NAVAL POSTGRADUATE SCHOOL
Monterey, California

ECE 3550 Fiber Optics Experiment 3A 11/99 Prof. Powers

FIBER COMMUNICATIONS LINKS

Purpose: In this experiment, we will examine fiber optic transmission of analog and digital data.

Equipment:

General purpose test equipment (signal generator, scope, multimeter, frequency counter, etc.)
Power supplies (± 5 volts, ± 15 volts, variable V^+)
HP digital transmitter and receiver
AMP analog transmitter and receiver
Fiber cable with connectors
IR viewer

Procedure:

A. Analog system

A simple low power audio demonstration link is shown in Fig. 1. With no input voltage applied to the XMTR, the voltage level out of output of the LM 386 is 1/2 of V_s. Analog signals with a plus and minus excursion will cause the voltage at this output to vary about $V_s/2$. The current through the LED is desired to be about 60 ma with no signal and to vary from 20 to 100 ma depending on the signal strength and polarity. Assuming $V_s = 8$ volts and $I_{\text{bias}} = 60$ mA, the resistor value of R_3 is chosen from the results of the following calculation :

$$R_3 = \frac{(V_s/2) - V_{\text{diode}}}{I_{\text{bias}}} = \frac{4 - 1.4}{60} = 43\ \Omega\,. \tag{1}$$

Adjust the transmitter adjustable resistor at the input to ensure that no clipping occurs at maximum signal.

In the RCVR, the input adjustable resistor is the gain control. The output of op-amp is again $V_s/2$ with no input. Any AC signal is then passed by the output capacitor and appears on the speaker. The input and output coupling capacitors are chosen for a 30 Hz to 20 KHz system response.

1. Ensure that the system is set up as in Fig. 1. Familiarize yourself with all meter and test equipment controls.
2. Speak into the microphone and observe the received signal on the scope. (Note: Because of widely differing impedance levels, the scope and speaker cannot be used at the same time. The switch setting on the receiver output will determine whether the scope output or the speaker output is used.) Vary the gain of the receiver by adjusting the input potentiometer.
3. Apply a 1 KHz tone to the input and observe the received signal on the scope. Vary the input frequency and observe the effect on the output.

4. Decrease the supply voltage to 5 volts and observe the effect on the output on the scope. Can you exlain what you observe?

5. Adjust V_s back to 8 volts.

6. Remove the 1 KHz tone. Remove the fiber from the XMTR and observe the LED with the IR viewer. Note that the LED is emitting with no signal applied. Why?

7. Reconnect the fiber to the XMTR and disconnect at the RCVR. Observe the light out of the fiber. Is there a perceived difference in intensity from step 6? Why?

8. Reapply the 1 KHz tone. Remove the XMTR end of the fiber after reconnecting the RCVR. Hold the fiber close to the LED and move the fiber longitudinally away from the source. Observe how far away the fiber can be and still capture enough light to obtain an output signal. Do the same with the receiver end. Also vary the axial alignment of the fiber with respect to the LED and the pin diode receiver. Which shows more sensitivity—the longitudinal displacement or the axial displacement? (The axial should.) Is there any difference in the sensitivity of the output level to the fiber/source and the fiber/detector displacements? Briefly explain your observations.

B. Digital System

Figure 2 shows the transmitter circuit. (The current meter is omitted.) The LED is is driven by a current from the supply when the transistor switch is OFF. The transistor switch bypasses the LED when the switch is ON. (In this way the current drawn from the supply stays constant.)

Figure 3 shows the receiver circuit. The internal detector produces a current that triggers a logic gate. The output is HIGH or LOW, accordingly.

1. Ensure that the system is set up as in Fig. 2. Check all meter and test settings.

2. Apply a 200 KHz square wave to the XMTR and observe the output. Adjust the offset adjustment for a 50% duty cycle. Observe the proper operation of the data link.

3. Apply a 1 Hz square wave to the XMTR. Remove the fiber from the XMTR and observe the light with the IR viewer. Does the observation differ from the analog XMTR? Why?

Report: Each group should submit a brief (but comlete) report summarizing its measurements. This report is due one week after completion of the laboratory exercise.

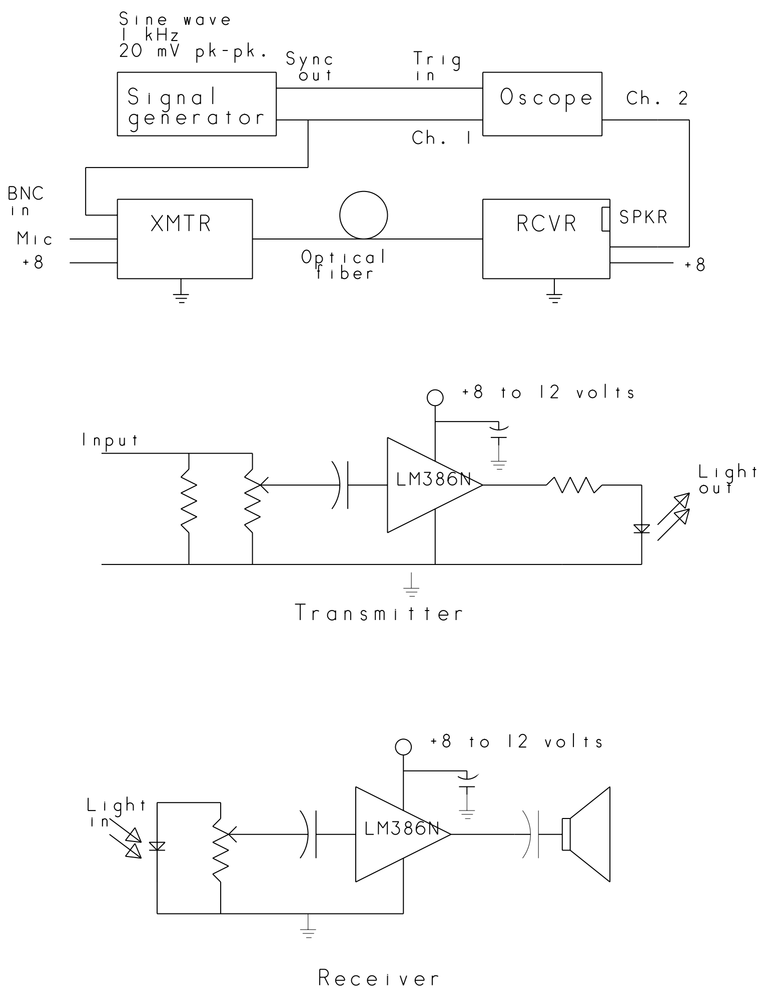

Figure 1: Analog fiber optic link

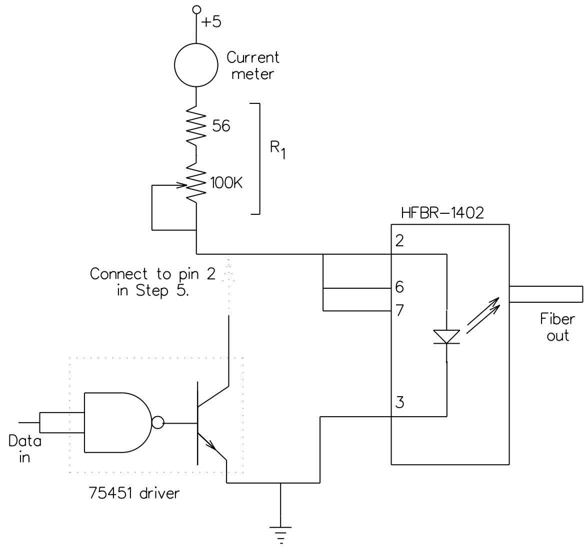

Figure 2: Transmitter circuit.

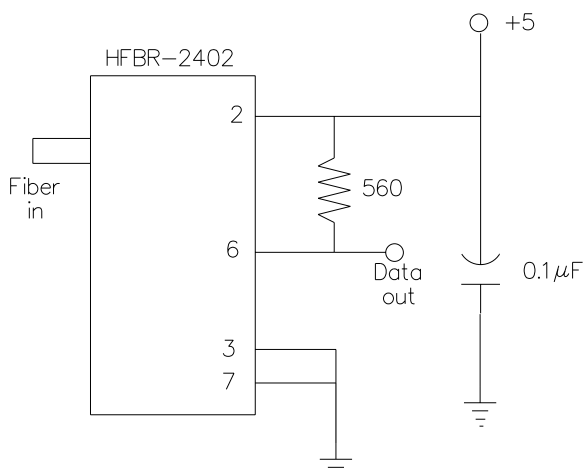

Figure 3: Receiver circuit diagram

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LASER DIODE CHARACTERISTICS

Purpose: In this experiment, we will examine the operating characteristics of a laser diode at different temperatures and look at the optical spectrum of a Fabry-Perot diode laser and a distributed feedback (DFB) laser.

Equipment:

Melles Griot DLD103 Laser Diode Controller
Computer controller (with LabVIEW instrument control software)
LaserJet printer connected to computer
Laser diode mount
Laser Diode Inc. SCW-1302 1300-nm laser diode (with fiber pigtail)
ILX 1880 Optical Multimeter
HP70951B Optical Spectrum Analyzer (with GPIB plotter connected)
BCP Laser Transmitter (Model 400A)
BCP High-Speed DFB Laser Transmitter (Model 410A)

Caution: Laser diodes are intolerant of abuse. The following conditions can cause destruction of the diode: reverse bias voltage (instead of forward bias), sudden application of a nonzero forward bias, exceeding the maximum drive current, operation at high temperatures, etc. The laser controller is designed to avoid all of these destructive operating conditions, but only if operated in accordance with the instructions of this procedure. These 1300-nm diodes cost several hundred dollars each; so please be careful.

Introduction:

The laser diode package contains the laser diode, a thermoelectric cooler to control the diode operating temperature, a thermistor to sense the diode temperature, a photodiode to sense the relative power emitted by the diode, and a precision-aligned fiber pigtail. The Melles Griot laser controller has inputs to sense the temperature (via the thermistor) and to control the thermoelectric cooler to increase or decrease the diode temperature. Using feedback, the diode temperature can be set and controlled with the controller. The photodiode in the laser package senses the optical power emitted at the rear facet of the diode laser. Since this power is proportional to the laser power in the output pigtail, it can be used to detect changes in relative power. With a single calibration measurement, the photodiode output can be used to measure the output power in the fiber pigtail. With feedback, the photodiode output can be used to maintain constant power over time and/or environmental temperature changes.

The Melles Griot laser controller has a GPIB (general-purpose instrument bus), allowing computer control of the instrument. LabVIEW is a commercial instrumentation-control software package for controlling instruments accessible with the GPIB bus, taking measurements, and manipulating the data. We have written a program (called *diodplot.vi*) to control the diode laser controller from the computer and to perform some of the measurements needed for this experiment.

Procedure:

A. Power vs. drive current characteristics

1. Ensure that the laser diode controller is tuned off.
2. Ensure that the fiber pigtail from the diode laser is connected to the power meter sensor head. *Do not open any connections while the laser is on!! This is a safety violation. Eye damage may result from looking at the end of the fiber connector at a close distance. The light is invisible and you won't be aware that your eyes are being irradiated.*
3. If the computer is not already on, turn it on. Log in by typing "EC3550" as the user name and "student" as the password. After the computer has logged you in, double click on the "EC3550 Laser Expt" icon. LabView will start up and place you in the control program.
4. You are now ready to set up the diode controller as follows.

    (a) Turn on the laser diode controller. It will go through a brief self-test. After completing the self-test, it will display a screen full of information on its present settings (saved from the last time it was turned off), indicate that the self-test was passed OK, and invite you to press any key to continue.

    (b) Press the "SAVE/RCL" button. (It is located just above the "9" button on the numerical keypad of the diode laser controller.)

    (c) The screen should now display the "Save Recall Menu". Push the leftmost button under the screen label "Action" until the "Recall" command is highlighted. (One button push should suffice.)

    (d) Push the second button from the left to "Recall DLD103 setup" (previously stored in memory). The screen should then show a list of several previously stored setups.

    (e) Push the "Press to select next item" button until the "EC3550" item is highlighted.

    (f) Push the "Press to recall setup" button to load the setup. The laser controller will perform a warm reset and will eventually display the initial screen showing the operating parameters from the recalled setup and inviting you to "Press any key to continue".

    (g) Press any of the keys *below* the screen. The screen will change and will display the "Mode Menu".

    (h) We now want to turn on the thermoelectric cooler control. Press the right button below the screen (under the TEC heading) to highlight "ON". You should observe the temperature reading and the "Itec" reading (both are at the top of the screen) start to fluctuate as the cooler controller functions. Eventually the temperature will stabilize. (The temperature stabilizes at a temperature that is slightly above the set temperature [shown at the bottom of the screen]. This is because the manufacturer of the diode laser provides typical calibration data for the thermistor in the laser package. Exact data for the thermistor in the device is not available. Thus, we will set the temperature for a desired value, but the actual operating value will be a bit higher. You should record the measured temperature.)

    (i) Check again that the TEC cooler is "ON". (The word "ON" in the lower right corner of screen should be highlighted.) *Do not proceed further if the cooler is off!! You will destroy the diode laser!!*

5. Returning to the computer, the operating instructions are displayed in the lower-right corner of the screen. Read these directions.

   (a) You will use the sliders to set "operating temperature" to the desired values (as detailed below).

   (b) When you are satisfied with the settings of "operating temperature", start the VI program by clicking the "RUN" icon. (This icon is a right-pointing arrow.)

6. We will measure and record the operating curves of the laser diode at five different temperatures. LabVIEW's capabilities have made us decide between either seeing the data plotted as it is measured (but only for a single curve) or being able to superimpose the curves on a single plot (but not plotting the data until all of the measurements have been done). We chose the former; hence, you will have to print one graph for each of the four operating temperatures.

   (a) Start the *diodplot.vi* program (if you have not already done so).

   (b) The "MAX CURRENT" slider should be set to 30 mA. If not, use the mouse, to set the maximum current to 30 mA. (We will not change this value any further in this experiment.)

   (c) Using the "Temperature" slider and the mouse, set the desired operating temperature of diode to 10C.

   (d) Click on the "Run" icon under the menu bar (or use the "OPERATION, RUN" menu commands).

   (e) You should observe that the diode controller screen shows that current is being applied to the cooler and the operating temperature is changing. Once the operating temperature stabilizes, the diode controller applies increasing current (in 1 mA steps) to the laser until the maximum current value is reached. The data is plotted on the screen as it is measured. (You should see a typical laser diode output curve. If in doubt, check with the lab technician. Note: the first current step frequently gives erroneous data for unknown reasons.) Note that the maximum laser power and the measured diode temperature are also recorded on the screen.

   (f) Print the screen display, by using the "File, Print" menu commands. Your printout should resemble Fig. 1.

   (g) Clear the screen plot. (See instructions on the screen, below the plot.)

   (h) Repeat the procedure for temperatures of 10C, 15C, 20C and 25C.

7. Turn-off procedure: Be sure to turn off the laser diode controller (with its key-switch before turning of the computer.

8. From your screen plots, find the approximate threshold current at each temperature and the incremental efficiency above threshold.

9. Prepare a table of results indicating the maximum power, the estimated threshold current, and the incremental efficiency at each of the six measured operating temperatures.

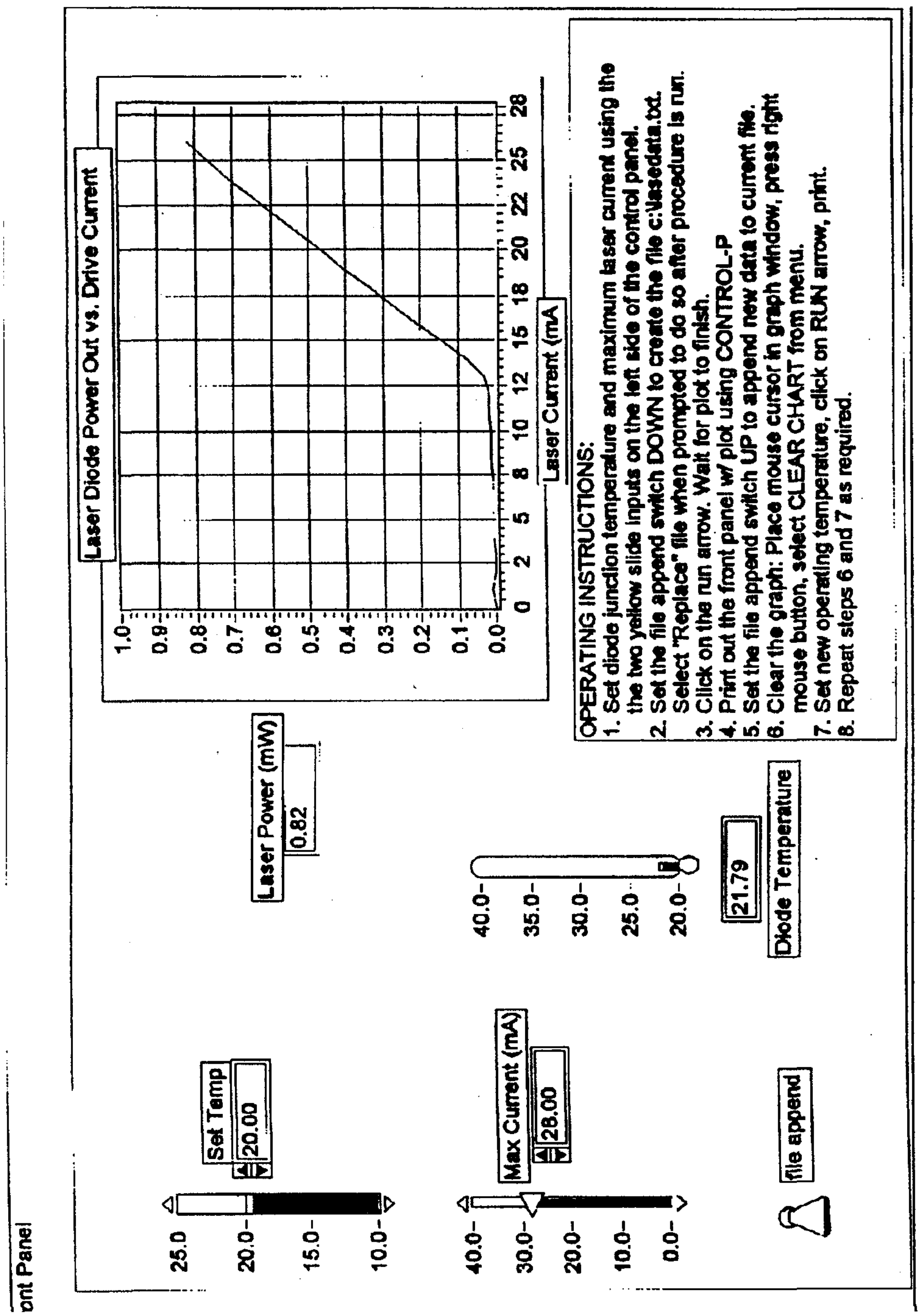

Figure 1: Representative screen printout.

10. The equation describing the temperature effects on a laser diode is

$$I_{\mathrm{th}} = I_0 \exp\left(T/T_0\right) , \tag{2}$$

where I_0 and T_0 are parameters associated with the diode. The T_0 parameter depicts the temperature sensitivity of the diode, with lower values being less sensitive. Using your measured values of I_{th} and T, find estimates for the values of T_0 and, then, I_0 for your diode. (Be sure to clearly describe your method for finding these parameters.)

B. Laser Spectrum

In this part of the experiment we will measure the laser spectrum using an optical spectrum analyzer (OSA). We are particularly interested in the nominal operating wavelength, λ, and the spectral width, $\Delta\lambda$, of the laser for both a Fabry-Perot laser diode and a distributed-feedback (DFB) laser.

1. If necessary, turn on the plotter connected to the OSA.
2. Connect the Model 400A laser transmitter to the OSA with a fiber cable. (You may need to clean the transmitter end of the fiber with alcohol.)
3. On the OSA, press the "INSTR PRESET" button (above screen to the right) and the "AUTO MEASURE" button (lower left). When the screen indicates that the automeasure is complete, press the "USER" button (under center of screen) and then the "FP" softkey (to the right of the screen). The OSA will show the spectrum of the laser and associated measurements. Push the "Single sweep" softkey on the upper right of the screen; the OSA will perform a single measurement and the readings will stabilize.
4. After ensuring that the display has stabilized, push the "PLOT" button on the OSA to record the optical spectrum and associated readings.
5. Repeat the measurement for the Model 410 DFB Laser transmitter. (In step 3, you will need to press the "DFB" softkey instead of the "FP" softkey.)

Report: Each group should submit a brief report summarizing its measurements. This report is due one week after completion of the laboratory exercise.