MAT 288S Spring 2010 Optoelectronic Measurements

Laboratory 4

Laser linewidth, optical feedback, and frequency domain reflectometry

Due: Tuesday June 2, 2010

Introduction

Optical feedback into diode laser cavities can produce both useful and deleterious effects: it can be used to lock the optical frequency to a master laser, to reduce the optical linewidth, and to provide some amount of wavelength tunability; if the feedback is uncontrolled, it can also broaden the laser linewidth and induce oscillation. In this lab exercise, we will observe the effects of optical feedback, and use the feedback to measure the length of an inaccessible optical fiber. We will also measure the linewidth of a DFB laser.

Resources

CAUTION: The laser requires +5V, -5V, and +24V from three separate DC power supplies. Leave these supplies powered on, to avoid driving spikes into the laser. Carefully turn up the voltage to power up the laser, and turn them down when you are done. The meter on the 24V supply is inaccurate: adjust it to +22V.

The yellow jacketed fiber cable is fairly robust, but the thin plastic clad fibers (900 um plastic cladding) are fragile. In particular, the weight of the connector, especially with a fiber-connecting union attached, can easily break the end of the fiber, as can careless handling when making connections. Handle these gently, and always be aware of loops of fiber that can snag your notebook, hand, or instrument cart.

Optical fiber connectors come in many varieties, which are generally not compatible with each other. The laser uses an FC/APC connector on the fiber inside the metal box, to be connected to a mating FC/APC connector. This is distinguished by the green strain relief at the connector. The white ceramic ferrule is polished at an angle, to reduce reflections at the interface between two connectors. The fiber 1x2 splitters that you will use in the fiber Mach Zehnder Interferometer use flat polished FC/PC connectors, and there are fiber patch cords and spools that also use flat polished FC/PC connectors. These have either black, white or blue strain reliefs. To mate the two types, always use a yellow patch cord that has a green connector at one end, and a black or blue connector at the other.

Always clean the faces of fiber connectors with a q-tip and isopropanol, and inspect them under a microscope or with a hand magnifier to insure they are free from particulates, before mating them. Permanent damage may occur otherwise.

1. 1310 nm DFB laser packaged with a thermoelectric cooler and current supply, and pigtailed with a single mode optical fiber leading to a FC/APC connector.

2. InGaAs photodiode, packaged in a FC/PC connector and soldered to an SMA electrical connector. We use this unbiased in this lab, connected to the input of the electrical spectrum analyzer.

3. Electrical spectrum analyzer, 100 Hz – 22 GHz frequency range, ~-90 dBm sensitivity.

4. Real time oscilloscope.

5. Single mode 1x2 fiber splitters: approximately 10% of the light introduced into the single blue fiber at one end is coupled into the red fiber at the other end, intended as a power sampling tap, the remainder going to the output blue fiber or to coupling loss.

6. Hand held optical power meter, with a fiber connector input.

7. Optical fiber patch cords 1 meter, 2 meters or 18 meters long; 100 meters of fiber on a black spool; 6 km of fiber on a blue spool.

8. Fiber polarizer

Experiments

1. Turn on the electrical spectrum analyzer and familiarize yourself with the front panel controls. Connect a function generator to the input (use <1 V amplitude), to observe the response to various signals.

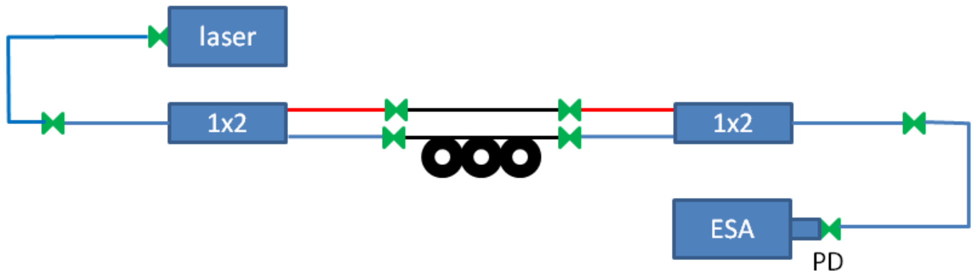
- What do you see with a sinusoidal input? A square wave? A triangle wave?

2. With no signal input, examine the noise floor of the ESA. Just as with photodiodes, the magnitude of the noise depends on the bandwidth of the measurement. This may be reduced using the RBW (resolution bandwidth) button in the lower left corner of the front panel.

- Plot the noise as a function of resolution bandwidth. Compare it to the noise expected from the 50 Ohm input impedance.

3. A fiber Mach Zehnder interferometer is diagrammed below. Carefully trace the fibers in the setup to insure that the splitters, polarization controller, laser input and photodiode output are properly connected. Since the twin ports of the splitters are unequal, we mix them (red to blue) to equalize the intensities in each path. The polarization controller consists of about one meter of fiber. To balance the MZI, you may insert one meter of fiber in the opposing leg.

- Connect the photodetector assembly to the oscilloscope to observe the time domain signal. As you jiggle a fiber in the MZI, or as acoustic noise does the jiggling, the phase changes resulting in a rapidly changing interference signal at the detector. Does the magnitude change if you adjust the fiber polarizer? What happens if you open one leg of the interferometer?
- Insert longer lengths of fiber into one leg of the MZI. What do you observe in the time domain signal? Why?



Fiber Mach Zehnder Interferometer with polarization controller

4. The instantaneous frequency of any laser drifts in time, largely due to the residual spontaneous emission in the cavity. This may be observed by combining the light with previously emitted light, delayed in some long optical path, and observing the beat frequency that arises from the interference. The width of the resulting spectrum is termed the laser linewidth. Note that if the relative delay is short compared to the coherence time, no beats are observed.

- Move the photodetector to the ESA. The minimum frequency of the ESA is 100 Hz, likely too fast to observe time varying signals produced by physical motion of the fiber.
- Try different fiber lengths in one leg of the MZI. How does the spectrum vary with fiber length?
- With the 6 km spool, what is the FWHM of the interference spectrum? This is the laser linewidth, under the present operating conditions. What is the corresponding coherence length? How does the coherence length compare to the other fiber lengths you have tried?

4. Optical reflections can produce unwanted oscillation of a laser, often occurring at the round trip frequency between the laser and the source of the feedback. This laser does not have an optical isolator and is particularly vulnerable to optical feedback.

- Restore the balanced path lengths in the MZI.
- Unscrew the locking ring on one of the fiber connections, and slightly separate the ferrule from its mating ferrule, without removing the ferrule completely. The resulting small air gap allows significant coupling from one fiber to the other, but also produces a significant reflection toward the laser. You should observe peaks

in the spectrum due to laser oscillation (sidebands on the optical frequency.) What do you see?

- Add additional fiber and observe the spectrum. What happens? With this frequency domain reflectometry technique, determine the length of fiber INSIDE the laser box, between the laser and the box mounted connector.

Report your answers to the questions above, along with any other observations of interest.