**ELEE 4145 Principles of Lasers and Photonics**

**Experiment 1: How Laser Works?**

This experiment studies the fundamental of how laser works by building a laser with a gain medium in a feedback loop. The threshold characteristic and slope efficiency will be studied. Furthermore, the effect of different laser feedback ratio as well as cavity loss on building a laser will be investigated.

**Introduction**

A laser is fundamentally an optical oscillator, which analogous to any other oscillators, is simply an optical amplifier with positive feedback (i.e. feedback with gain). A semiconductor optical amplifier (SOA) fiber ring laser is shown in Figure 1. An SOA is used as the gain medium for the laser, while the optical feedback is completed by a fused fiber optical coupler. Unidirectional oscillation is ensured by the optical isolator. The laser output is obtained at one of the output port of the optical coupler that used to complete the feedback.

In a fiber ring laser, the fused fiber coupler is equivalent to the partially reflecting mirror in a semiconductor Fabry-Pérot laser, while the coupling ratio is similar to the transmission/reflectivity of the mirror in a FP laser. The optical filter is inserted in the ring to select the operating wavelength of the laser and to minimize the level of amplified spontaneous emission at the laser output. The variable attenuator mimics the cavity loss in a FP laser, which enables investigation of the effects of intra-cavity loss on both the laser threshold and slope efficiency.



Laser output

**Objective:**

1. To understand the operating principle of laser through the use of SOA fiber ring laser as an example.
2. To understand the relationship between laser characteristics (i.e. output power, threshold, L-I curve) and (i) different driving current apply to the SOA (ii) intra-cavity loss, (iii) feedback power, and (iv) intra-cavity loss.

**Operation Instructions**

1. Before powering up the SOA unit and the laser, ensure that the bias current control knob for driving the SOA is turned fully anti-clockwise (i.e. zero biasing current).
2. Never disconnect or connect fiber terminations with significant levels of power propagating in the system. Before making or breaking any optical connections or terminations (fiber or instrument), always ensure that the power controls are set for minimum output or switched off. The system must be fully connected with no free end optical outputs when the power levels are anything other than zero.
3. Before making a connection, remove the dust cap and carefully clean the end face of the optical fiber with the optical tissue provided moistened with IPA (isopropyl alcohol). And then wipe the end face with a dry tissue to remove residual moisture. The TA will show you how.
4. When the experiment is completed, firstly reduce the SOA bias current to zero and then switch off the current driver. Disconnect all the fiber patch cords and put on the dust caps.

**Experimental Procedures**

1. Identify all the optical components on the optical bench. Do not turn on the SOA yet.
2. Start from the SOA, connect the optical isolator and then the optical filter, as shown in Figure 1. Ensure the directions of the components are correct. In this experiment, we will use an optical circulator and a fiber Bragg grating as an optical filter.
3. Connect the filter output to the input of the 80/20 optical coupler. The 80% output is used as the feedback while the 20% output is used as the laser output.
4. Complete the laser cavity by connecting the 80% feedback to the SOA. In this configuration, the excess intra-cavity loss is 0 dB.
5. Measure the laser output power as a function of the SOA driving current using an optical power meter.
6. Repeat the measurement by placing an optical attenuator in the ring as shown in Figure 1. Make sure the SOA driving current is at zero before disconnecting the ring. The two attenuators are 5 and 10.
7. Repeat step (4) and (5) using an optical coupler with 90/10 coupling ratio.
8. The data you took during the experiment will be used for the discussion part below.

**Discussion**

1. Plot out the results you obtained in steps (4) – (6). Use a proper axis to make sure you can compare the results.
2. Describe the trend of your measurement in step (4), and explain why.
3. Describe the results in Step (5), with attenuations of 0 dB, 5 dB, and 10 dB. How the excess intra-cavity loss affect the laser output characteristic.
4. Describe the laser output characteristic when an optical coupler with 80/20, and 90/10 coupling ratios are used. Explain your observation.
5. How will the setup look like if an EDFA is used as the gain medium to EDFA instead. Design a ring laser system using EDFA and draw the schematic diagram.