Optical power measurement and resolution

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This article describes the relationship between optical power measurement and resolution in an optical spectrum analyser (OSA), and shows how understanding the operation of the OSA is crucial for correct interpretation of the measurement results.

The modern optical spectrum analyser (OSA) is a powerful tool for carrying out a variety of measurements, but many users do not appreciate some of its potential applications. In this article, the relationship between power measurement and resolution will be discussed, with the aim of showing users how understanding the technical principles of the OSA will allow them to get the most out of the instrument.

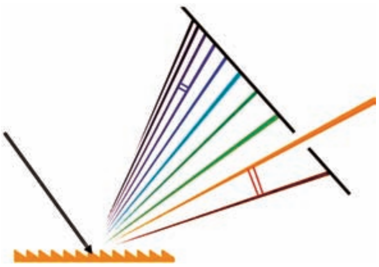

Figure 1. The wavelengths that are diffracted from the grating are not evenly distributed

The particular type of OSA described in this article is 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 (Fig.1).

Effective resolution

It is 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 the slit and reaches the surface of a photodetector. Here, the slit acts as a bandpass filter. The narrow spectrum that passes through the slit is often referred to as "resolution bandwidth".

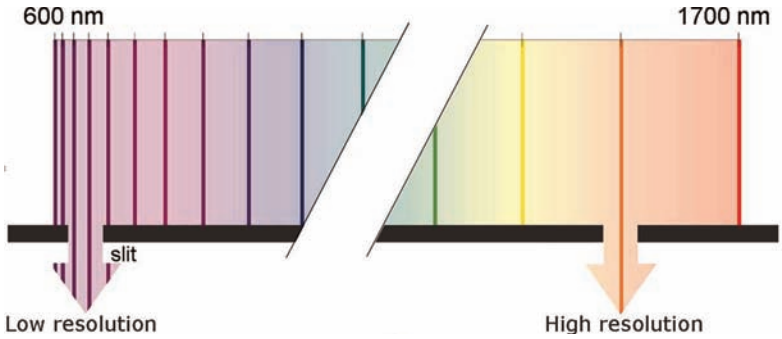

Figure 2. The same slit provides a different resolution for different wavelengths

Owing to the uneven distribution of wavelengths, the bandwidth that is selected by the filter depends on the selected wavelength (Fig.2). Whereas many wavelengths fit through the slit (i.e. low resolution) at short wavelengths, the same slit allows passing of only few wavelengths (i.e. high resolution) at long wavelengths. This means that the bandwidth of this filter (effective resolution) is often quite different from the selected resolution setting on the instrument (Fig. 3). The effective resolution vs. wavelength curve is determined and stored during factory calibration of the OSA.

Figure 3. Application example: at 1550 nm, the OSA has a stored value for the effective resolution of 17 pm, i.e. higher resolution than the selected 20pm

Absolute power display

Assume an OSA that records the output of a lamp with a perfectly flat spectral power distribution, so that within each 1 nm bandwidth the lamp offers the same amount of radiant power. One might expect that the OSA (with its power/wavelength display) will produce the same perfectly flat spectrum. However, this is not the case (Fig. 4).

In fact, the increasing effective resolution towards longer wavelengths causes the recorded trace to drop. At short wavelengths, the slit allows passing of more wavelengths (i.e. more power reaches the photodetector). On the other hand, at long wavelengths the same slit offers higher resolution and less power reaches the photodetector. The spectrum is shown in an absolute power display, which plots power (PdBm) against wavelength.

Dividing the recorded power at each point by the local effective resolution again produces the flat spectrum. Now the spectrum is shown in the power density display, which plots power per nanometre (PdBm/nm) as a function of wavelength (Fig. 5). The OSA does this automatically when the user selects dBm/nm instead of dBm for the power level scale. For the calculation, the OSA uses values for the

Figure 4. Absolute power display: the recorded spectrum of a perfectly flat spectrum is dropping towards longer wavelengths

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

effective resolution that are determined during factory calibration.

Because of the opto-mechanical nature of the OSA, the stored values for the effective resolution will deviate slightly from the true value. 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

In contrast to the absolute power display, the power density display can immediately be read and understood. This is the display used for publication of results. There is no need to know the effective resolution at each point in the spectrum for interpretation of the power level. This 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.

If the recorded spectrum is extremely narrowband (i.e. less 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. Ω

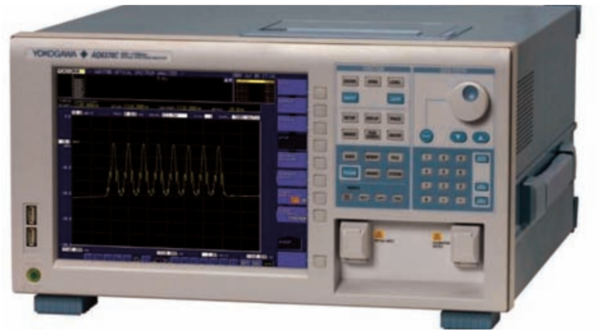

Figure 6. The Yokogawa AQ6370C optical spectrum analyser