Lab 1 –SOAI

Spectrometer (Sp) and Optical spectrum analyzer (OSA)

Objectives: to understand the spectrometer and optical spectrum analyzer functioning and role in the troubleshooting monitoring of the optoelectronic devices and optical link system.

1.1 Theory: Without reflected light, our eyes would be unable to see the color or texture of objects. Reflection allows us to perceive the world around us. The human eye does amazing things with reflected light, using it to identify shapes and patterns, and even sense the distance of an object. To a spectrometer, however, reflection is simply the fraction of light reflected from a surface as a function of wavelength. **Spectroscopy is the study of the interaction of light with matter (in chemistry, physics and engineering).** In optical communication engineering for instance we can monitor the light intensity of different communication channels, over the transmission medium (optical fiber or wireless).

Our eyes are the "receivers" for our "world system perception". In the same manner, the "receivers" for the optical communication systems work.

An instrument that includes a light source is known as a *spectrophotometer*. It is constructed so that the sample to be studied can be irradiated with light. The wavelength of light incident on the sample can be varied and the amount of light absorbed or transmitted by the sample determined at each wavelength. From this information, an absorption spectrum for a species can be obtained and used for both qualitative and quantitative determinations.

Spectrophotometers measure the amount of light **transmitted** through a sample/optical medium (such as optical fibers, waveguides). Once the transmission for a sample is measured, it can be converted into other values. Percent transmittance (%T) is the ratio of the transmitted light (I) to the incident light (Io) expressed as a percent.

When properly measured, **spectral reflectance** can yield much of the same information as the eye, but it does so more quantitatively and objectively. A spectral reflectance measurement can compare two yellow objects, or different textures. It can also offer information about the material from which a sample is made, since light that is not reflected from a sample is absorbed due to its chemical composition, otherwise it is scattered or transmitted. **Reflectance measurements** can measure the color of a sample, or examine differences between objects for sorting or quality control or for optical filters behavior (such as gratings, microrings in the optical communication systems). The samples may be automotive parts, paint, coffee beans, dyed human hair or lizards, waveguides, optical integrated chips, making it challenging to choose the right system.

Question 1.1. Please name and describe some other applications in which Spectrometer or OSA can be found.

We understand how each optic works to probe the sample. Once you understand them as well, the choice is simple. Just be warned – you might find yourself measuring everything in the lab once you get the hang of it, even your lunch.

Question 1.2 – Propose the appropriate way to measure the spectrum for a particular object (examples: smartphone flash-lamp, other light sources, or in food quality monitoring or in the optical fiber link).

The leader for the spectrometers providers/sellers on the market are:

- OceanOptics (link: https://oceanoptics.com/measurementtechnique/reflectance-transmittance/
- Ocean Optics Announces Name Change and Rebranding to Ocean Insight),
- Thorlabs (link: https://www.thorlabs.com, please search "Compact CCD Spectrometers")
- Hamamatsu (link: https://www.hamamatsu.com/eu/en/product/photometry-systems/mini-spectrometer/ .

Question 1.3. What do you notice as difference between these spectrometers? (excepting prices)

Examples: electromagnetic spectrum range (to associate it with an appropriate application – for instance VIS: for visible, IR for optical communication), CCD/CMOS chip (characteristics?), dimension (is important for the integrated systems)

The hardware associated with the spectrometer is depicted in the figure 1.

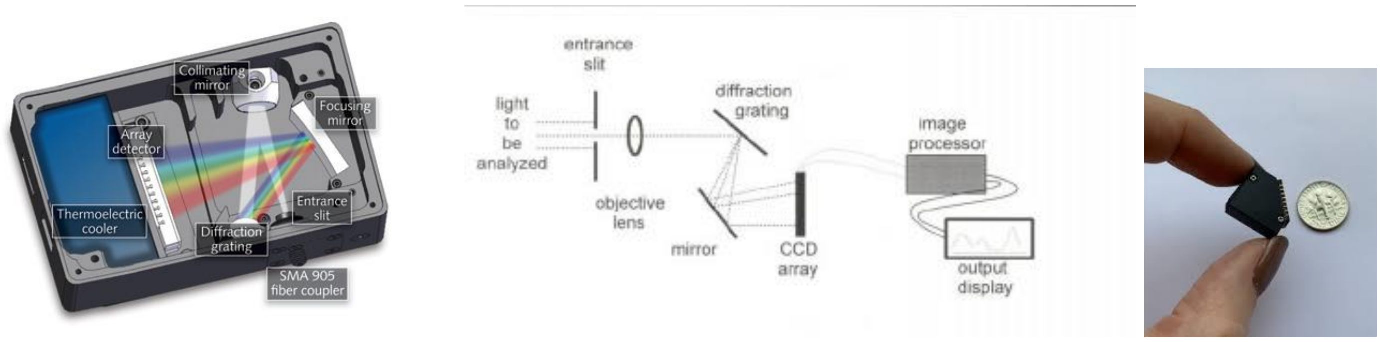


Figure 1. Hardware description of the Spectrometers (diagram of the CCD spectrometer)

Question 1.4. Describe the role of each component in the hardware described in Figure 1 (7 components in total).

The software associated with the image processor represents the intensity versus wavelength range.

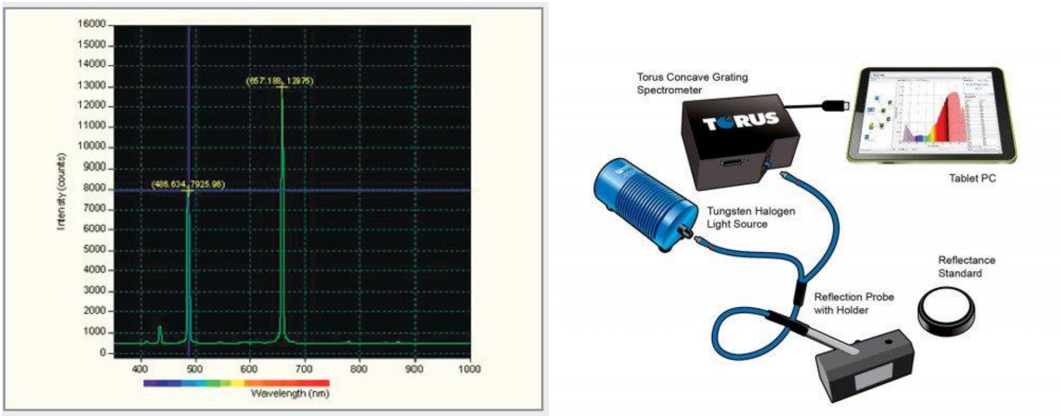


Figure 2. Spectral analysis with dedicated software and Example of the setup

Dedicated for the SOT Lab activities, there is an Educational Spectrometer Kit from K-MAC (http://www.kmac.com) with the parameters description in Figure 3.

Specifications		
Optical Entrance	Input Round	Diameter : 0.5 ㎜ NA = 0.22 monted in SMA-coupling
Slit	Output Linear	50 ㎛ × 1000 ㎛ (standard)
Grating		Flat-field, 600 Line/㎜ (center) Blazed at 500 ㎚ (350 ~ 850 ㎚)
Spectral Range		400 ㎚ ~ 800 ㎚ (Tungsten Halogen)
Dimension	Total (with case)	35 × 98 × 250 ㎣
	Light (TH 2100)	35 × 98 × 118 ㎣
	Spectrometer(SV2100)	35 × 98 × 118 ㎣
	Cuvette Holder	52 × 95 × 95 ㎣
CCD Array	Producer	Sony
	Number of Pixels	2048 element
	Dimensions of Pixels	14 × 200 ㎛²
	Maximum Clock-rate	2 ㎒
	Current Consumption	10 ㎃
	Supply Voltage	5 V
	Intefration Time	1 ㎳ ~ 60 sec
	Effective Range	185 ~ 1100 ㎚ (at UV enhanced coating)
Light Source (TH 2100)	Spectral Range	360 ㎚ ~ 5 microns
	Power Input	9 V DC /3A
	Color Temp.	2,800 K
	Bilb Life	1,500 hours
	Bilb Output	70 Lumens
	Connector	SMA 905
Interface	Connector Assignment	USB 2.0

Figure 3. Technical parameters

The content of the Educational Kit (Halogen Lamp, LED lights, Spectrometer, Cuvette, Filters, Power supply) and corresponding Measurement Modes are depicted in the following figure:

Figure 4. Measurement Modes

1.2 Activities. Using different measurement modes, describe the characteristics of different light sources and materials, using as many as components in the KIT – color filters, polarizers. Describe in the Report your observations. **Be creative in an useful way!**

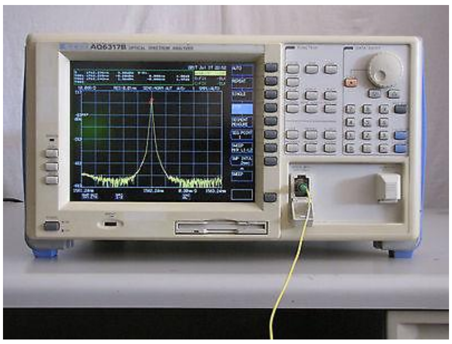
Question 1.5. Do you think that LIDAR (automotive) works similar with spectrometer, but for long distances? (no,...there is a dedicated receiver for the emitter wavelength, it works much more similar with photometer/ powermetter)

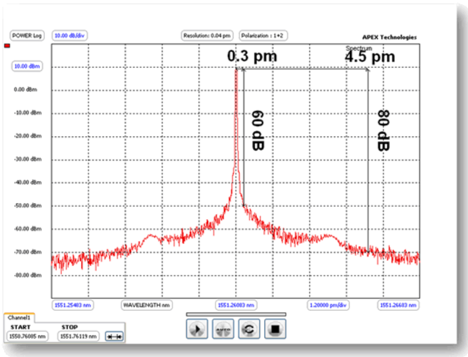
2. Optical spectrum analyzer (OSA)

An Optical Spectrum Analyzer (or OSA) is a precision instrument designed to measure and display the distribution of power of an optical source over a specified wavelength span. An OSA trace displays power in the vertical scale and the wavelength in the horizontal scale.

The expanding field of optics related applications has created a vast variety of industries and organizations that require advanced optical spectral measurements for both R&D and manufacturing. These industries include telecommunications, consumer electronics, healthcare, life science/medical research, security, sensing, microscopy, and gas/chemical analysis, and environmental monitoring.

EXFO and Yokogawa (formerly Ando) are the global leader in optical spectrum analyzers, delivering high quality, cutting edge technology with dependability, performance and flexibility for over thirty years.





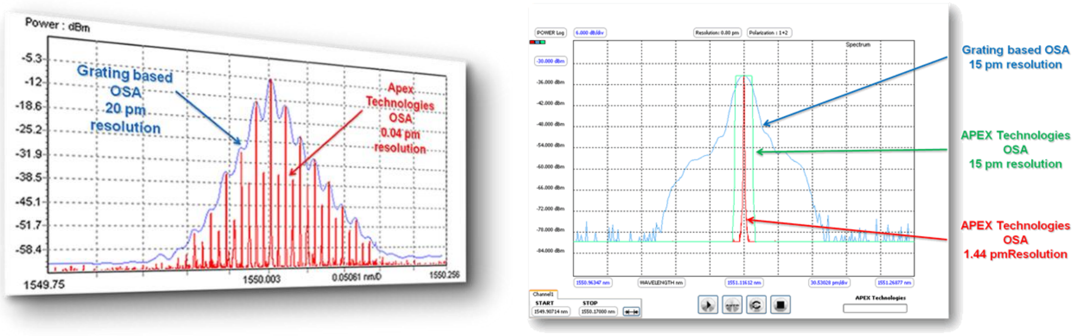


Figure 5. Courtesy of EXFO Company

Useful links:

https://www.exfo.com/en/products/lab-manufacturing-testing/optical-spectrum-analyzers/osa20/)

https://tmi.yokogawa.com/solutions/products/optical-measuring-instruments/optical-spectrum-analyzer/

Question 2.1 For the following OSA, with wide wavelength range analysis, 350 – 1750 nm, check the technical parameters and describe (based on your experience with Spectrometer KIT activities at the LAB) the interpretation of the measurement graphic in the Figure 6.

Hint: the wide light source spectrum is analyzed passing through a material (optical fiber), for the material characterization or optical transmission (OT) link monitoring (in this case unappropriated, because for OT, there are performance measurements and analysis of the WDM Networks, with particular channels monitoring)

Figure 6. Measurements with OSA (only transmission mode)

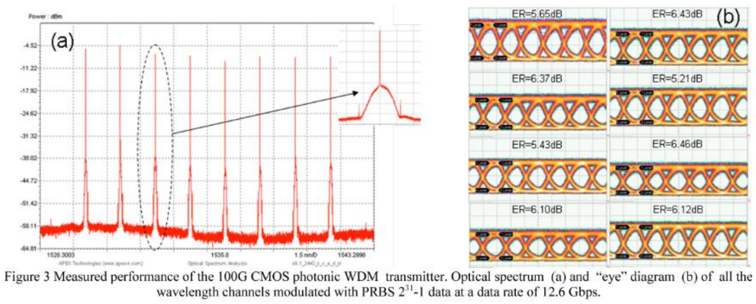


Figure 7. For WDM monitoring

In Figure 7. Is depicted the graphic corresponding to the WDM (wavelength division and monitoring) with particular communication channels (ITU-T WDM) and for each channel the EYE Diagram (that you check it for different link length in the 1. Simulation section)

Question 2.2. Write all the observations related to the figure 7.

Activity 2.3. To play with your own very simple WDM system ☺, with just 3 colors (this time Visible, not Infrared), use the 3 LED driver from Eyest.

Activity 2.4. To make a wide-range analyzer (K-MAC Spectrometer range 400nm-1100nm), make your own setup, based on UV LED, 7 visible LEDS and IR LEDS with Arduino, and analyze them at the same time with the Spectrometer (by using direct slit or by using optical fiber and couplers).

To make the interpretation of the BER and SNR please check the technical notes from Huawei:

http://support.huawei.com/onlinetoolweb/resources/en/16_osnr.html

Observation: to see different measurements, we recommend this software:

https://tmi.yokogawa.com/library/documents-downloads/firmware/aq6374-wide-range-optical-spectrum-analyzer/

3. REPORT

In your lab report include the following:

1. Answers for the first section (Questions 1.1 -1.5)
2. Answers for the second section (Questions 2.1 -2.4)
3. Follow the activities related to the section 1.2 make a Report with observations