1. A laser diode emits 10mW constant optical power with a flat RIN spectral density of -130dB/Hz. What is the electrical bandwidth so that the standard deviation of optical power fluctuation is less than 0.1mW?

Solution:
Standard deviation of optical power fluctuation is 
\[ \sigma = \sqrt{RIN \cdot f \cdot P_{ave}^2} \]
so that 
\[ f = \frac{\sigma^2}{RIN \cdot P_{ave}^2} = \frac{0.01}{10^{-13} \times 100} = 10^9 \text{ Hz} = 1 \text{ GHz} \]

2. For a DFB laser based on first order Bragg grating, and the refractive index of the semiconductor material is \( n = 3.6 \), (a) in order for the Bragg wavelength to 1540.8nm, what is the grating period? (b) if the cavity length is 400\( \mu \text{m} \), what is the width of the stop band?

Solution:
(a) Based on eq. (3.4.1), Bragg wavelength is \( \lambda_B = 2n\Lambda / m \), with \( m = 1 \).
\[ \Lambda = \frac{\lambda_B}{2n} = \frac{1540 \text{ nm}}{2 \times 3.6} = 214 \text{ nm} \]

(b) The width of the stop band is \( \Delta \lambda = \frac{\lambda_B^2}{nL} = \frac{(1540.8 \times 10^{-9})^2}{3.6 \times 400 \times 10^{-6}} = 1.65 \text{ nm} \)

3. A laser diode has a cavity length of \( L = 300 \mu \text{m} \), refractive index \( n = 3.5 \), linewidth enhancement factor \( \alpha_{lw} = 5 \), and the spectral linewidth of 100MHz. An mirror is placed at one side of the laser to form an external cavity with the effective reflectivity \( R_3 = 0.1 \), and the refractive index in the external cavity is \( n_e = 1 \). The facet reflectivity of the laser diode facing the external cavity is \( R_2 = 0.05 \). In order to reduce the spectral linewidth to 1MHz, what should be the length of the external cavity? (assume that the phase of the external feedback can be precisely controlled)

Solution:
Based on equation (3.4.5), in order for a 100 times reduction of spectral linewidth, \( k = 99 \) is required. The feedback parameter \( k \) can be evaluated from equation (3.4.6):
\[ k = \frac{\tau_c (1 - R_2) \sqrt{R_3}}{\sqrt{R_2}} \sqrt{1 + \alpha_{lw}^2} = \frac{L_e \times 1}{300 \times 3.5} \sqrt{1 - 0.05} \times \frac{1 - 0.05}{\sqrt{0.05}} \times \sqrt{26} = 0.0065L_e \]
Thus, \( L_e = k / 0.0021 = 99 / 0.0065 = 15.23 \text{ mm} \)

4. Silicon has a bandgap of 1.13eV. For a silicon photodiode with a quantum efficiency of 0.85, what are the responsivities of this photodiode at signal wavelengths of 700nm, 1000nm, and 1500nm?

Solution: Responsivity is \( R = \eta \frac{q\lambda}{hc} \)
at $\lambda = 500\text{nm}$, $\Re = 0.85 \times \frac{1.6 \times 10^{-19} \times 500 \times 10^{-9}}{6.626 \times 10^{-34} \times 3 \times 10^8} = 0.342 A/W$

at $\lambda = 1000\text{nm}$, $\Re = 0.85 \times \frac{1.6 \times 10^{-19} \times 1000 \times 10^{-9}}{6.626 \times 10^{-34} \times 3 \times 10^8} = 0.684 A/W$

Since $\lambda = 1550\text{nm}$ is longer than the cutoff wavelength, there is no response: $\Re = 0$

5. An optical signal $P(t) = P_{\text{ave}} \left[1 + \cos(2\pi f_0 t)\right]$ is detected by a photodiode with the bandwidth much higher than $f_0$. The photodiode has a responsivity $\Re = 0.9 A/W$, and there is a DC block (which removes the DC component from the photocurrent) at the photodiode output circuit.

(a) For $P_{\text{ave}} = -20\text{dBm}$, what is the mean-square of the photocurrent at the photodiode output?

(b) For every dB increase of the $P_{\text{ave}}$, what is the corresponding increase (in dB) of the electrical signal power at the photodiode output?

Solution:

The photocurrent is, $I(t) = \Re P(t) = \Re P_{\text{ave}} \cos(2\pi f_0 t)$ where DC term is removed

(a) $P_{\text{ave}} = -20\text{dBm} = 10^{-5}W$.

Mean-square photocurrent is $\langle I(t)^2 \rangle = \langle (0.9 \times 10^{-5})^2 \rangle / 2 = 4.05 \times 10^{-11} A^2$

(b) mean-square photocurrent is proportional to the electrical power, so that a 1dB increase of the optical power is equivalent to the 2dB increase of the signal electric power.