NAVAL POSTGRADUATE SCHOOL
Monterey, California

EC 3550 FINAL EXAM 6/01 Prof. Powers

- This exam is open book and notes.
- There are four problems; each is equally weighted.
- Partial credit will be given; be sure to do some work on each problem.
- Be sure to include units in your answers.
- Please circle or underline your answers.
- Show *ALL* work.
- Write only your name on these exam sheets.
- Exams and course grades: I will email you an announcement when they are ready.
- If you want me to send you your exam score and course grade, send me an email request. (This request will waive your privacy rights.)
- Enjoy your break!

Course grade: _____

1		3	
2		4	
TOTAL			

Name: _____

1. Please provide brief, concise answers to the following questions. (Long, verbose answers are *not* required.)

   (a) Explain why the following wavelengths are special in a silica fiber link.

      i. 1300 nm

      ii. 1550 nm

   (b) List the two dispersion components of the group-velocity dispersion (GVD) in a single-mode fiber.

   (c) Describe the primary advantage of using an external modulator in a high data-rate transmitter.

   (d) Describe the two purposes for using the five-layer heterojunction structure in a semiconductor laser diode. (The inventors of this structure won the Nobel prize in Physics last year.)

   (e) Draw a block diagram identifying all of the components of an erbium-doped fiber amplifier.

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2. Short problems ...

   (a) A multimode, step-index, 50/125 fiber has a core index of 1.456 and a Δ of 1.2%. Approximately what fraction of the total power is in the core at a 850-nm wavelength?

   (b) A graded-index fiber has a $n(r)$ with a parabolic shape. The index of refraction at the center of the core is 1.455 and the index of the cladding is 1.460. What is the NA of this fiber?

   (c) A pin detector has a quantum efficiency of 80% at 1300 nm. Calculate the mean-square noise-current due to the signal-dependent shot noise that is produced when 50 nW of light power is incident on it at a bit rate of 500 Mb/s?

   (d) A single-mode fiber has a GVD of 20 $\text{ns}\cdot\text{nm}^{-1}\cdot\text{km}^{-1}$ at 1550 nm. Calculate the dispersion-limited distance at a bit rate of 10 Gb/s with RZ coding if the link uses a DFB-laser source operating at that wavelength with a spectral width of 0.5 nm.

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3. A link is designed to operate at 1530 nm with a BER of 10^{-12}. The link receiver is placed at the output of an optical amplifier. The signal power at the receiver is 5 mW and the ASE noise power is 3 mW. The properties of the amplifier and its optical filter are given in the table below. Calculate the maximum bit-rate that this link can support.

Amplifier Properties (Prob. 4)

Parameter	Value
n_{sp}	1.3
$\Delta\lambda_{\text{amplifier}}$	41 nm
B_o	1.3 nm
P_{sat}	0.55 mW

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4. Consider the link shown in Fig. 1.

   The properties of the various components are ...

   - Bit rate: 1 Gb/s
   - Transmitter: DFB laser; wavelength = 1525 nm; spectral linewidth = 0.5 nm; 0.90 mW of power in the fiber
   - Splice: insertion loss = 0.2 dB; return loss = 30 dB
   - Isolator: insertion loss = 0.5 dB; isolation = 30 dB; return loss = 40 dB
   - 3x3 coupler: excess loss: 1.0 dB
   - Grating: see Fig. 2
   - Fiber: length = 50 km (lossless splices); loss coefficient = 0.3 dB/km
   - Detector: pin diode; responsivity @ 1525 nm = 1.00 mA/mW; dark current = 6 nA
   - Load resistor: 50 Ω; Noise temperature = 380K
   - Preamp: Current gain = 1000; Noise figure = 3.5 dB

   Calculate the signal-to-noise ratio (both as a number and in dB) at the output of the preamp. (Do *not* make any assumptions about any of the noise terms being negligible.)

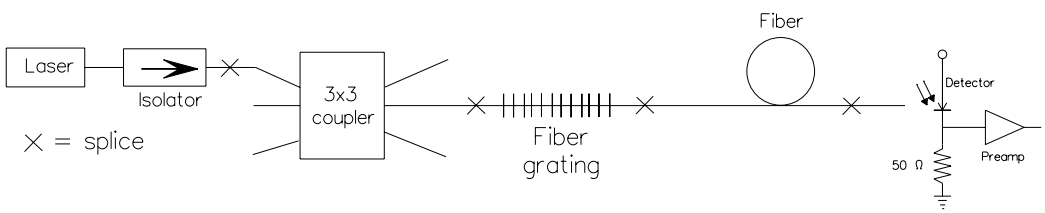


Figure 1: Data link for **Prob. 4**

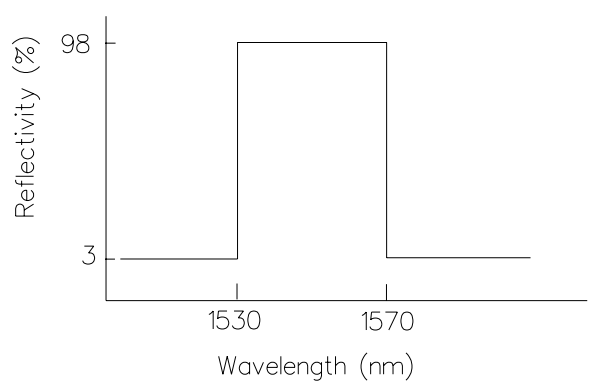
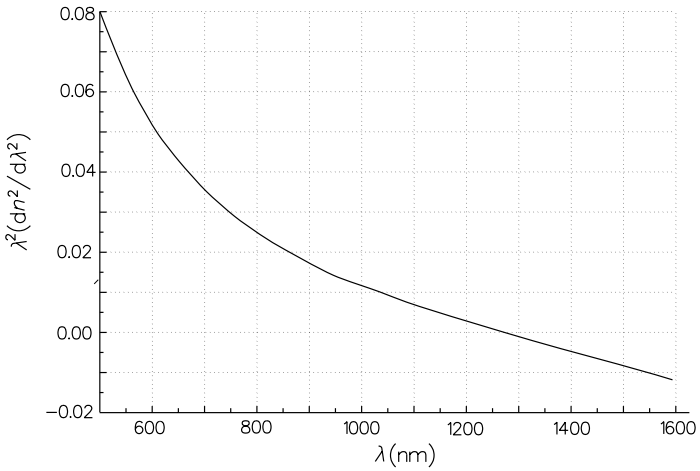
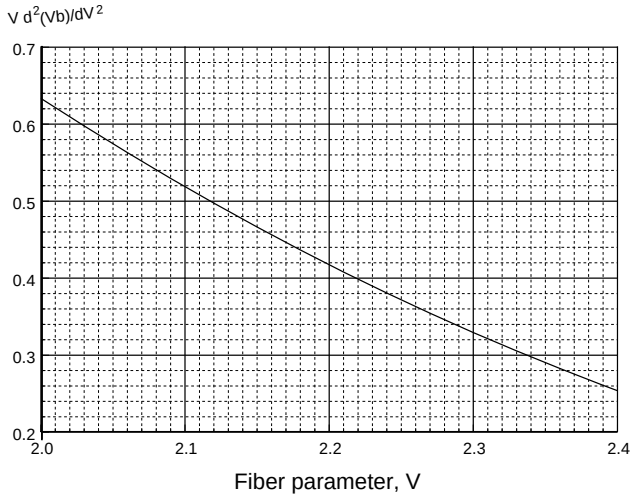


Figure 2: Fiber grating reflectivity for **Prob. 4**



(a)



(b)

Figure 3: (a) Fig. 3.8 and (b)Fig. 3.10 of text.

BER	Q exact	Q approx
10^{-3}	3.090	3.12
10^{-4}	3.719	3.73
10^{-5}	4.265	4.28
10^{-6}	4.753	4.76
10^{-7}	5.199	5.21
10^{-8}	5.614	5.62
10^{-9}	6.00	5.998
10^{-10}	6.36	6.361
10^{-11}	6.71	6.706
10^{-12}	7.034	7.04
10^{-13}	7.349	7.35
10^{-14}	7.651	7.65

Table 1: Table 6.3 of text.