

VILNIUS UNIVERSITY  
FACULTY OF PHYSICS  
STUDIES OF LASERS LABORATORY

Laboratory work No. **KE** – 7

## **Research of the laser diode**

Methodical instructions



**Attention! Laser radiation sources are used during work – it is necessary to familiarize and strictly follow the respective rules of safety**

Vilnius 2018

### **Purpose of the experiment**

Investigate AlGaInP semiconductor laser diode operation and radiation characteristics.

### **Experiment tasks**

1. Measure laser diode beam divergence angles.
2. Measure laser diode radiation power dependence on pump electric current at different laser diode temperatures.
3. Measure laser diode output radiation polarization degree dependence on pump electric current.
4. Measure laser diode output radiation spectral characteristics dependence on laser diode temperature.

### **Theoretical topics**

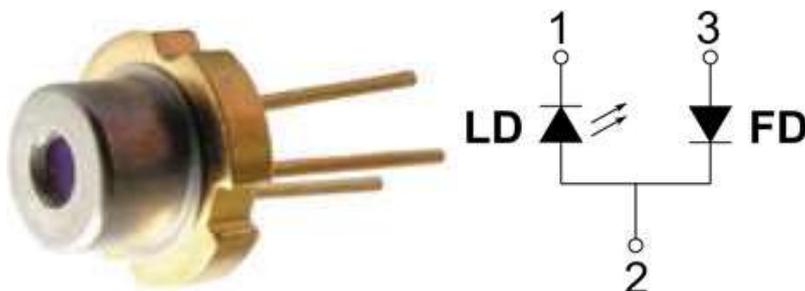
1. p and n semiconductors. pn junction.
2. Semiconductor diode lasers.
3. Spectral characteristics of semiconductor diode lasers.

## **METHODICAL INSTRUCTIONS**

### **Equipment and materials**

1. An AlGaInP laser diode.
2. A laser diode power supply.
3. A laser diode power and cooling unit.
4. A laser diode power and cooling control unit.
5. An objective.
6. An optical power meter.
7. A spectrometer.
8. A computer.
9. A polarizer.
10. A screen.
11. A filter.

### AlGaInP laser diode DL-65103TL



**Fig. 1:** The laser diode.

**Table 1:** Laser diode electrical and optical characteristics.

Parameters	Not.	Min	Typ.	Max	Unit	Conditions
Spectrum peak wavelength	$\lambda$	645	650	660	nm	$P_o=10mW$
Threshold electric current	$I_{sl}$	-	20	25	mA	
Working electric current	$I_d$	-	31	40	mA	$P_o=10mW$
Working voltage	$V_d$	-	2.2	2.5	V	$P_o=10mW$
Reverse voltage (FD)	$V_{ai}$		2	30	V	
Working temperature	$T$	-10	25	+50	°C	
Parallel divergence angle*	$\theta_{\parallel}$	6	9.5	12	°	$P_o=10mW$
Perpendicular divergence angle*	$\theta_{\perp}$	25	28	32	°	

\* - FWHM beam divergence angle

### Laser diode power and cooling unit

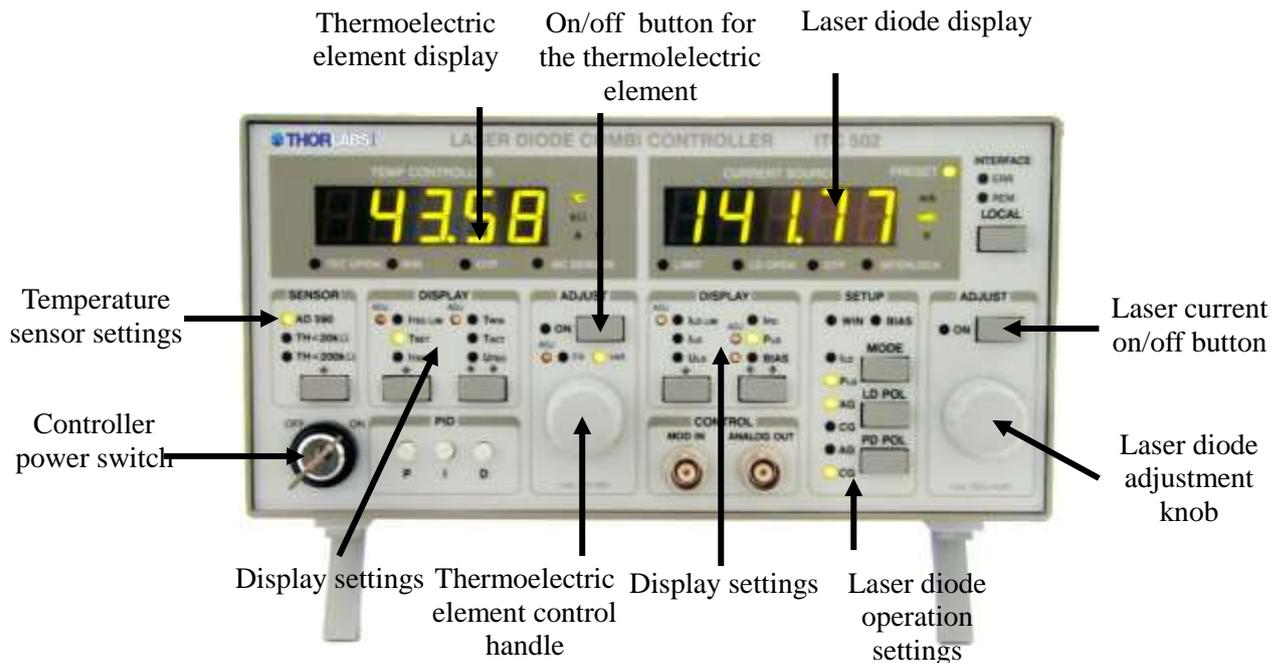


**Fig. 2:** Laser diode power and cooling unit.

Attention! Positions of the laser diode switch settings in the upper part of the block must be:



### Laser diode power and cooling control unit



**Fig. 3:** Laser diode power and cooling control unit.

The laser diode power and cooling control unit is used for setting the laser diode pump electric current and temperature. The main control unit on/off key-switch is on the left corner of the front panel (**Attention! Connect the cooling block before turning on the control unit.**). The front panel is divided into two parts. The right part of the panel is for setting the laser diode pump parameters. The left part of the panel – for setting the laser diode temperature parameters. A polarity of the laser diode and the monitoring photodiode connections are set in the right side section **SETUP**. The laser diode can operate with grounded anode (**AG**) or with grounded cathode (**CG**). The connection polarity is set using the **LD POL** (**Attention! The selected polarity of the output must be indicated by the LED "AG"**). If a polarity of the photodiode is set correctly, the photocurrent value will be positive. If the polarity of connection is set incorrectly, the photocurrent value will be negative. The photodiode can operate with connected external voltage (from 0 to 10 V). Presence of external voltage is indicated by **BIAS** indicator light in the **SETUP** section. By pressing **PD POL** one of four positions is set:

**AG** (an anode of the monitoring photodiode is grounded)

**AG+BIAS** (an anode of the monitoring photodiode is grounded with connected external voltage)

**CG** (a cathode of the monitoring photodiode is grounded)

**CG+BIAS** (a cathode of the monitoring photodiode is grounded with connected external voltage).

**ATTENTION! Settings must be adjusted such that LED CG would be on! Before turning on the external voltage, make sure that monitoring photodiode is connected correctly. Otherwise it (laser module) could be damaged!**

The laser diode can operate in two modes: constant current ( $I_{LD}$ ) and constant power ( $P_{LD}$ ). The mode is set by pressing the **MODE** button in the **SETUP** section. In the constant current mode the constant electric current in the laser diode is kept. In the constant power mode the constant monitoring photodiode current is kept.

The value of the selected measured quantity is displayed in the **DISPLAY** section of the laser diode screen. If the displayed value is being set, the **PRESET** indicator is on. If the value is being measured, the **PRESET** indicator is off. In the **DISPLAY** section the buttons “ $\Downarrow$ ” and “ $\Leftarrow\Rightarrow$ ” allow setting quantities that are displayed in the laser diode screen: the current limit  $I_{LD\ LIM}$ , the laser diode current  $I_{LD}$ , the laser diode voltage  $U_{LD}$ , the photodiode current  $I_{PD}$ , the optical power  $P_{LD}$ , the monitoring photodiode external voltage **BIAS**. The laser diode current, the monitoring photodiode current or the optical power can be set continuously with the adjust knob. The laser current can be set continuously between 0 mA and the selected current limit  $I_{LD\ LIM}$ .

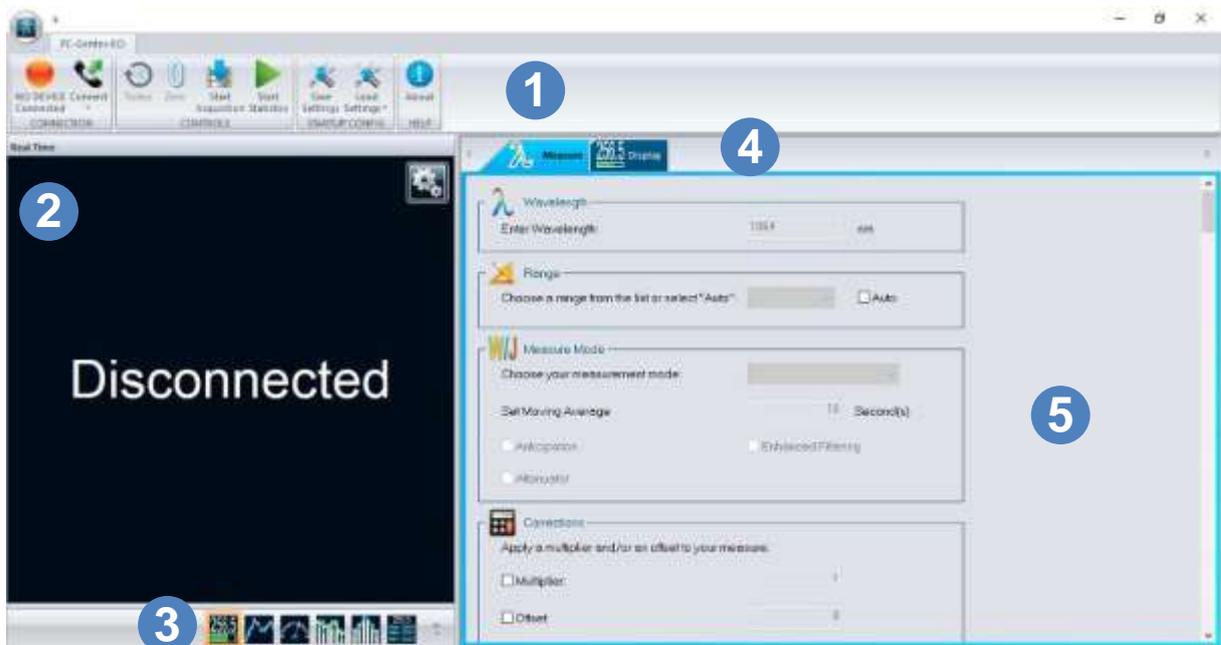
The temperature sensor is set using the “ $\Downarrow$ ” button on the left side of the front panel in **SENSOR** section (**Attention! Settings must be adjusted such that AD 590 indicator would be on.**). The value of the measured quantity selected in **DISPLAY** section is displayed in the thermoelectric element screen. The quantities that are selected using “ $\Downarrow$ ” and “ $\Leftarrow\Rightarrow$ ” buttons in the **DISPLAY** section can be: the thermoelectric element current limit  $I_{TEC\ LIM}$ , the target thermoelectric element temperature  $T_{SET}$ , the thermoelectric element current  $I_{TEC}$ , the temperature window  $T_{WIN}$ , the actual thermoelectric element temperature  $T_{ACT}$  and the thermoelectric element voltage  $U_{TEC}$ .

#### Power meter control software

For the laser radiation optical power measurement an optical power meter PH100-Si is used. The control software PC-Gentec-EO of the optical power meter is launched when the computer is turned on and the power meter is connected to it through the USB port.



**Fig. 4:** Shortcut of PC-Gentec-EO software.



**Fig. 5:** PC-Gentec-EO software control window.

1 – Main controls menu with the Connection, Controls, Startup config and Help functions panels.

2 – Display panel.

3 – Change panel for changing the type of Display panel.

4 – Setup Panel – Selection tabs for choosing the desired set of controls.

5 – Setup Panel – Controls for choosing and control of the different options of measurement, acquisition and display parameters.

Automatic connection of the power meter is performed by pressing the button **Connect** in the Main controls menu CONNECTION functions panel, while the disconnection is performed by pressing button **Disconnect** .



**Fig. 6:** CONNECTION functions panel when power meter is disconnected (left) and connected (right).

Display of the measured data statistics is enabled by pressing the button **Statistics** in the Change panel.



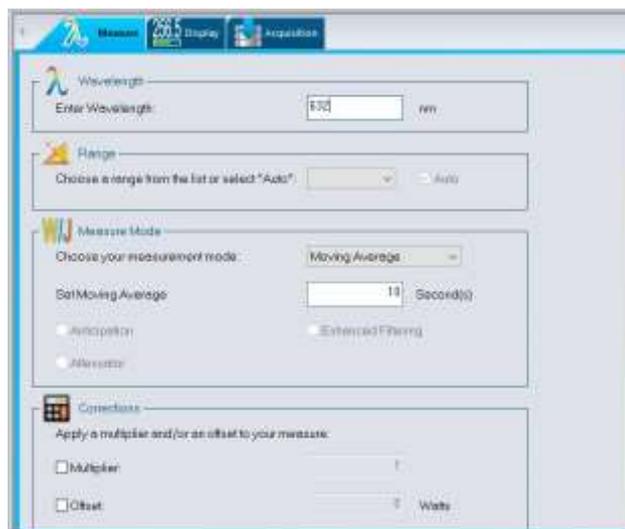
**Fig. 7:** Display panel when power measurement statistics is enabled.

Before measurement it is necessary to set zero power level in the power meter. To do it, when laser and alignment laser radiation are blocked, press button **Zero** in the main control menu CONTROLS functions panel.



**Fig. 8:** Controls functions panel.

In the Setup panel Measure tab set Wavelength to **650 nm**.



**Fig. 9:** Setup panel Measure tab

In the Setup panel Display tab Statistics Settings set measurement **Duration** to **Continuous** and power meter statistics calculation duration to 10 s.



**Fig. 10:** Setup panel Display tab.

Power meter statistics calculation is launched by pressing main control menu **CONTROLS** functions panel button **Start Statistics** (Fig. 8). Statistics calculation is stopped pressing button **Stop Statistics**.



**Fig. 11:** CONTROLS functions panel when statistics calculation is launched.

### Spectrometer control software

#### “AvaSoft 6.1 for AvaSpec” software

Connect the spectrometer to the computer through USB port and on the back side of the spectrometer press the switch to “USB” position. The indicator light “POWER” should flash on the front of the spectrometer.



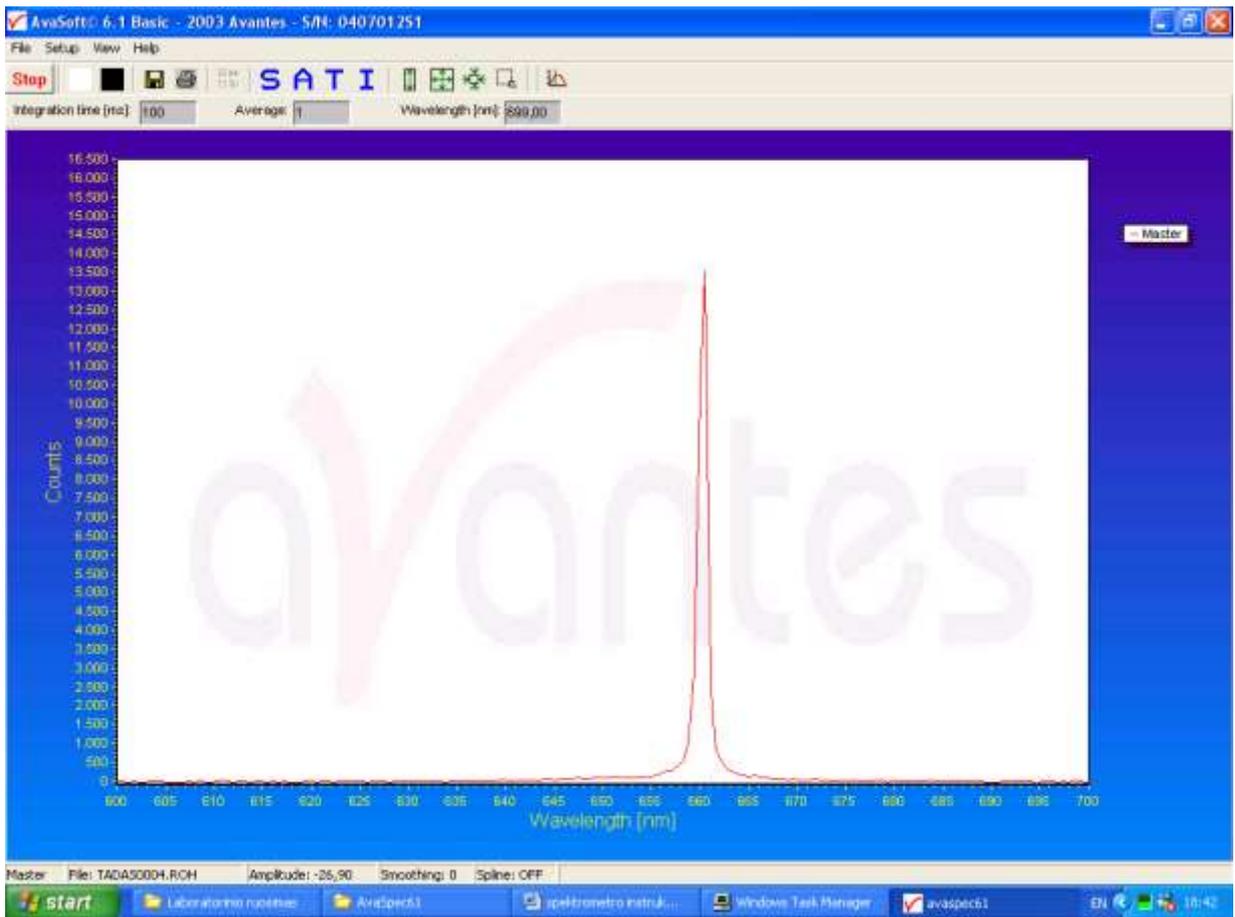
**Fig. 12:** Indication message that spectrometer is connected.

Launch “AvaSoft 6.1 for AvaSpec” software. If the

spectrometer is connected correctly, an indication message is visible (Fig 12).

The main working window of the software is opened after clicking **OK** (Fig. 13). The measurement is launched/stopped by clicking **Start/Stop**. The radiation spectrum (intensity dependence on wavelength) is depicted in the main window of the programme. By clicking  one can select the range of the displayed spectrum (600 nm ÷ 700 nm or less). The radiation spectrum peak positions (**Wavelength [nm]** field) can be determined by adjusting the cursor

 position with the mouse to match the peak.



**Fig. 13:** Spectrometer control software AvaSoft 6.1.

To create a sequence of measurements one needs to select: File > Start New Experiment. The measured spectra are saved by clicking **Save Experiment**. Measurement files are kept in **C:\AvaSpec61\data 0407012S1** folder with their name consisting of experiment name and graph number. After measurements are finished all graphs need to be converted into text format: File > Convert > To ASCII.

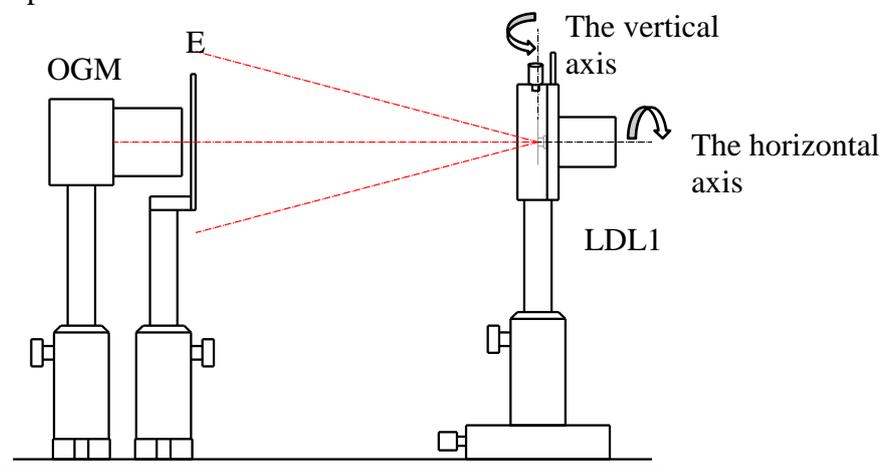
## Experiment procedure

Investigation for each task is performed by constructing the experimental setup according to the provided setups.

Attention! Before beginning it is necessary to familiarize with descriptions of the used equipment and a work safety features.

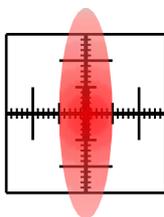
### 1. Measurement of the laser diode beam divergence angles.

- Connect the laser diode power supply unit LDM1 to electricity.
- By rotating the laser diode mount LDL1 around the vertical axis, set it to  $0^\circ$  position.
- Place the screen E with the vertical slit ( $10\text{ mm} \times 1\text{ mm}$ ) within  $\sim 150\text{ mm}$  distance from the laser diode mount LDL1. The center of the generated beam must match the center of the slit in the screen.
- Place the optical power meter OGM after the screen E.



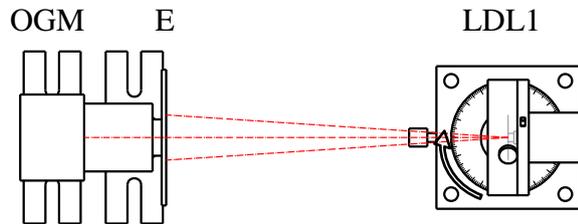
**Fig 14:** Semiconductor diode laser beam divergence angle measurement setup.

- By rotating the laser diode mount LDL1 around the horizontal axis, set it such that the “fast” component of the elliptical beam would be vertical (Fig. 15).



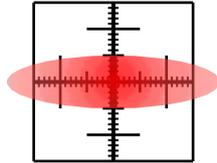
**Fig. 15:** Laser diode beam view on the screen E when measuring the “slow” component of the elliptical beam.

- When rotating the laser diode mount LDL1 around the vertical axis with  $2^\circ$  steps, measure the optical power of the laser diode beam, which has passed the slit in the screen, dependence on a rotation angle.



**Fig. 16:** Laser diode beam divergence angle measurement setup.

- Rotate the laser diode mount LDL1 around the horizontal axis by  $90^\circ$ .

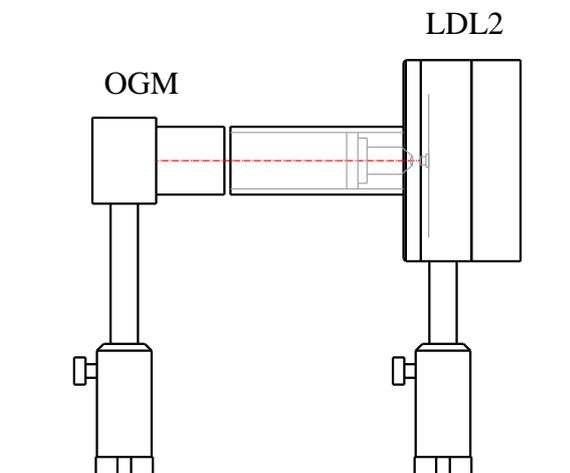


**Fig. 17:** The laser diode beam view on the screen E when measuring the “fast” component of the elliptical beam.

- When turning the laser diode mount LDL1 around the vertical axis with  $2^\circ - 8^\circ$  steps, measure the optical power of the laser diode beam, which has passed the slit in the screen, dependence on a rotation angle.
- Calculate generated laser diode beam divergence angles at FWHM and  $1/e^2$  levels. Compare with specified values.

## 2. Measurement of the laser diode optical output power dependence on the input current at the different laser diode temperatures.

- Turn on the laser diode power and cooling unit controller.
- Set  $20^\circ\text{C}$  temperature at the laser diode power and cooling unit. Turn electric current handle counterclockwise until 0 mA is reached.
- Turn on the temperature regulator and the laser diode power supply.
- The laser diode current adjustment knob is slowly rotated clockwise until the input current is set to 25 mA – 30 mA. The laser diode should start generating.
- Place the optical power meter OGM in the beam path as close to the optical beam output as possible. All of the radiation needs to be collected in the optical power meter detector.



**Fig. 18:** Laser diode optical power dependence on input current measurement setup.

- Again set the laser diode input current to 0 mA. Set the power meter zero point.

- Measure the optical output power and the laser diode voltage dependence on the laser diode input current at the laser diode temperature 20 °C with 2 mA steps of the input current from 0 mA to 40 mA,
- Measure the optical output power dependence on the laser diode input current (**do not measure the laser diode voltage**) at the laser diode temperatures 25 °C, 30 °C, 35 °C, 40 °C and 45 °C.
- Graphically depict the optical output power of the laser diode dependence on input current at various temperatures. The laser diode voltage dependence on the input current. Explain the dependencies.
- Calculate and determine the conversion coefficient of the laser diode electric power to the optical output power dependence on the input current:

$$\eta = P_o/(UI). \quad (1)$$

- To determine the threshold input current, one needs to determine the point at which a straight-line fit to the linear portion of the curve of the optical output power dependence on the input current above the threshold intercepts the straight-line fit to the linear portion of the curve below the threshold.

Determine the threshold input current dependence on the laser diode temperature.

- Calculate the external differential quantum efficiency for the linear part of optical output power dependence on the laser diode input current when the current exceeds threshold value using the following expression:

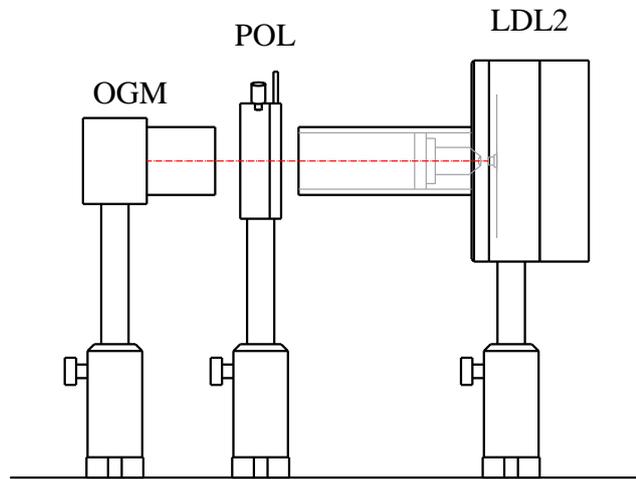
$$\eta_{ex} = \frac{d(P_o\lambda/hc)}{d(I/e)}, \quad (2)$$

where  $\lambda$  is the wavelength,  $h$  – Planck constant,  $c$  – the speed of the light,  $e$  – the electron charge.

Determine external differential quantum efficiency dependence on laser diode temperature.

### **3. Measurement of the laser diode beam polarization degree dependence on input current.**

- Set 20 °C temperature at the laser diode power and cooling unit. Turn the laser diode current adjustment knob counter-clockwise until 0 mA.
- The polarizer POL is placed between the laser diode power and cooling unit LIDL2 and the optical power meter OGM.



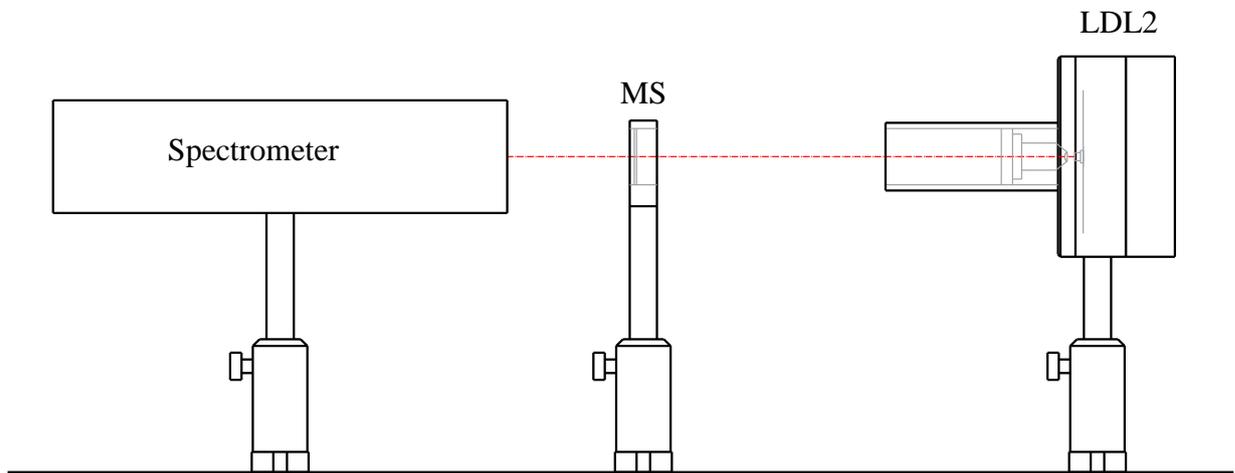
**Fig. 19:** Measurement setup of the laser diode beam polarization degree dependence on input current.

- Set the laser diode input current to 25 mA – 30 mA.
- When rotating the polarizer with 5° steps from 0° to 355°, measure laser diode optical output power dependence on the polarizer rotation angle.
- More accurately measure minimum ( $P_{min}$ ) and maximum ( $P_{max}$ ) power of optical output which has passed the polarizer and determine the corresponding polarizer rotation positions.
- Graphically depict the optical output power dependence on the polarizer rotation angle in polar coordinate system.
- Rotate the polarizer to position where the optical output power is maximal.
- Measure the optical output power dependence on the laser diode current with 2 mA step from 0 mA to 40 mA.
- Rotate the polarizer position where the optical output power is minimal.
- Measure the optical output power dependence on the laser diode current with 2 mA step from 0 mA to 40 mA.
- From measured data determine the polarization degree  $K_p$  dependence on the laser diode current:

$$K_p = (P_{max} - P_{min}) / (P_{max} + P_{min}). \quad (3)$$

#### **4. Measurement of the laser diode optical output spectrum central wavelength dependence on laser diode temperature.**

- Set the laser diode input current between 25 mA and 30 mA.
- Set the temperature in the laser diode power and cooling block to 20 °C.
- Direct the laser diode optical output through the optical diffuser MS to the spectrometer entrance slit.



**Fig. 20:** Measurement setup of the laser diode optical output spectrum central wavelength dependence on the laser diode temperature.

- Measure the laser diode optical output spectrum peak dependence on the laser diode temperature with 2-3 °C step form 20 °C to 45 °C. The spectrometer integration time during the measurement needs to be such that the measured signal intensity would be between 8000 and 16000 units. If necessary, place an optical filter between the spectrometer and the diffuser.
- Depict measurement results graphically.

**Literature:**

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