# ECE469 Optical Communications and Networks

# Lab 2: Laser Diodes and Light-Emitting Diodes

Rev. 2015

## Purpose

- Characterize the opto-electronic properties of laser diodes (LD) and light-emitting diodes (LEDs) by measuring the optical power as a function of the drive current.
- Characterize the spectral properties of laser diodes (LD) and light-emitting diodes (LEDs) by measuring the optical spectrum.
- Learn how to use optical power meters and optical spectrum analyzers to characterize the optical components.

## References

- G. P. Agrawal, Fiber-Optic Communication Systems, 4$^{th}$ Ed., Ch. 3
- Ramaswami et al., Optical Networks: A Practical Perspective, Section 3.5
- Ando AQ6317 Optical Spectrum Analyzer Instruction Manual.

## Apparatus

- Laser Diode: Thorlabs pigtailed laser diode with FC connector LPS-660-FC (Hitachi HL6501MG laser diode)
- LED: Optek Technology OPF372A Fiber Optic GaAlAs LED with ST adaptor
- Power cable connecting laser/LED to current source: Thorlabs SR9C-DB9 cable with some modifications

- Laser current source: Newport Model 505 or ILX LDX-3525
- Photodetector: Newport 818-SL or 818-IS-1
- Optical power meter: Newport 1815-C or Newport 1830-C
- Ando AQ6317 Optical Spectrum Analyzer (OSA)

## Cautionary Notes and Safety

- **DO NOT** look directly into the laser diode.
- The equipment and components are fragile and expensive. Optical fibers, connectors, devices must be handled very carefully. The fibers and fiber connectors can break if too much stain is applied or bent too sharply. **DO NOT** touch the fiber connector ends.
- Turn the output current of the Laser Current Source OFF when connecting and disconnecting fibers. Only turn the current on when you are ready to measure.
- DO NOT EXCEED A DRIVE CURRENT OF 70 mA FOR THE LASER DIODE. THE LASER DIODE WILL BE DAMAGED BEYOND THIS CURRENT.

## Procedure

### Measurement of the Laser Diode

#### Optical Power vs. Current

1. Connect the 9-pin male D-sub connector of the **laser diode power cable** to the 9-pin female D-sub adapter at the rear panel of the Laser Current Source. Turn on Laser Current Source power switch. Set the mode to “I” and the display to “current”.
2. Connect the pigtailed laser diode output to the photodetector. **Do not bend the fiber and handle it very gently.** Turn on the current output of the Laser Current Source.
3. Turn on the Power Meter.

   For the Newport 1830-C power meter, it will go through a system initialization and calibration. Set the wavelength to 660 nm.

   For Newport 1815-C power meter, find the calibration factor at the wavelength of 660 nm from the calibration sheet on the table, press the CAL button, adjust the CAL ADJ to set the calibration factor to the corresponding number, and then release the CAL button.

Gradually increase the drive current from 0 to 70 mA, and record the light power vs. current in 10 mA steps. The unit for the power reading on the power meter is blue colored Low Power W/ATTN.

Identify the interval for the laser threshold current.

4. Zoom into the interval for the laser threshold and take light power vs. current measurements in 1 mA steps. Measure at least 6 data points around the laser threshold to identify the knee.

   Do not increase the current further if you find that the optical power is no longer increasing above threshold. Do not keep the high current on for a long time. A slight over-current will damage the laser diode.

5. **Gradually ramp down the current to zero** when you finish the measurements.

6. Plot the light power versus input current (*L-I*) curve. Determine the threshold current of the laser diode, which is the knee in the *L-I* plot.

## Optical Spectrum

7. Disconnect the laser diode output from the photodetector and connect it to the input of the ANDO Optical Spectrum Analyzer (OSA). Turn on the OSA.

8. Set the laser diode driver current to slightly below the threshold. Use chapter 8.1.2 Measurement Examples on OSA manual as a reference. The wavelength of the laser diode is around 660nm. Set the peak wavelength as center wavelength. Adjust the [SPAN], <RESOL>, <SEN> until you see the spectrum with multiple longitudinal modes under laser gain envelope. Note how OSA parameters such as resolution, sensitivity affect the spectrum measurement.

9. The laser diode is a Fabry-Perot semiconductor laser. Determine the FWHM (full width at half maximum, i.e., the spectral width down 50% or 3 dB from the peak wavelength amplitude) of the gain profile *just below the threshold current*. The functions under [ANALYSIS], <SPEC WD, THRESH> may be useful, or you can analyze the data collected by the computer afterward.

10. Reduce the wavelength span until you can measure the wavelength separation between two longitudinal modes. Measure four consecutive peak wavelengths and calculate the average peak wavelength space between adjacent longitudinal modes.

11. Slowly increase the current from below to above the threshold current. Observe the change in the optical spectrum. Using the same OSA settings, record a few representative spectra of the laser diode below threshold and above the threshold.

12. **Gradually decrease the current to zero after the measurement and turn off the Laser Current Source**. Disconnect the laser diode from the OSA and laser current source.

## Measurement of the Light-Emitting Diode

### Optical Power vs. Current

1. Adjust the current to zero. Turn off the Laser Current Source power switch. Connect the 9 pin male D-sub connector of the **LED power cable** to the 9 pin female D-sub adapter at the rear panel of the laser current source. Turn on the Laser Current Source power switch. Set the mode to "I" and set the display to "current".

2. Connect the fiber from the LED output to the photodetector. Turn on the current output of the Laser Current Source.

3. Turn on the Power Meter.

   For the Newport 1830-C power meter, set the wavelength to 850 nm.

   For the Newport 1815-C power meter, find the calibration factor at the wavelength of 850 nm from the calibration sheet, press the CAL button, adjust the CAL ADJ to set the calibration factor to the corresponding number, and then release the CAL button.

4. Gradually increase the driving current (from 0 to 100 mA), and measure the optical power vs. current in 10 mA steps.

5. Gradually decrease the current back to zero after the measurements**.**

6. Plot the light power-current (*L*-*I*) curve. Determine the slope of the *L*-*I* curve.

### Optical Spectrum

7. Connect the LED output to the input of the OSA.

8. Increase the drive current and measure the spectra of the LED at driving currents of 40 mA and 70 mA. Note the peak wavelength of the LED and determine the spectral width (FWHM) of the LED at the two currents.

9. **Decrease the current to zero after measurements.** Turn off the laser current supply, optical power meter and OSA.

## Pre-Lab Questions

1. What are the expected differences in the optical spectrum and light power vs. current characteristics between the laser and the light emitting diode?

2. What effect causes a rounded knee in the *L-I* plot at the laser threshold?

3. Aside from optical communications, give two examples of applications that use semiconductor laser diodes.

4. Aside from optical communications, give two examples of applications use light emitting diodes.

## Post-Lab Analysis and Questions

### Laser diode

1. What is the threshold current of the laser diode?

2. What is the slope efficiency of the laser diode ($dL/dI$)?

3. Although you did not measure the voltage across the laser diode, from energy conservation (between the electron-hole pair recombination and a generated photon), the voltage would be roughly equal to the photon energy of the light emission divided by the charge of the electron.

   Estimate the overall power efficiency of the laser diode ($L/(IV)$). This efficiency is known as the wall-plug efficiency.

4. Compare the output spectrum of laser diode below threshold, just above the threshold, and in the linear *LI* range. What are some differences and similarities? What is the FWHM gain bandwidth below threshold? What is the main peak wavelength? Does this peak wavelength change when the current increase? Why?

5. Explain whether the laser diode used in this lab single-mode or multi-mode.

6. The longitudinal modes of a laser diode are spaced by $\Delta\nu = c/2n_g l$, where $l$ is the length of the laser, and $n_g$ is the effective group index of the laser mode. Assuming $n_g = 3.5$, what is the length of the laser diode from the spectrum of laser diode just below threshold?

### Light emitting diode

7. What is the slope of the LI curve? Did you observe any saturation in the optical power? What is the saturation current?

8. What are the main peak wavelength and the spectral width (FWHM) of the LED?

## Comparison

9. Compare the *L-I* plots and optical spectra of the laser diode and LED. What are the main differences?

10. Referring to your experiment results, how do the characteristics of the laser diode and LED relate to the issues of dispersion, data rate limitation, and wavelength division multiplexing in optical communication links?