

## Optical power measurement and resolution

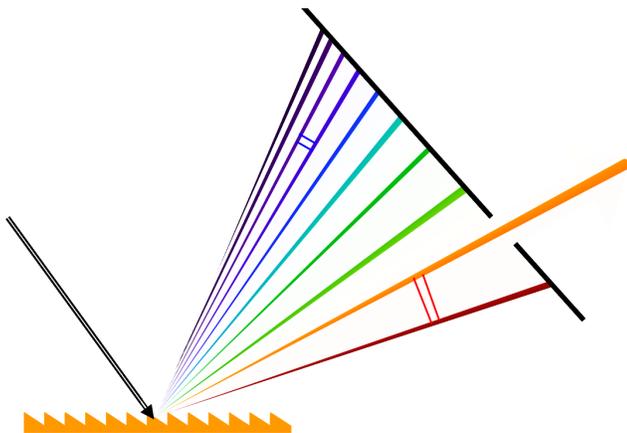
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The Optical Spectrum Analyzer (OSA) that you own may still surprise you. For example; did you realize that power measurement and resolution are related? Understanding the operation of the OSA is crucial for correct interpretation of measurement results. In fact, understanding the technical principles of the OSA allows you to get the most out of the instrument.

In the below, I will explain some aspects of OSAs that are based on a Czerny-Turner monochromator. In this type of monochromator, the different wavelengths of input light are spatially separated by a diffraction grating.

By rotating the grating, a spectrum of wavelengths is swept across a narrow slit, allowing passage of only a narrow bandwidth of light (see figure 1).



**Figure 1** - The wavelengths that are diffracted from the grating are not evenly distributed

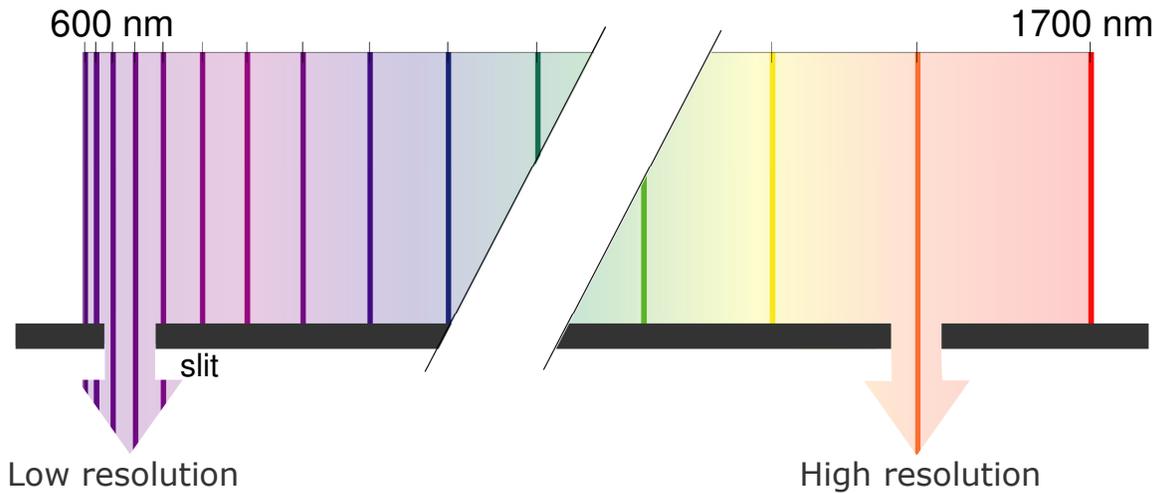
### Effective Resolution

It's important to understand that the separation between the diffracted wavelengths is not evenly distributed.

In fact, at long wavelengths, the separation between the diffracted wavelengths is larger than at short wavelengths.

In the monochromator, almost all of the diffracted wavelengths are blocked. Only a narrow portion of the light passes through a slit and reaches the surface of a photodetector. Here, the slit acts as a band-pass filter. The narrow spectrum that passes through the slit is often referred to as "resolution bandwidth".

Due to the uneven distribution of wavelengths, the bandwidth that is selected by the filter depends on the selected wavelength.



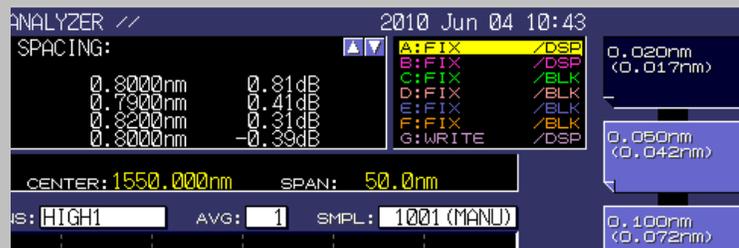
**Figure 2** – The same slit provides a different resolution for different wavelengths

You can conclude that many wavelengths fit through the slit (i.e. low resolution) at short wavelengths, while the same slit allows passing of only few wavelengths (i.e. high resolution) at long wavelengths.

The bandwidth of this filter (effective resolution) is often quite different from the chosen resolution setting on the instrument.

**NOTE**

During factory calibration of the Yokogawa OSA, the effective resolution vs. wavelength curve is determined and stored. In the menu for resolution setting, the effective resolution at the selected center wavelength is displayed between brackets (ref. Figure 3).



**Figure 3** – (example) At 1550nm, the AQ6370B offers an effective resolution of 17pm, i.e. higher resolution than the selected 20pm.

## Absolute Power Display

Let's assume an OSA that records the output of a lamp with a perfectly flat spectral power distribution, i.e. within each 1nm bandwidth the lamp offers the same amount of radiant power. You may expect that the OSA (with its power vs. wavelength display) should produce the same perfectly flat spectrum. This is not the case.



**Figure 4** – Absolute Power Display: the recorded spectrum of a perfectly flat spectrum is dropping towards longer wavelengths

It is the increasing effective resolution towards longer wavelengths that causes the recorded trace to drop. At short wavelengths, the slit allows passing of more wavelengths (i.e. more power reaches the photodetector). Vice versa, at long wavelengths the same slit offers higher resolution and less power reaches the photodetector. The spectrum is showed in Absolute Power Display – i.e. power ( $P_{dBm}$ ) vs. wavelength.

Dividing the recorded power at each point by the local effective resolution produces again the flat spectrum. Now the spectrum is shown in Power Density Display – i.e. power per nm ( $P_{dBm/nm}$ ) as a function of wavelength.

$$P_{dBm/nm}(\lambda) = \frac{P_{dBm}(\lambda)}{Res_{eff}(\lambda)}$$



**Figure 5** - Recorded OSA trace (a) is converted to the power density spectrum (b) by dividing the measured power by the local effective resolution.

The OSA does this automatically when selecting "dBm/nm" (instead of "dBm") for power level scale. For the calculation, the OSA uses values for the effective resolution that are determined during factory calibration.

### **Absolute Power Display**

Due to the opto-mechanical nature of the OSA, the stored values for the effective resolution will deviate slightly from the truth. This will cause a small error in the calculation of the power density display. These errors are kept to a minimum by regular calibration of the instrument, but the **Absolute Power Display** will always offer slightly better level accuracy.

### **Power Density Display**

On the other hand, the Power Density Display can immediately be read and understood. This is the display used for publications. There is no need to know the effective resolution at each point in the spectrum for interpretation of the power level. That means that power levels at different wavelengths can be compared in a single view, and the power inside a peak is easily calculated by integrating the trace over the desired bandwidth.

NOTE: If the recorded spectrum is extremely narrowband, i.e. more narrow than the effective resolution bandwidth, the absolute power is independent of the effective resolution. Here, the recorded peak level equals the total power inside the spectral peak.

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