PRACTICUM: OPTOELECTRONICS–II

Laser diodes will be characterized as a function of injection current and temperature. The student group will measure the optical modes and optical output power of a DFB laser and calculate the grating period for Bragg wavelength from the measured data. The measured data will be analyzed and documented.

Tasks:

I. Measure the Bragg wavelength of a DFB laser and side-mode suppression ratio (SMSR) as a function of injection current
II. Evaluation of characteristics temperature of the DFB laser
III. Calculation of grating period (\(\Lambda\)) of the DFB Laser

1. Basic principle of laser

Laser is the abbreviation for Light Amplification by Stimulated Emission of Radiation. There are several main types of laser, such as gas lasers, chemical lasers, solid-state lasers, semiconductor lasers, and so on. However, all lasers can be considered...
to contain such basic parts in principle: pumping, active medium and resonator (Figure 1). Pumping is an action of energy transfer that pumps the external energy into the active medium to achieve the so-called inversion. The active medium converts the energy into light by stimulated emission. The active mediums could be certain crystals, gases, semiconductors, liquid solutions of dyes, etc. The resonator, normally a cavity with an arrangement of mirrors, can form standing wave of light. This kind of resonator not only applies the feedback for the stimulated emission, but also confine and modify the laser beam.

2. Semiconductor lasers

Semiconductor lasers are lasers based on semiconductor gain media. The semiconductor laser can be distinguished into two categories, i.e., horizontal (in-plan) and vertical cavity resonator structures.

In the horizontal resonator, so called Fabry-Perot (FP) structures the optical reflection (feedback) is provided by the borders of the cleaved facets (resonators), Figure 2. In many cases, the high refractive index difference between semiconductor edge and air is already sufficient, providing an optical reflection coefficient of about 30%. By additional facet coatings this coefficient can be tailored continuously between 0% (antireflection) and 100% (perfect reflection). The resonator modes are given by

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Figure 2. Schematic diagram of the Fabry-Perot and Distributed Feedback lasers.
$m \left[ \frac{\lambda_B}{2n_{\text{eff}}} \right] = L$

Intuitively spoken, the resonator length $L$ has to be a positive integer multiple of the half light wavelength in the medium, where $n_{\text{eff}}$ is the effective refractive index.

In the conventional FP semiconductor lasers the feedback is provided by the facet reflections whose magnitude remains the same for all longitudinal modes. Most F-P lasers lase on several longitudinal modes simultaneously. Some applications (e.g. optical communication) need single mode lasers. There are many different laser structures for single mode operation; one such laser structures is Distributed FeedBack (DFB) laser structure. The DFB laser structure replaces the cleaved facets resonators with a periodic grating along the cavity axis which sharpens the cavity resonance, Figure 2.

In the DFB laser structure the optical reflection is extended over the whole resonator therefore a very efficient feedback occurs at Bragg wavelength $\lambda_B$, which is correlated with the DFB grating period $\Lambda$ via Bragg condition.

$$\lambda_B = 2 \cdot n_{\text{eff}} \cdot \Lambda \cdot \frac{1}{m}$$

$m$ - a positive integer and describes the grating order

$\lambda_B$ – Bragg wavelength

$n_{\text{eff}}$ – effective refractive index
3. Measurement setup

The schematic diagram of the measurement setup is shown in Figure 3. Injection current and temperature of the laser are controlled by Lightwave LDC 3900 system (Figure 4). The light output is connected to Optical Spectrum Analyzer (OSA) using fibre optical cable, Figure 5. A typical spectrum of a DFB laser ($\lambda_B = 1.3 \, \mu m$) is shown in Figure 6. A power meter is used to measure the optical output power of the laser, Figure 7. Measurement parameters such as current, temperature and wavelengths will be explained before starting the experiments.

Figure 3. Schematic diagram of the measurement setup.

Figure 4. Current and temperature controller of the laser.
Figure 5. Optical Spectrum Analyzer (OSA)

Figure 6. Spectrum of a DFB laser with threshold current of $I_{th} = 18.01$ mA at 18°C.
Task I:

Measure the spectra for different injection current at 20°C

Injection current (mA): 10, 15, 20, 25, 30, 35, 40 and 45

Evaluation:

- Wavelengths, $\lambda_B$, $\lambda_l$ and $\lambda_r$ as a function of injection current
- Side-mode suppression ratio (SMSR) as a function of injection current
- Estimate $\Delta \lambda / \Delta I$
Task-II

Measure light output power as a function of injection current (10, 15, 20, 25, 30, 35, 40 and 45 mA) at different temperatures 15, 25, 35 and 40 °C

Evaluation:

Calculate the characteristics temperature $T_0$ of the laser.

Characteristic temperature $T_0$ often used to express temperature sensitivity of threshold current $I_{th}$. Low $T_0$ means $I_{th}$ increases more rapidly with increasing temperature. This dependency can be obtained using the equation:

$$I_{th} = I_{th0} \exp\left(\frac{T}{T_0}\right)$$

$I_{th}$ – threshold current

$T$-Temperature

$$I_{th} = I_{th0} \times \exp\left(\frac{T}{T_0}\right)$$

$$\ln(I_{th}) = \ln(I_{th0}) + \frac{T}{T_0}$$

Slope $= \frac{1}{T_0}$

$$T_0 = \frac{1}{\text{Slope}}$$
Task-III

Calculate the grating period ($\Lambda$) for Bragg wavelength from the measured data

$$\lambda_B = 2 \cdot n_{\text{eff}} \cdot \Lambda \cdot \frac{1}{m}$$

$m = 1$
$n_{\text{eff}} = 3.42$

4. Literatures: