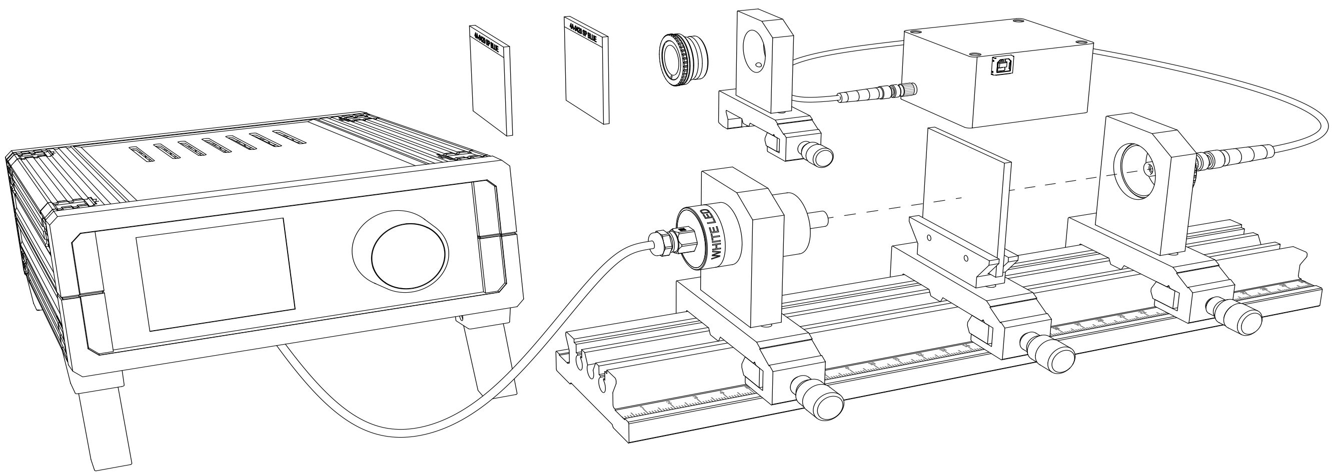
Photonik
Ingenieurbüro
Dr. Walter Luhs

PE-1400 Spectrometer



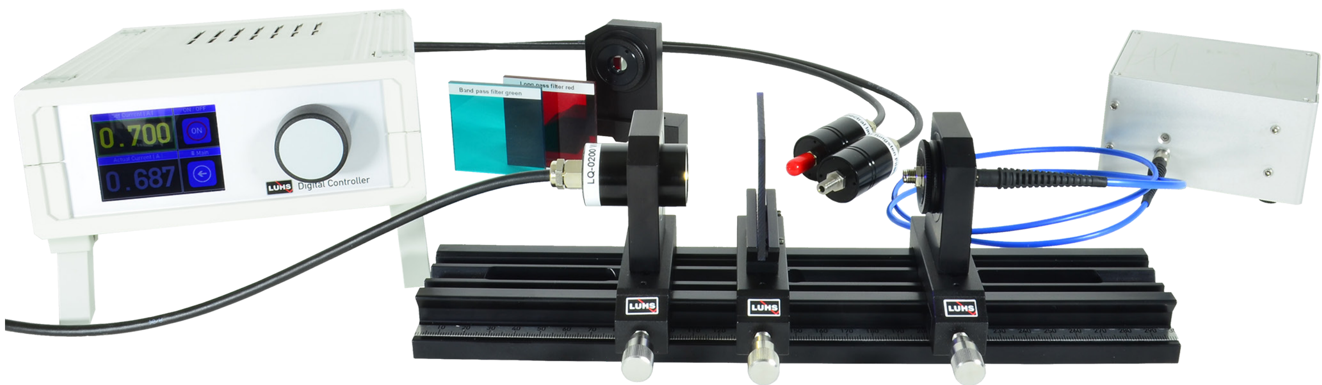


Table of Contents
Introduction
Theory
Experimental Setup
Measurements

Table of Contents

1.0 Introduction

An optical spectrometer or simply spectrometer is an apparatus to record the intensity distribution as a function of the wavelength of a light source. Spectrometers played and still play an important role in a variety of applications. The emitted radiation from a source provides information about the atomic and molecular energy structure. It is a keyhole into the fascinating world of quantum mechanical and optical processes.
The first spectrometer used prisms to achieve the required spatial separation of the incoming light. By using a precise goniometer, the exit angle is measured and related to the wavelength. The emerging optical gratings made the spectrometer more precise and enhanced the resolution significantly. Another step towards more convenient use can be seen in the development of two dimensional CCD chips allowing the real time measurement and data storage with a computer. Last, but not least the optical fibre made it very convenient to bring the light to the spectrometer.
Today's spectrometers are available in a size of half a brick providing a spectral range from 200 to 1200 nm with a resolution of 1 nm. Such a spectrometer is part of this experiment to train the students in the application of the most important optical measuring apparatus.

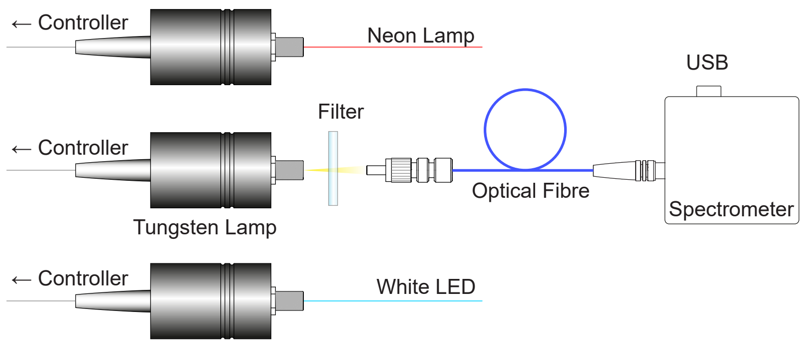


Fig. 1: Principle idea of the experiment

Within the scope of the experiments three different light sources are used and characterised by the spectrometer. The spectra of a white light, a Neon spectral lamp and an incandescent lamp are compared and discussed. Four optical filter are placed in the front of the light sources and the transmission spectrum recorded.
The light entrance of the spectrometer is formed by the entry slit with a width designed for the intended use. It is typically 50 µm to achieve a resolution of 1 nm in a range of 200-1200 nm. Of course, the resolution depends on further parameters like the internal geometry and the grating constant. The slit is located directly behind the fibre panel jack and is illuminated directly or by the attached fibre. The provided sample lamps are equipped with matching fibre jacks to allow the direct connection with the fibre. To learn about the important absorption measurement a set of different filters are used. Finally, a Neon spectral lamp is provided which emits a number of lines with precisely known wavelengths. The comparison of the spectrometer reading to these lines allows the calibration of the spectrometer.

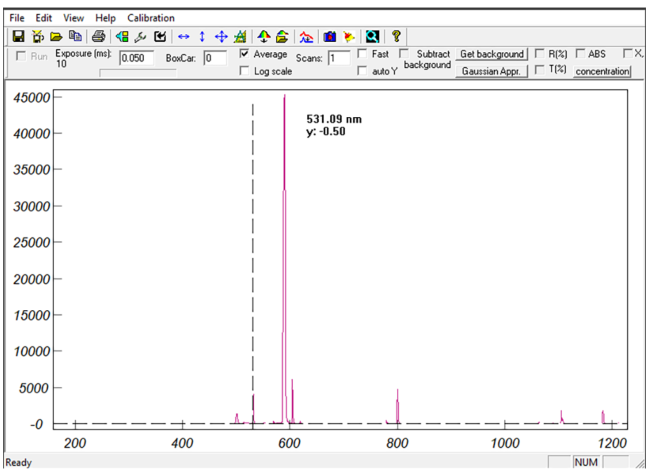


Fig. 2: Typical software screen of an USB spectrometer.

The spectrum is displayed almost real time and can be stored as a picture or as a data file on a USB stick. Such a data file can be read by a sheet related software like Excel and processed further.
Although the software provides a rich variety of tools to refine the measured data, we recommend just to use the capability to store the data and make use of a sheet oriented common software like Excel.
Here the students can control and see the process of the data and create graphs as desired.

2.0 Description of the components

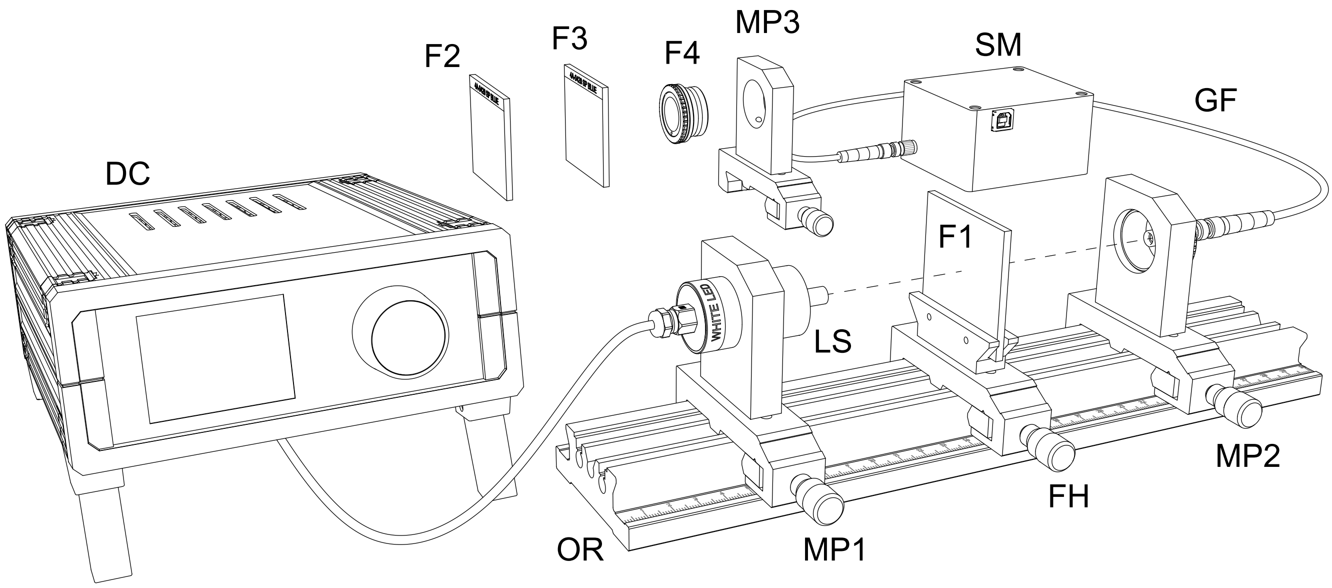


Fig. 3: Setup of the PE-1400 Spectrometer Experiment

Fig. 4: Mounting plate (MP1-MP3) on carrier 20 mm

This frequently used component is ideal to accommodate parts with a diameter of 25 mm where it is kept in position by three spring loaded steel balls. Especially C25 mounts having a click groove are firmly pulled into the mounting plate due to the smartly chosen geometry. The mounting plate is mounted onto a 20 mm wide carrier.

Fig. 5: Filter plate holder

This filter plate holder is designed to accommodate standard optical filter plates with a thickness of 3 mm, a width of 50 mm and a height of 50 mm. The plate is held in position by two grub screws which have spring loaded balls at their tips.

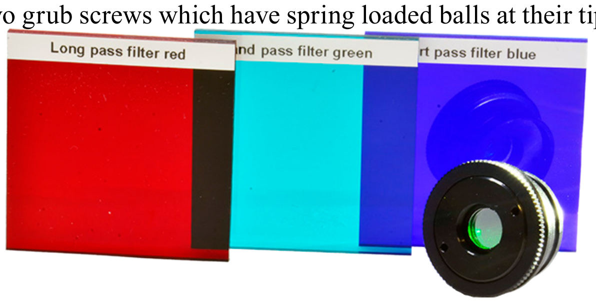


Fig. 6: Set of four filter (F1, F2, F3, F4)

The Fig. 6 shows the filters used in the experiment. From left to right: filter F1, filter F2 and filter F3.
In front of the filter 3 the narrow laser line (532 nm) filter F4 is shown in a C25 mount. This filter is inserted into one of the mounting plates (MP), whereas the other filter are accommodated in the filter plate holder (FH)

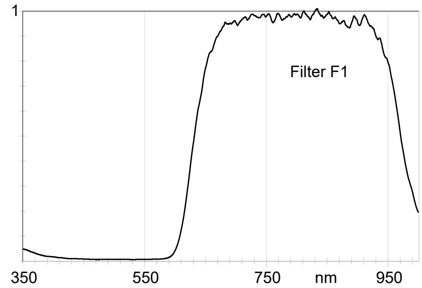


Fig. 7: Filter F1 transmission curve

This filter has a size of 50x50 mm and is designed to pass the blue light in the visible range and blocks the red part of the visible spectrum.

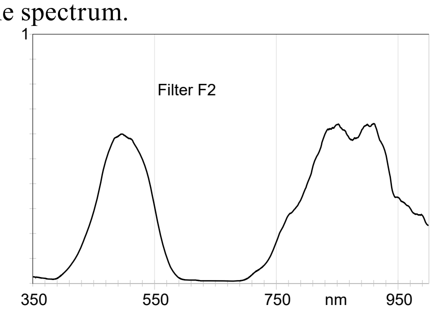


Fig. 8: Filter F2 spectral transmission

The filter F2 has a size of 50x50 mm and is designed to pass the blue green and blocks the red part of the visible spectrum.

Experimental Setup

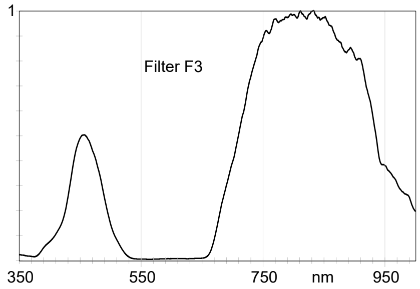


Fig. 9: Filter F3 transmission curve

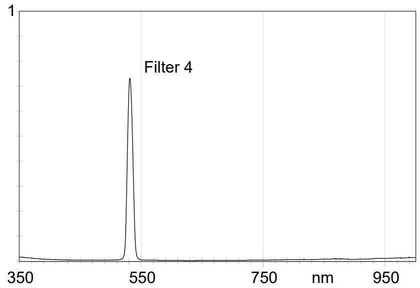


Fig. 10: Laser line Filter F4

The filter F3 is named as red long pass filter because it passes the red and near infrared part of the spectrum and blocks the range below 600 nm. A totally different behaviour is shown by the filter F4 which is a so called interference or laser line filter. The designed behaviour is achieved by coating a glass plate with different layers. Such a filter is useful in spectroscopy in a narrow spectral range without distortion of undesired light. The filter is mounted into a C25 holder (see Fig. 14) and can be inserted into a mounting plate (Fig. 4).

Fig. 11: Tungsten filament white light source

Three different light sources are provided:

White LED
Tungsten Filament Lamp
Neon Lamp

Each lamp is mounted into a 25 mm housing and connected to the controller (DC-0270 Filament and LED lamp controller) via a 15 sub D connector. The connector contains an EEPROM which holds the operating parameters of the lamp device. Once connected to the controller and powered up, these informations are read and the controller provides the related operation power and displays

Fig. 12: Fibre coupled spectrometer 200 - 1200 nm, USB

The spectral range of the spectrometer covers 200 to 1200 nm with a resolution of 1 nm. The entrance slit is 50 µm wide and the provided fibre has a core diameter of 600 µm. The spectrometer has a FSMA fibre jack and the data are available via the USB bus.

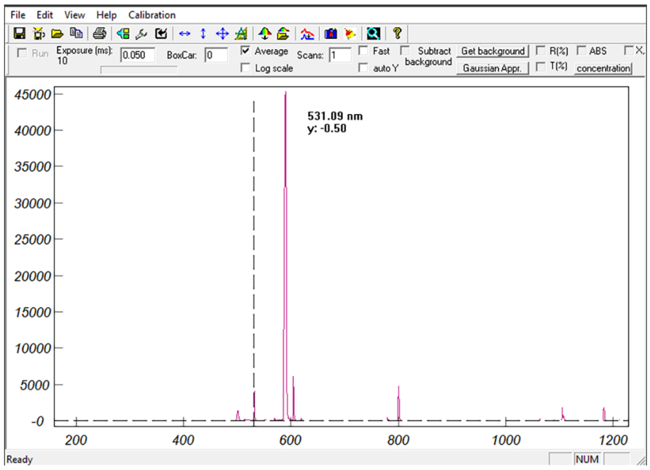


Fig. 13: Spectrometer software

The spectrometer comes with the USB cable and Windows compatible software. The spectrum is displayed in almost real time and can be stored as a picture or as a data file.

Fig. 14: Fibre jacket in C25 mount

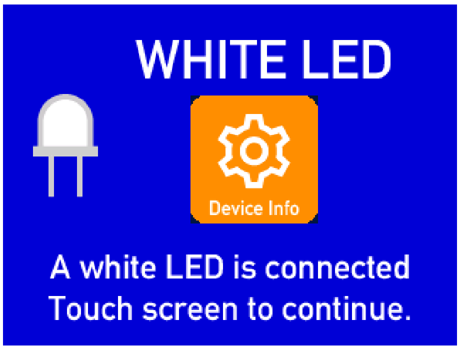
A FSMA fibre coupler is mounted into a C25 mount to enable the use of optical fibre with C25 mounting plates.

Fig. 15: DC-0270 Filament and LED controller

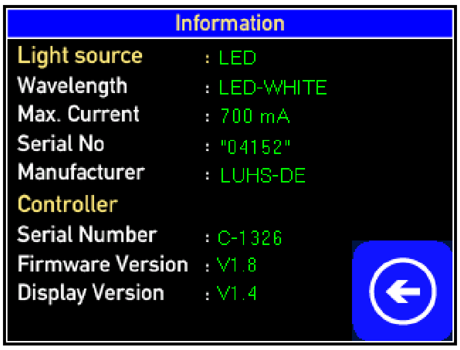
This microprocessor operated device contains a precise current controller. A touch panel display allows in conjunction with the digital knob the selection and setting of the parameters for the attached LED or lamp. The controller reads the operation values of the connected lamp from the EEPROM located inside its connector. The device comes with a 230 VAC / 12 VDC wall plug power supply.

When the external 12 V is applied and switched on, the controller starts displaying the screen as shown on the left.
The processor tries to read the content of the EEPROM of the attached light source.

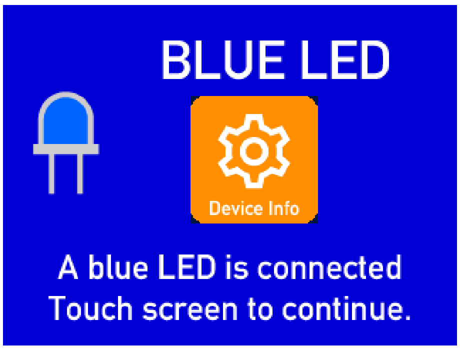
If no light source has been connected, this error screen is displayed.



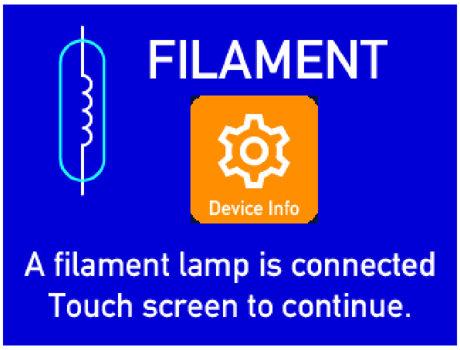
In case the white LED has been connected, the processor displays the page for this lamp. After touching the “Device Info” button the information of the related EEPROM is displayed in the next page.
After touching any other area of the screen brings up the control page.



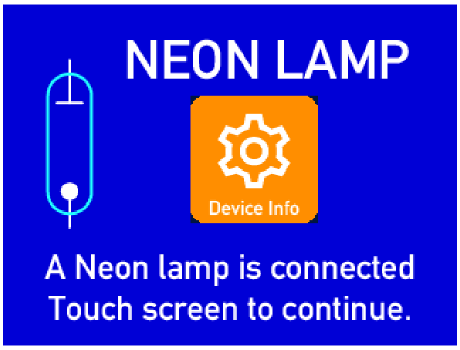
Display of the properties of the connected light source and the controller.



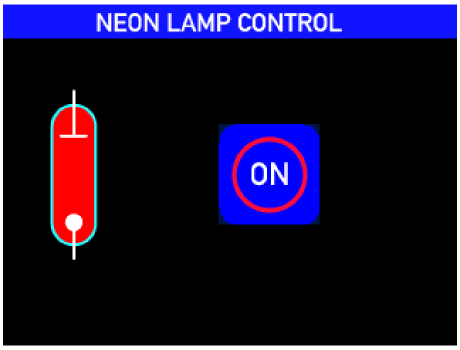
If the blue LED is connected, the processor selects and displays the related screen. After touching the “Device Info” button the information of the related EEPROM is displayed on an extra page.
After touching any other area of the screen brings up the control page.



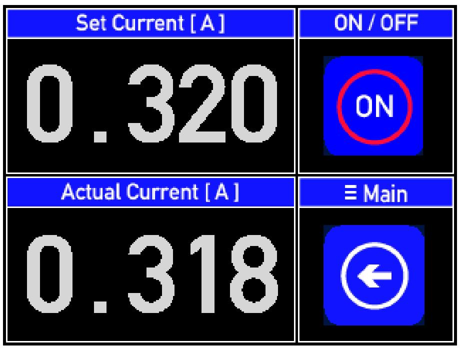
In case the tungsten filament lamp is connected the related screen is displayed. After touching the “Device Info” button the information of the related EEPROM is displayed on an extra page.
After touching any other area of the screen brings up the control page.



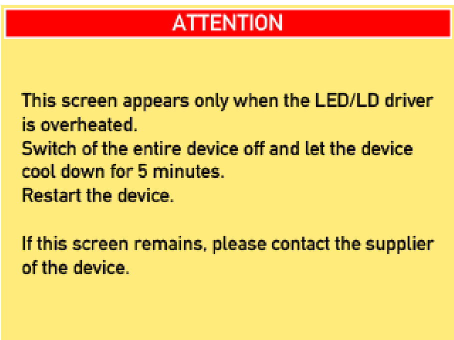
In case the tungsten filament lamp is connected the related screen is displayed. After touching the “Device Info” button the information of the related EEPROM is displayed on an extra page.
After touching any other area of the screen brings up the control page.



The control screen of the Neon lamp provides an ON/OFF button to switch the Neon lamp accordingly.



All lamps, except the Neon lamp, have the same control page to set and read the desired current. The maximum current of the connected lamp is read from the EEPROM and the processor limits the current to this value. To set the desired current, touch into the number field which will be highlighted and turn the set knob until the desired value appears. Touching again the field deactivates the set knob.



This screen you normally should never see. It appears only when the chip of the injection current controller is over heated.
Switch off the device, wait a couple of minutes and try again. If the error persists please contact your nearest dealer

3.0 Measurements

3.1 Emission spectrum of the provided light sources

3.1.1 White light LED

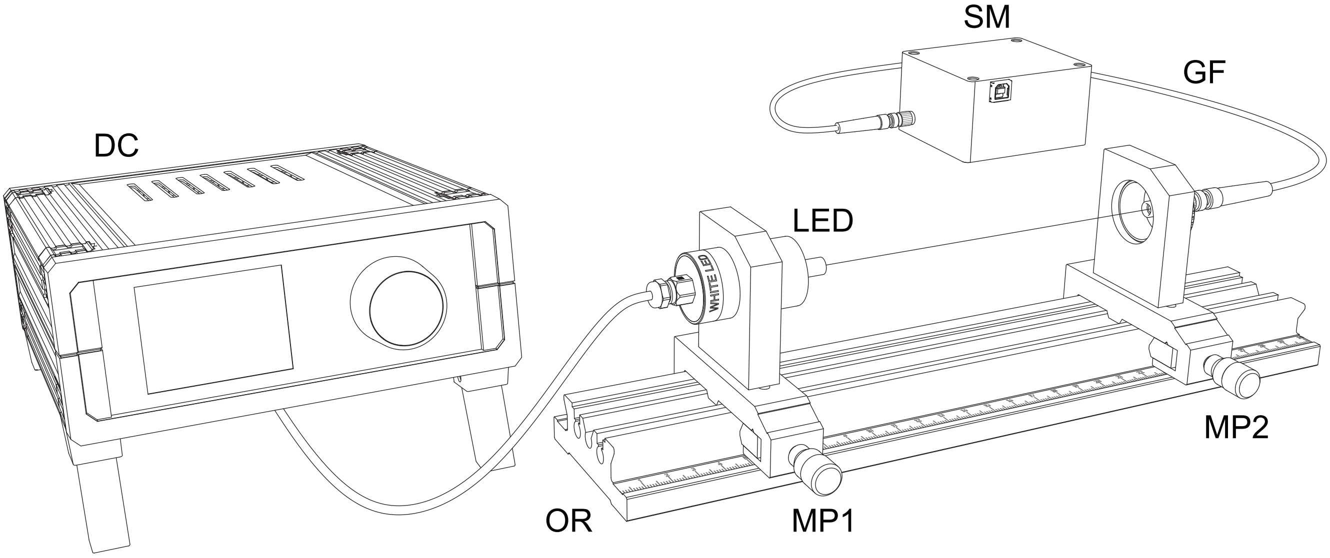


Fig. 16: Setup to characterise the white light LED

Two mounting plates (MP1) and (MP2) are placed onto the optical rail (OR) as shown above. The LED is inserted into the mounting plate (MP1). The spring loaded balls of the mounting plate keep the LED in position. One end of the optical glass fibre (GF) is attached to the click mount which is inserted into the mounting plate (MP2) and the other end is connected to the spectrometer (SM). The spectrometer software is started and by setting the current of the LED by the controller in such a way, that the amplitude of the spectrum is not clipped. The Fig. 17 has been created following the steps:

→ Save the spectrum as text file.
→ Use Microsoft Excel (or any other sheet oriented software)
→ Import the text file of the spectrum as data.
→ Insert a scatter graph and select the data column accordingly.
→ Modify the generated graph to your convenience.

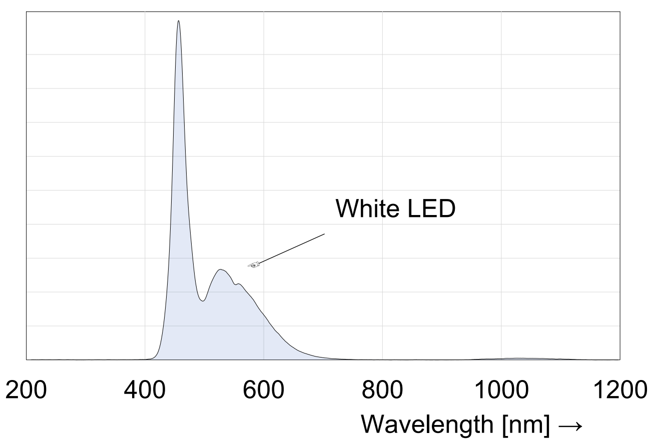


Fig. 17: Measured spectrum of the white light lamp

Measurements

3.1.2 Tungsten Filament Lamp

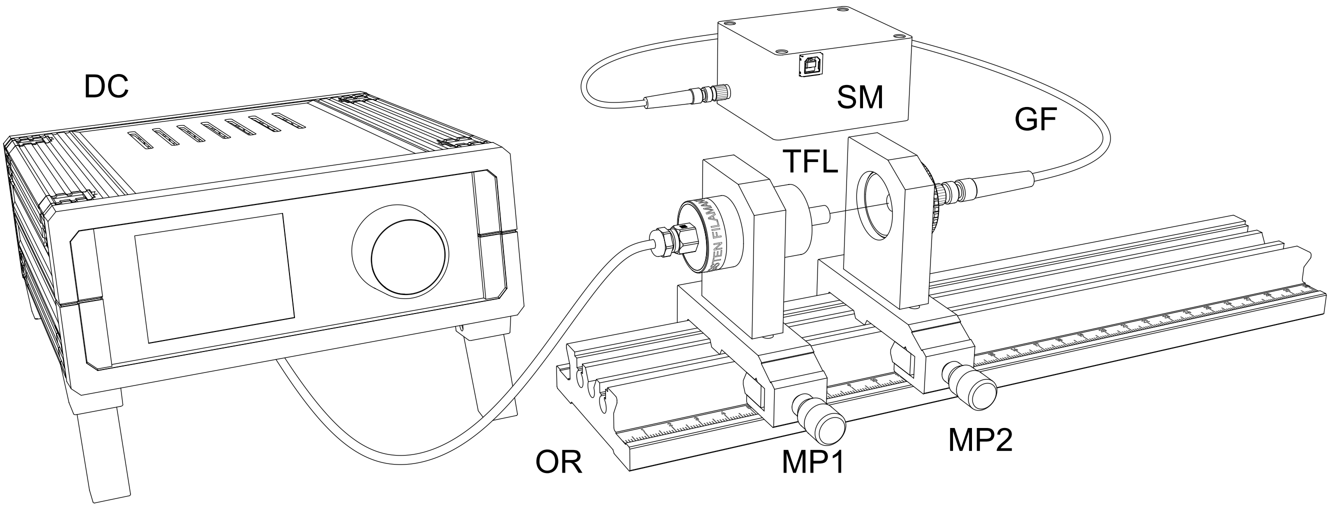


Fig. 18: Setup for the measurements with the tungsten filament lamp

Instead of the white light LED we place the tungsten filament lamp (TFL) into the MP1 mount. Since the light intensity is less than that of the white LED, we move the glass fibre with its holder (MP2) closer to the TFL. Following the same procedure of data handling we create the graph as shown in Fig. 19.

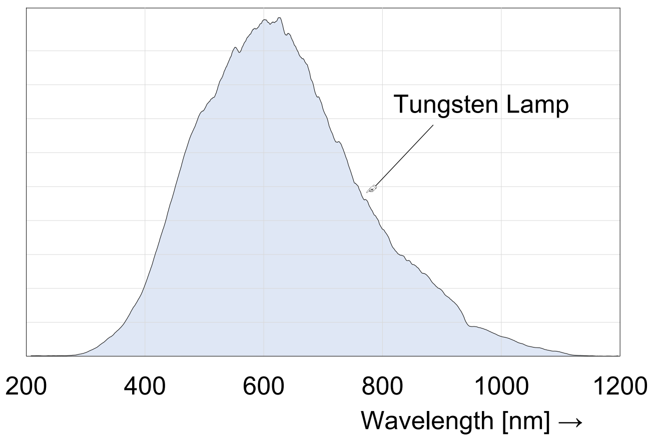


Fig. 19: Measured spectrum of the tungsten filament lamp

In first approximation we can consider the TFL as black body radiator. However the curve shows above 800 nm a deviant behaviour. This is caused by the spectral sensitivity of the CCD array of the spectrometer, which is dropping to higher wavelengths.

Measurements

3.1.3 Neon Spectral Lamp

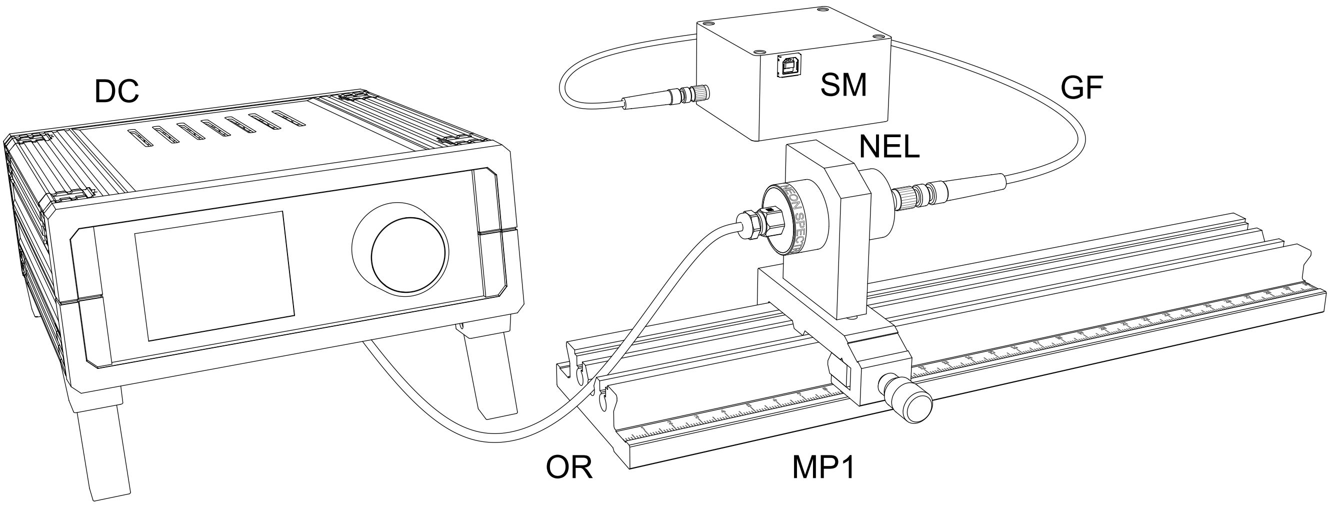


Fig. 20: Recording the spectral lines of the Neon lamp

Since the intensity of the Neon lamp (NEL) is comparatively low, we connect the glass fibre (GF) of the spectrometer directly to the Neon lamp. The emission wavelengths of the Neon are quite well known and can be used for the calibration of the spectrometer.

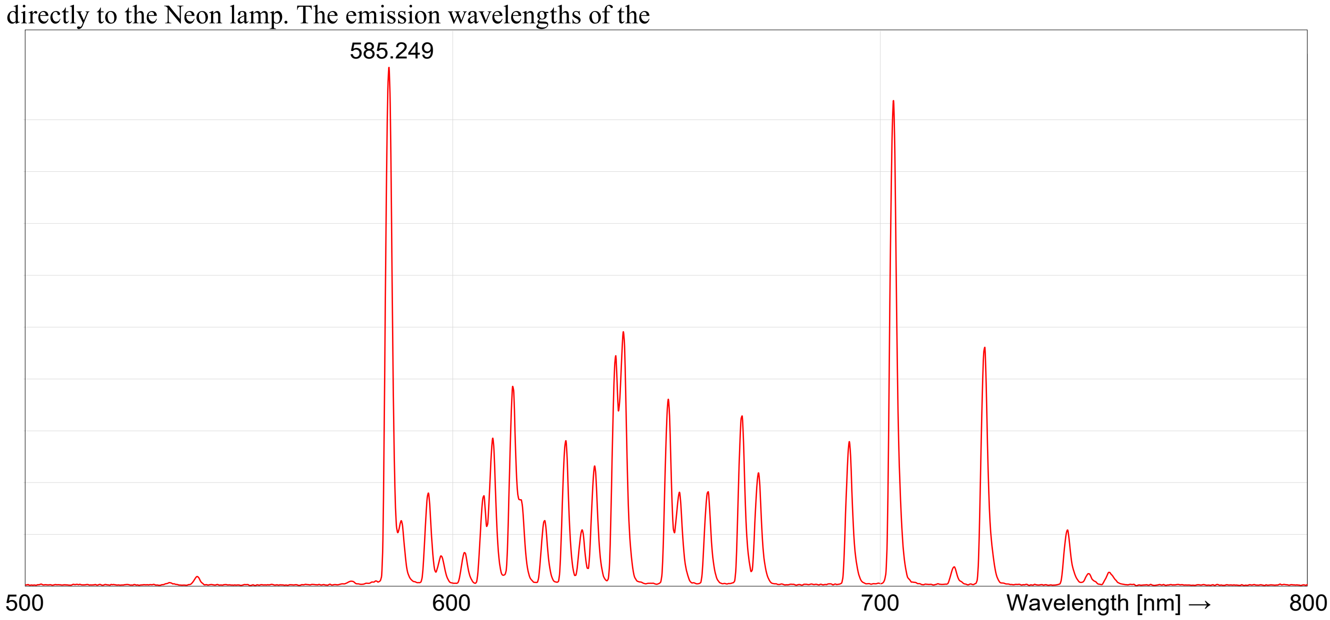


Fig. 21: Measured line spectrum of the Neon lamp

The Fig. 21 shows the measured spectrum of the Neon lamp. The first dominant peak should have the wavelength of 585.249 nm as per the Table 1. All other peaks can be assigned as well.

585.249	588.189	594.483	597.553	603.000	607.434
609.616	614.306	616.359	621.728	626.649	630.479
633.443	638.299	640.225	650.653	653.288	659.895
667.828	671.704	692.947	703.241	717.394	724.517
743.890					

Table 1: Known emission wavelengths of the Ne atoms

The data of the spectrometer are actually the intensity *I(n)* per pixel *n* of the CCD linear array. Typically the equation for the wavelength as function of the pixel n is given as:

$$\lambda = \alpha \cdot n + \beta \cdot n^2 + \gamma \cdot n^3$$

The data file of the spectrometer contains the pixel number and the related intensity. Taking the pixel number of the maximum of each peak for the known wavelength and do this for all peaks we can draw a graph pixel number versus wavelength. Performing a least square fit with a polynomial approximation of third order we get the values for the coefficients α, β, and γ. These values are stored to the spectrometer's EEPROM to get a calibrated spectrometer.

Measurements

3.2 Measuring Optical Filter

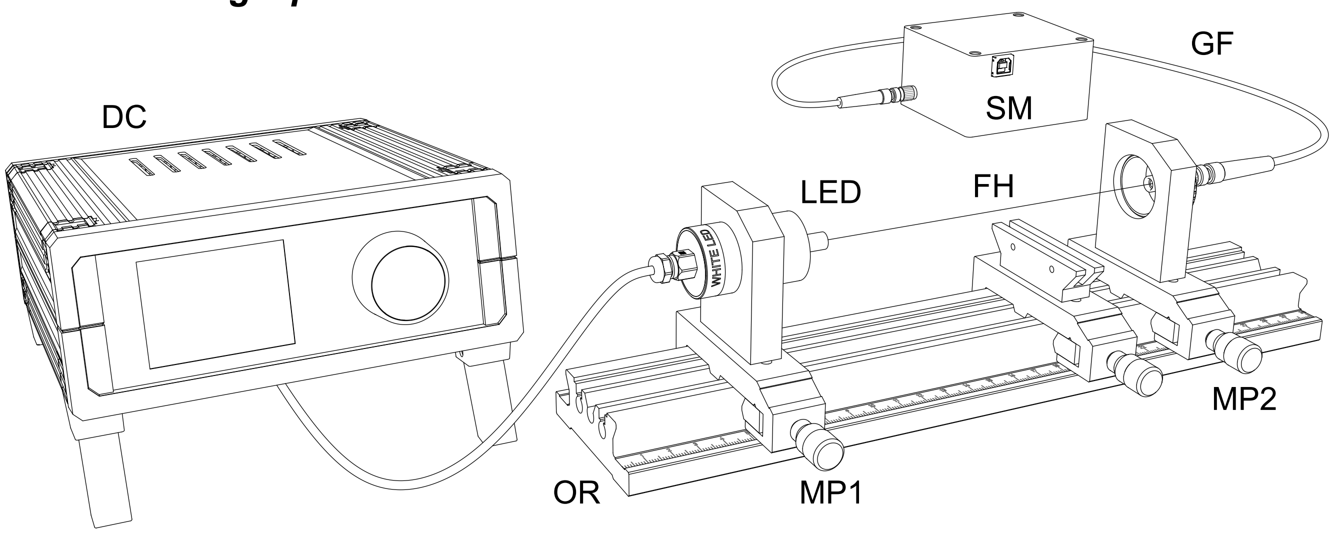


Fig. 22: Step 1 to measure the transmission or absorption of an optical filter

The measurement of either the transmission or absorption is a two step process since we need to know $I_0(\lambda)$ and $I(\lambda)$ to calculate the transmission T:

$$T(\lambda) = \frac{I(\lambda)}{I_0(\lambda)}$$

With the setup of Fig. 22 we measure the spectrum $I_0(\lambda)$.

Without changing anything, we place the filter to be measured into the holder FH

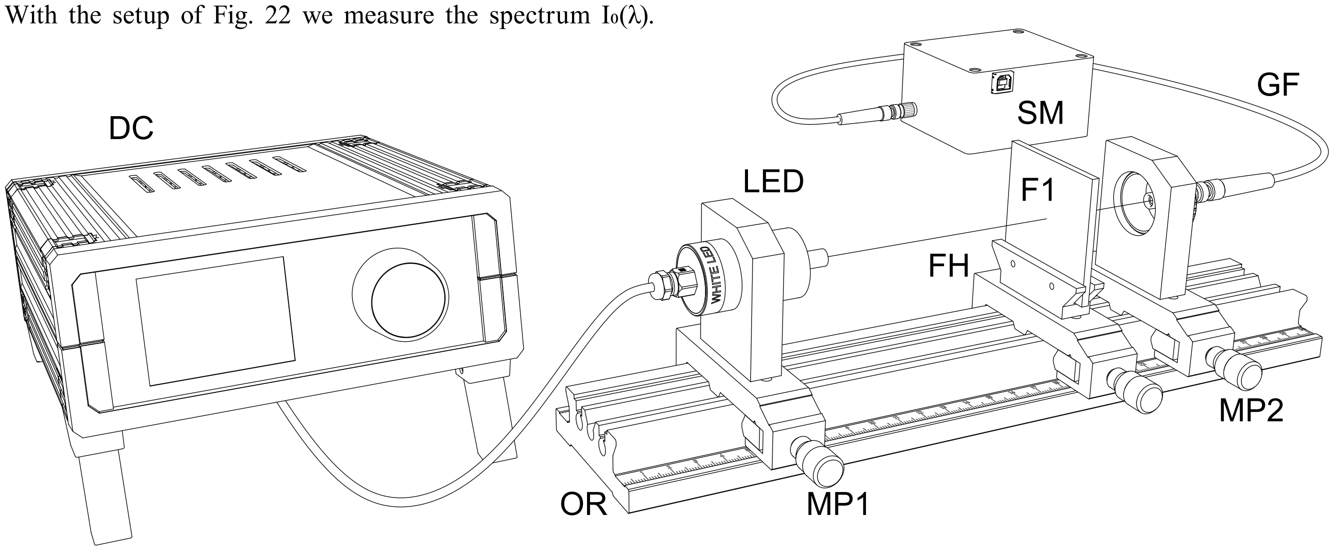


Fig. 23: Step2 to measure the characteristic of the inserted filter

With the inserted filter we take the spectrum $I(\lambda)$. The transmission can be obtained in two ways. Either the software of the spectrometer is used to do the job, or we save both measurements as data file and use Excel to calculate $I(\lambda)/I_0(\lambda)$. It should be noted, that good measurements can only be obtained, if the used light source provides a suitable range of wavelengths. If $I_0(\lambda)$ is close to zero the transmission curve becomes noisy. Therefore only those values shall be used for which the light source provides decent intensities.

3.2.1 Long Pass Filter Red (F1)

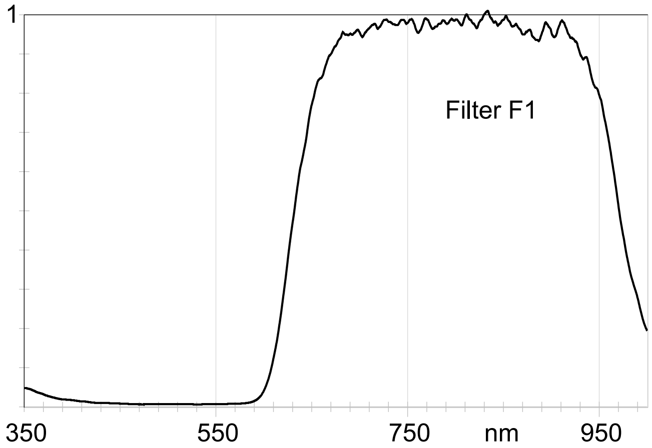


Fig. 24: Measured curve of filter F1, generated with Excel

3.2.2 Band Pass Filter Green (F2)

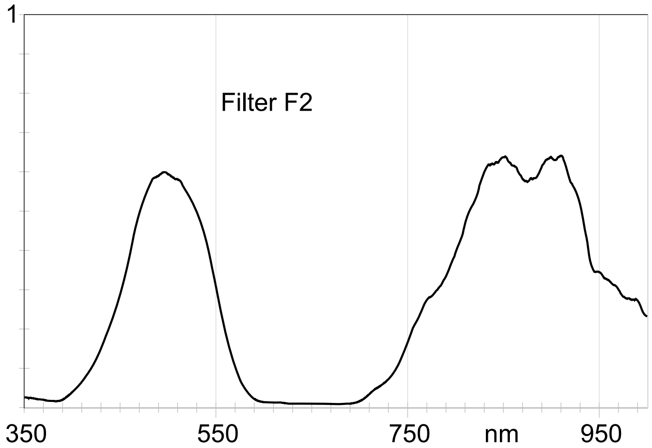


Fig. 25: Measured curve of filter F2, generated with Excel

3.2.3 Short Pass Filter Blue (F3)

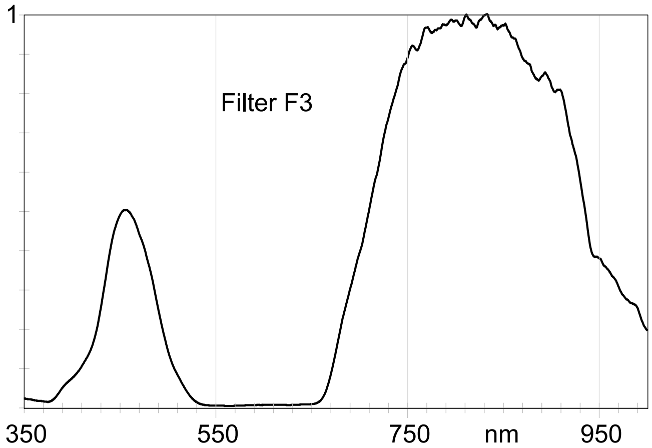


Fig. 26: Measured curve of filter F3, generated with Excel

3.2.4 Line Filter Green (F4)

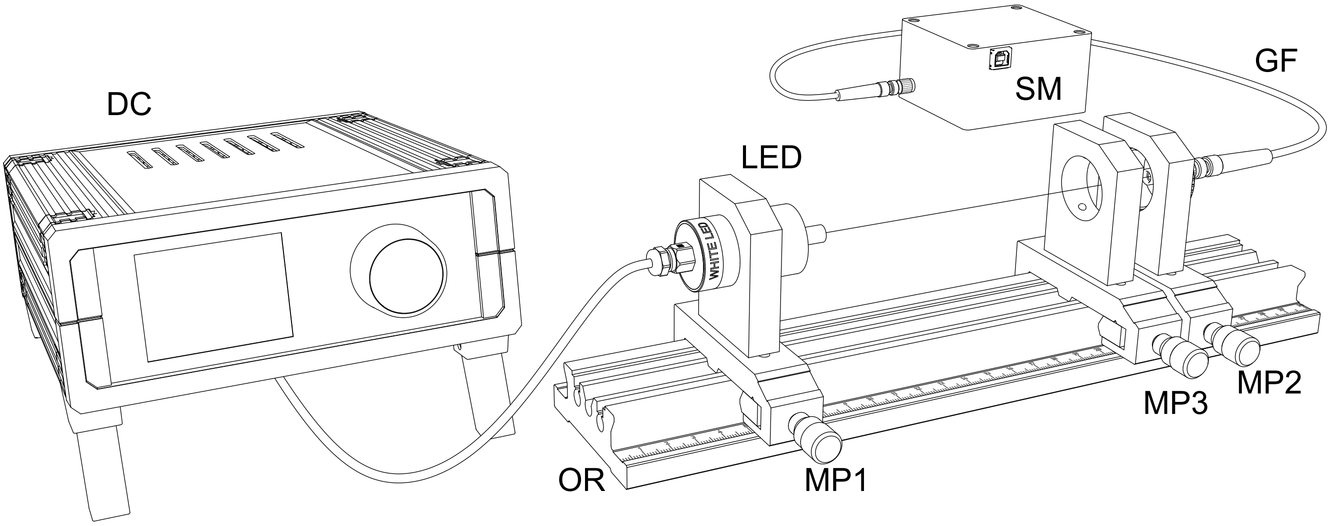


Fig. 27: Measurement of $I_0(\lambda)$

In the same way as we proceeded with the previous measurements with the filter plates we are adding an extra mounting plate (MP3) onto the rail to accommodate the filter (F4). It is mounted into a click mount, which can be inserted into this mounting plate (MP3). One starts with the recording of the $I_0(\lambda)$ spectrum.

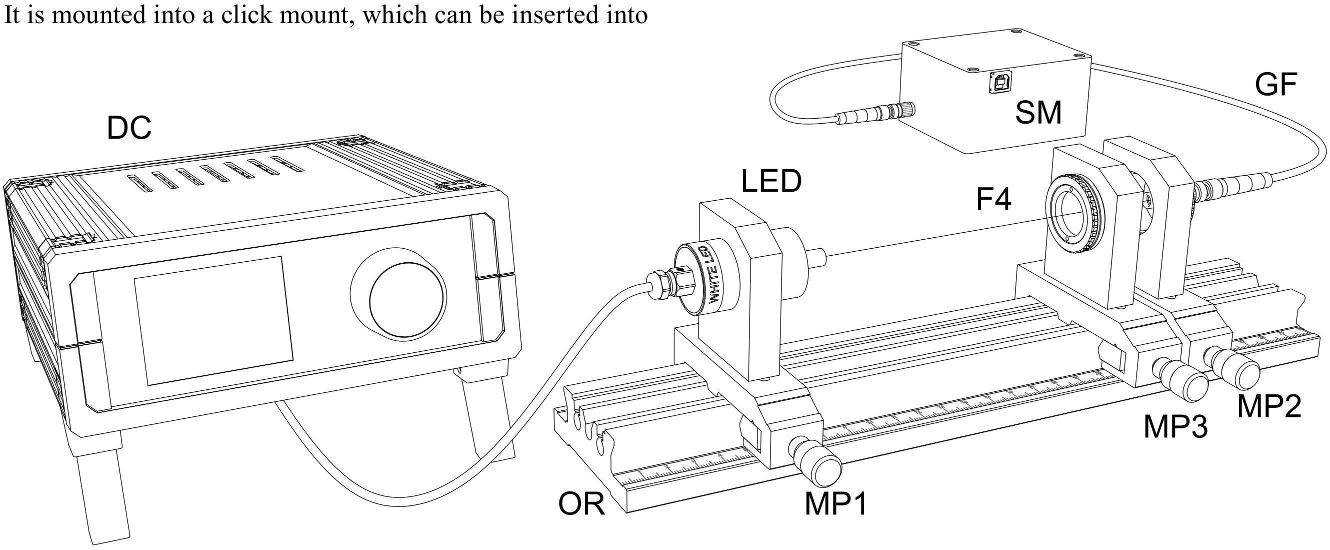


Fig. 28: Measurement of $I(\lambda)$ with filter F4

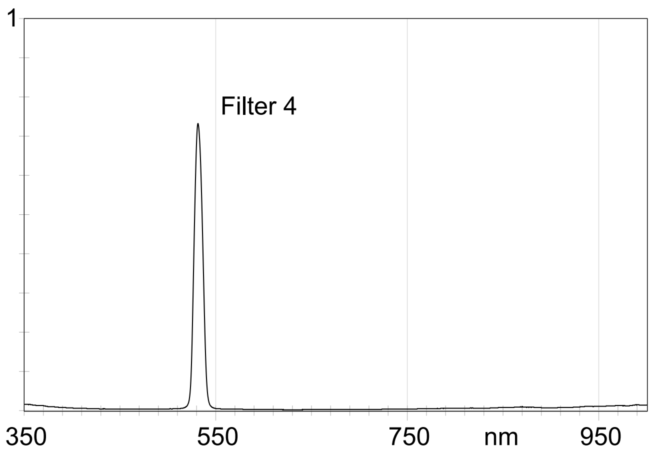


Fig. 29: Result of the measurement calculated and treated with Excel