Integrated Photonic Device

Homework 4
2007, Fall

1. Pure GaAs has a refractive index of 3.56. However, a planar waveguide is fabricated by proton bombardment on a GaAs substrate with an initial free carrier concentration of 6×10^{18} /cm^3 (n-type). The free carrier concentration in the guide area is reduced to 1×10^{15} /cm^3 after bombardment, and the bombarded depth is 5 μm. The device configuration is shown in Fig. 1a. Please answer the following questions.

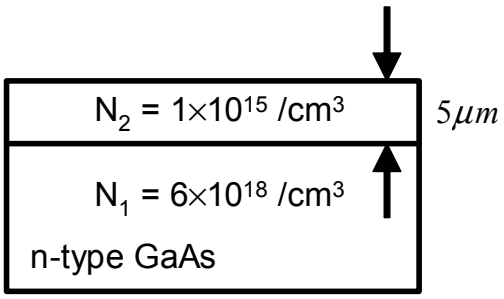


Fig. 1a

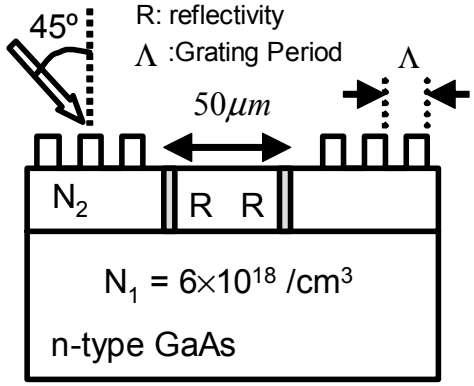


Fig. 1b

(a) Suppose TE polarization and small index contrast. The cut off concentration for different mode number is given by $\Delta N \geq (2\nu+1)^2 \frac{\pi^2 c^2 m^* \varepsilon_0}{4e^2 t^2}$, where ΔN is the difference of free carrier concentration, v is mode number (0,1,2,…), c is the speed of light, m^* is effective mass, e is the charge of electron, and t is the thickness of a planar waveguide. How many TE modes are in the waveguide region?

(b) Suppose the wavelength is 1.15 μm (TE polarization), what is the effective thickness for the fundamental mode? What is the confinement factor?

(c). Continue in (b). What is the absorption coefficient α due to free carrier absorption supposing the power is only lost in the highly-doped region (substrate with initial free carrier concentration of 6×10^{18} /cm^3)? (Suppose the light is only confined in the semiconductor)

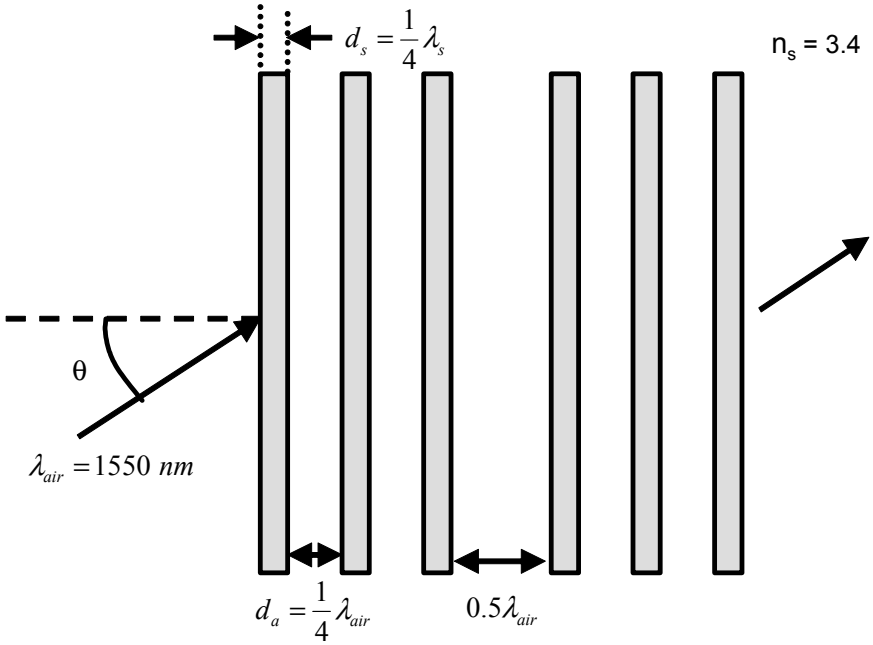
(d). Now, if we implant metal in the waveguide region to form a Fabry-Perot cavity and put grating couplers at the two ends of the waveguide, as shown in Fig. 1b. If the laser beam is incident from air with an angle of 45°, what is the grating period used for light coupling to the fundamental mode? (Hint: you may need to know the

propagation constant in (b))

(e). If the cavity length is 50 μm, what is the reflectivity such that the Fabry-Perot cavity operates in critical coupling condition for the fundamental mode? (Hint: you may need to know the answer in (c))

(f). Continue in (e). What is the intrinsic quality factor of cavity if only the fundamental mode is concerned? Supposing the group velocity is equal to the phase velocity.

2. Six silicon slabs are arranged periodically except for the central gap with a separation of half optical wavelength. The index of silicon is 3.4. Please answer the following questions.



(a) Suppose the incident wave is s-wave and the incident angle is 0 degree. Please plot the transmittance spectrum from 1000 nm to 2500 nm. (You have to use Matlab to code the program)

(b) Same as (a). Plot the spectrum as the incident wave is p-wave

(c) Same as (a). Plot the spectrum as the central gap varies from 0.5 λ_{air} to 0.55 λ_{air}

(d) Same as (a). Plot the spectrum as the incident angle varies from 0 degree to 20 degree.