Sample Exam 2 Solutions

Problem 1

a.

Material masked in black is oxide (SiO₂)
$V_G$ 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. Current $I_{SD}$ 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 dispersion: different color; light travels with different speed because refractive index is function of $\lambda$.

![Diagram of modal dispersion and materials dispersion]

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: $2 \text{ eV} = 620 \text{ nm}$ light, and silica is quite absorbent at this $\lambda$).

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

c.

![Diagram](image-url)