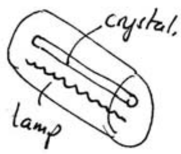
Need stimulated B_{31} emission to dominate B_{13} absorption $\Rightarrow$ need population inversion since $B_{31} = B_{13}$ $\Rightarrow$ need a 3 or 4 level system that can be pumped (Not equilibrium)



Also need stimulated energy to dominate spontaneous emission.
Need high density of photons.
Confine light in laser cavity, with reflective surfaces.

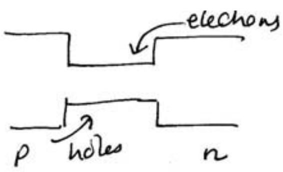






b.

Heterostructure confines carriers in potential well $\Rightarrow$ can get population inversion at forward bias; carriers must recombine.



Also traps light due to change in refractive index (plus shiny sides of laser confine light). Also cladding doesn't reabsorb light since band bap larger.

c.