CHARACTERIZATION OF OPTICAL EMITTERS

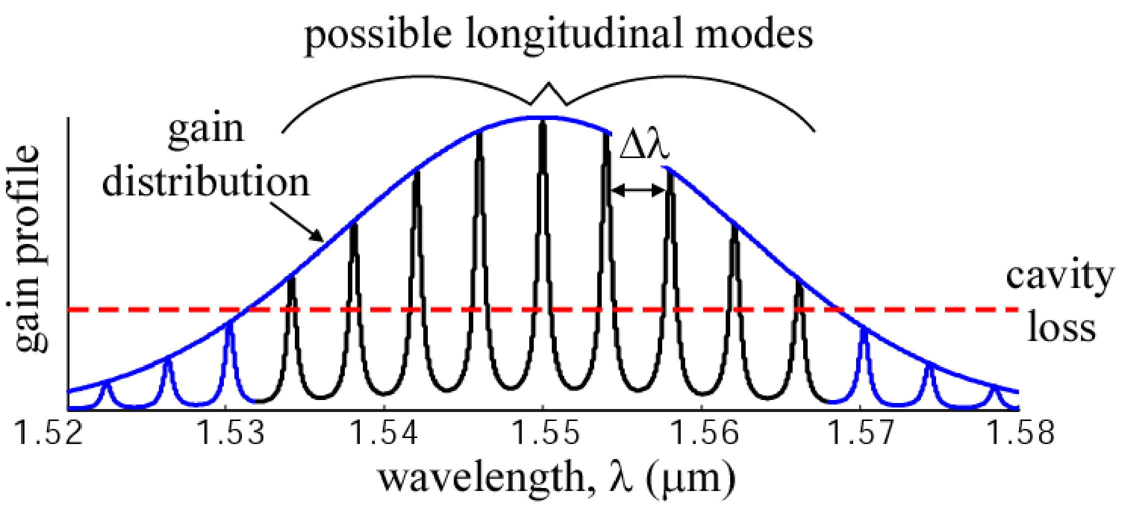
The aim of this practice is to measure properties of different emitters: Light emitting diode, He-Ne laser and semiconductor lasers.

Characteristic of a light emitting diode:
It is based on spontaneous emission
The emitted light is incoherent
Large spectral width
Low directional
Low power output

Characteristic of a laser
It is based on stimulated emission
The emitted light is coherent
Narrow spectral width
High directional
High power output

To make a laser, it is necessary to obtain population inversion and build a resonant cavity

By putting the LED in an optically resonant cavity, the device can act as a laser.
Lasing occurs if the forward current is so large that population inversion takes place.
The current at which the laser action starts is called the threshold current. For currents below the threshold the device behaves like a LED.
Typical semiconductor laser spectra can be seen in the next figure. The multiple peaks are due to the resonant cavity



The optical cavity excites various longitudinal modes.
Modes with gain above the cavity loss have potential to lase.
Gain distribution depends on the spontaneous emission band.
Wavelength width of the individual longitudinal modes depends on the reflectivity of the end faces.

Wavelength separation of the modes depends on the length of the cavity

The wavelength at each peak in the spectra of the laser is:

$$\lambda_m = \frac{2nL}{m}$$

Where
L = cavity length
n = refractive index of the material in the cavity
m = integer number

The frequency can be computed from the wavelength

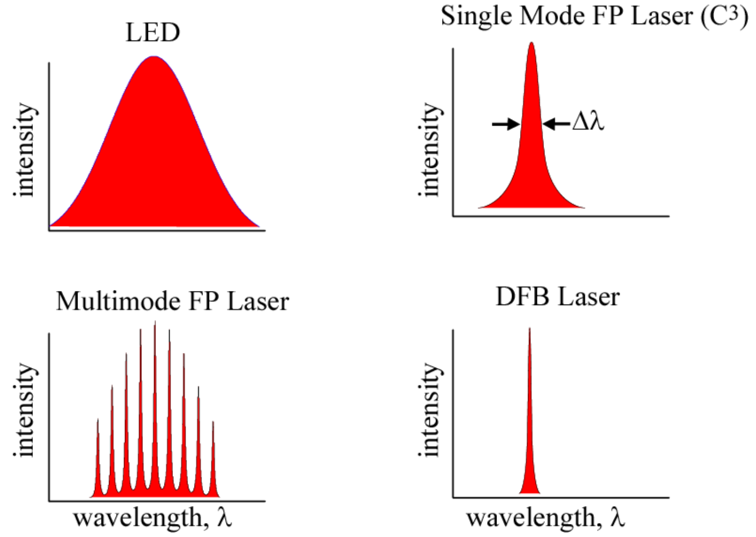
$$f_m = \frac{c}{2nL} m$$

Where
c = speed of the light in the vacuum

From the wavelength or frequency of two consecutive peaks can be deduced the cavity length:

$$\Delta f = \frac{c}{2nL}$$

Comparison between LED spectra and semiconductor laser spectra:



In these spectra, the spectral width can be measured from the FWHM (full width half maximum) which is the spectral width between the two wavelengths where the optical power is the half of the maximum optical power.

An optical spectrum analyzer can be used for analyzing optical spectra in the 600 to 1600 nm wavelength band. The input section can be used to measure the spectra of LDs and LEDs.

Material

He-Ne laser
Red semiconductor laser
1310 and 1550 nm semiconductor lasers
Red Light emitting diode
850 nm Light emitting diode
Coupling laser-fiber
Short multimode graded-index fiber
Short plastic optical fiber
Optical spectrum analyzer

Characterization of the He-Ne laser

- Couple the light from the laser into the short fiber
- Connect the other end of the short fiber to the optical spectrum analyzer
- Measure the optical spectra with the optical spectrum analyzer by selecting
    - o the scale (logarithmic or lineal)
    - o the sensitivity (high or not)
    - o the averaging (1, 10 ,100)
    - o the reference level
    - o Start wavelength
    - o Stop wavelength
    - o Resolution

From the recorded spectra, measure the next parameters:

Peak wavelength	
Optical power	
Wavelenght 1 (half power)	
Wavelenght 2 (half power)	
FWHM	

Characterization of the red semiconductor laser

- Couple the light from the laser into the short fibre.
- Connect the other end of the short fibre to the optical spectrum analyzer
- Measure the optical spectra with the optical spectrum analyzer by selecting the same items as before

From the recorded spectra, measure the next parameters:

Peak wavelength	
Optical power	
Wavelenght 1 (half power)	
Wavelenght 2 (half power)	
FWHM	

Characterization of the 1310 nm semiconductor laser

- Connect the output connector of the laser with the short fibre
- Connect the other end of the short fibre to the optical spectrum analyzer
- Measure the optical spectra with the optical spectrum analyzer by selecting the same items as before

From the recorded spectra, measure the next parameters:

Peak wavelength	
Optical power	
Wavelength 1 (half power) (envelope)	
Wavelenght 2 (half power) (envelope)	
FWHM (envelope)	
Wavelength 1 (half power) (individual peak)	
Wavelength 2 (half power) (individual peak)	
FWHM (individual peak)	

Calculate the cavity length from the wavelength of two consecutive peaks from the next formula

$$\lambda_m = \frac{2nL}{m} \qquad f_m = \frac{c}{2nL}m \qquad \Delta f = \frac{c}{2nL}$$

Assume that
Speed of the light in the vacuum: c = 300,000,000 m/s
Refractive index of the cavity: n = 3.5

Wavelength peak 1	
Wavelength peak 2	
Frequency peak 1	
Frequency peak 2	
Cavity length	

Characterization of the 1550 nm semiconductor laser

- Connect the output connector of the laser with the short fibre
- Connect the other end of the short fibre to the optical spectrum analyzer
- Measure the optical spectra with the optical spectrum analyzer by selecting the same items as before

From the recorded spectra, measure the next parameters:

Peak wavelength	
Optical power	
Wavelength 1 (half power) (envelope)	
Wavelenght 2 (half power) (envelope)	
FWHM (envelope)	
Wavelength 1 (half power) (individual peak)	
Wavelength 2 (half power) (individual peak)	
FWHM (individual peak)	

Calculate the cavity length from the wavelength of two consecutive peaks from the next formula

$$\lambda_m = \frac{2nL}{m} \qquad f_m = \frac{c}{2nL}m \qquad \Delta f = \frac{c}{2nL}$$

Assume that
Speed of the light in the vacuum: c = 300,000,000 m/s
Refractive index of the cavity: n = 3.5

Wavelength peak 1	
Wavelength peak 2	
Frequency peak 1	
Frequency peak 2	
Cavity length	

Characterization of the red light emitting diode

- Connect the output connector of the LED with the short plastic optical fibre
- Connect the other end of the short fibre to the optical spectrum analyzer
- Measure the optical spectra with the optical spectrum analyzer by selecting the same items as before

From the recorded spectra, measure the next parameters:

Peak wavelength	
Optical power	
Wavelenght 1 (half power)	
Wavelenght 2 (half power)	
FWHM	

Characterization of the 850 nm light emitting diode

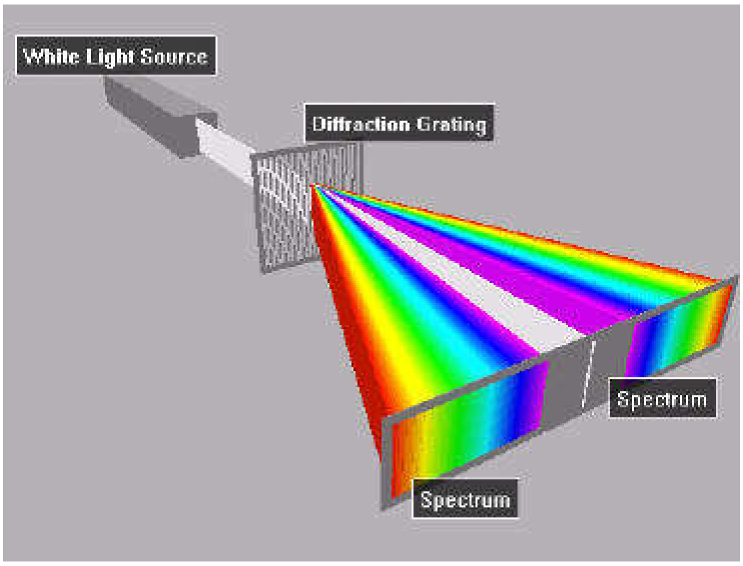
- Connect the output connector of the 850 nm LED with the short fibre
- Connect the other end of the short fibre to the optical spectrum analyzer
- Measure the optical spectra with the optical spectrum analyzer by selecting the same items as before

From the recorded spectra, measure the next parameters:

Peak wavelength	
Optical power	
Wavelenght 1 (half power)	
Wavelenght 2 (half power)	
FWHM	

Measurement of the wavelength by using grating diffraction.

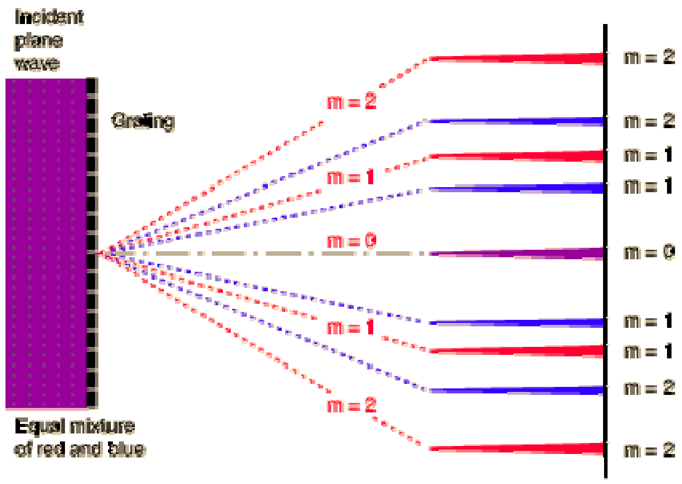
A large number of parallel, closely spaced slits constitutes a diffraction grating.
A grating separates polychromatic (or multiple wavelength) light from its component wavelengths by diffraction. Diffraction is a process where light incident to a surface is dispersed at certain angles with dimensions similar to the size of its wavelength. This diffraction angle depends on the wavelength of light (see the grating equation above). Thus, polychromatic light will have a separate diffraction angle for each individual wavelength. This difference in diffraction angle is what separates light into its component wavelengths. In a transmission grating, the diffracted light is passed through at an angle equal to the diffraction angle.



Grating equation is an expression that can be used for calculating the diffraction angle from light incident to the grating's grooved surface for a particular order, given the wavelength and angle of incidence for that light. Knowing where the light will be diffracted, the grating can be rotated to redirect the light to the desired location. The grating equation is shown below for normal incidente.

$$d\,\mathrm{sen}\theta = m\lambda$$

Where
d = separation between consecutives slits
θ = angle where the diffracted light has a maximum
m = integer number (order of diffraction)
λ = wavelength



Optical spectrum analyzer

Optical spectrum analyzers (OSA) divide a lightwave signal into its constituent wavelengths. This means that the spectral profile of the signal over a certain wavelength range can be seen. The profile is graphically displayed, with wavelength on the horizontal axis and power on the vertical axis.

Optical spectrum analyzer is made up to rotate a diffraction grating for diffracting light which is to be analyzed and irradiated to the diffraction grating, the diffracted light is thereby moved on a slit, and the optical spectrum is analyzed on the basis of the angle of rotation of the diffraction grating at the time of detection of the diffracted light across the slit.

Diffraction grating technology is the most widely used for optical spectrum analyzers in fibre testing equipment. Diffraction gratings can disperse incident light with high resolution, so that in the grating output the diffracted angle is a function of wavelength. When a beam that comprises a plurality of wavelengths cut into a diffraction grating, the beam is diffracted into sub-beams that can be focused by a lens onto a detector that receives a specific wavelength.

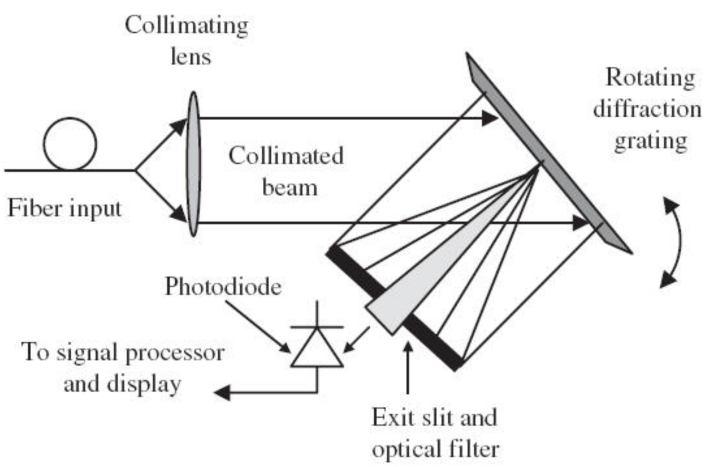


Figure 19.5. Operation of a grating-based optical spectrum analyzer.