February 1, 2024

ECEN 721: Optical Interconnects

Homework #2

Due: February 13, 2024, 5:00PM
Homeworks will not be received after due.
Instructor: Sam Palermo

1. **Multi-Mode Fiber Channel**. A short distance 32Gb/s interconnect system uses a graded-index multi-mode fiber (GRIN-MMF) channel with n_{core}=1.48 and n_{clad}=1.46. What is the maximum transmission distance such that the pulse spreading due to modal dispersion is 10% of the bit period? Refer to Lecture 2 for the GRIN-MMF modal dispersion model.

2. **Single-Mode Fiber Channel**. A 32Gb/s system operating at λ=1310nm utilizes a single-mode fiber channel with loss of 0.4dB/km and D=0.5ps/(nm*km). The transmitter laser source has a 1nm linewidth and outputs 500μW average power. Assuming a receiver sensitivity $\bar{P}_{sens}$ = -23dBm, answer the following.
    a. What is the maximum transmission distance? Is the link loss- or (chromatic) dispersion-limited? For chromatic dispersion, assume that ΔT should be at most half the bit period.
    b. If the fiber length is 5km, what is the maximum data rate?

3. **Vertical p-i-n Detector**. An InGaAs vertical p-i-n detector has a 1μm intrinsic region with an absorption coefficient $\alpha=10^4$cm^{-1}. The device is biased to yield carrier velocities of 10^5m/s and electrical parasitics of R_{PD}=20Ω and C_{PD}=70fF.
    a. Assuming no reflection losses, what is the responsivity at λ=1550nm?
    b. What is the total PD bandwidth, including both transit-time and RC effects?

4. **Waveguide p-i-n Detector**. A Ge waveguide p-i-n detector has a 340nm intrinsic with an absorption coefficient $\alpha=10^3$cm^{-1} and a 15μm absorption length. The device is biased to yield carrier velocities of 10^5m/s and electrical parasitics of R_{PD}=50Ω and C_{PD}=10fF.
    a. Assuming no reflection losses, what is the responsivity at λ=1550nm?
    b. What is the total PD bandwidth, including both transit-time and RC effects?

5. **Simple Resistive Front-End Sensitivity**. A simple front-end with noise bandwidth BW_n=22GHz is constructed with a 50Ω resistor. This front-end is used with 3 effective photodetector configurations.
    a. p-i-n detector with R=1A/W
    b. APD with R=1A/W, M=8, F=4
    c. OA + p-i-n with R=1A/W, G=50, ηF=2

    For these 3 effective photodetector configurations:
    i. Give the optical sensitivity for a BER=10^{-12} considering both amplifier and detector noise. Hint: You need to first compute the "amplifier" noise, which is the resistor rms current noise over a 22GHz bandwidth. Assume T=300K.
    ii. With the computed sensitivity and assuming a high extinction ratio, what is the high-level detector shot noise, $i_{n,X,1}^{rms}$?