

## Chapter 3 Performance optimization

*The performance of spectral sensors is commonly characterized by different parameters that are usually interdependent. The software enables optimization of performance by allowing a set of values for some parameters to be changed and certain hardware settings to be adjusted.*

*This chapter describes the effect of the different parameters on the Signal to Noise Ratio (SNR), as well as some advanced settings that can be used to optimize the overall performance of the system.*

### 1. Measurement parameters

NeoSpectra is based on FT-IR, so the independencies between the different performance parameters are governed by the same relationships as conventional FT-IR systems. Scan time and resolution are two parameters that can be set with the software to optimize the performance of the system depending on target requirements. In this section, we summarize the main elements that need to be considered when adjusting these two parameters.

#### 1.1. Scan time

Scan time is defined as the time taken by the interferometer to scan input light signal. Higher scan time implies higher number of scan cycles to be averaged, hence higher SNR.

The scan time can be adjusted by setting a value higher than 10 ms.

The Signal to Noise Ratio (**SNR**) of the system is directly proportional to the square root of the scan time ( $t_s$ ) [ $SNR \propto \sqrt{t_s}$ ] [1]. More details about the characterization of the SNR at different scan times are explained in Chapter 7 - Section 2.3.

#### 1.2. Resolution

There are several definitions for resolution. In FT-IR, nominal resolution is often defined as the reciprocal of the maximum OPD. Practically, resolution is defined as the minimum spacing between two consecutive wavelength ( $\Delta\lambda$ ) / wavenumber ( $\Delta\nu$ ) points that can be fully resolved by the module. Two neighboring spectral features of equal height and width are said to be resolved if there is a dip of at least 20% between the two maxima. More details about the characterization method of the resolution are explained in Chapter 7 - Section 3.2.

The Signal to Noise Ratio (SNR) of the system is directly proportional to resolution ( $\Delta\nu$ ) [ $SNR \propto \Delta\nu$ ] [1].

## 2. Advanced settings

### 2.1. Gain settings

The Neospectra module has an internal Analog to Digital Converter (ADC) that converts the interferogram data (Analog current detected by the photodetector) to a digital signal.

The conversion ratio  $G_{opt}$  of the detected current to the voltage signal at the input of the ADC is expressed as:

$$G_{opt} = \frac{\text{Volts at the input of the ADC } (V_{ADC})}{\text{Current at the output of the photodetector } (I_{PD})}$$

$V_{ADC}$  is pre-set in the system, while  $I_{PD}$  depends on the optical power coupled into the system. Hence, it is set after acquiring a measurement (see Chapter 6 - Section3 for details on how to adjust gain settings with SpectroMOST)

NeoSpectra SWS62221 is delivered with two main gain settings:

- 1- **Transmission**: optimum gain setting corresponding to the coupled power by typical transmission setup (referred to in Chapter 6 - Section1).
- 2- **Reflection**: optimum gain setting corresponding to the coupled power equivalent to 1/32 of the coupled power by typical transmission setup.

The conversion ratio can be adjusted in order to:

- 1- Avoid saturation of the amplifiers: saturation leads to signal clipping and attenuation.
- 2- Enhance the SNR: using **Transmission** gain option for diffuse reflection signals degrades optimum SNR by a factor that ranges around 3-5 depending on the optical power coupled from the reflection setup.

### 2.2. Apodization

The interferogram can be multiplied by one of a number of different apodization functions to make a gradual decay to zero values at both sides of the interferogram, and hence to smoothe the spectrum.

It must be understood that the process of apodization affects both the resolution and the noise level of FT-IR spectra:

- **Resolution**: the information near the interferogram's centerburst determines the shape of the single-beam spectrum, and this low-resolution spectrum is largely unchanged when the interferogram is multiplied by an apodization function. Conversely, the sinusoids of narrow spectral features take much longer to decay and are therefore far more attenuated when the spectral data are apodized, leading to degradation of resolution.
- **Noise**: low-spatial-frequency noise and very broad bands are also largely unaffected by apodization. High-spatial-frequency noise is attenuated on apodization. On the average, the root mean square (rms) noise on the spectrum is decreased on apodization and the SNR increases.

The specific apodization function that should be used for a certain application is chosen by experimentation [1].

The currently available apodization function is "Tukey window" which represents a tapered cosine function with tapering factor 0.25. More apodization functions will be

added in upcoming software releases.

### 2.3. Zero Padding

Spectra being measured on FT-IR spectrometers consist of intensity values at equally spaced intervals. The discrete nature of the data leads to highly unlikely that the maximum absorption of any band will correspond exactly with one of these data points. In addition, the slope of the spectrum can appear to change markedly from one point to the next. To eliminate these problems, some form of interpolation or alternative data processing is necessary. One of the most useful of these is zero padding (also known as Zero Filling).

Considering complex Fourier transformation of an interferogram that consists of  $N$  data points, the real and imaginary spectra each contain  $N/2$  data points. Increasing the number of points by  $N$  (adding  $N/2$  zeros to each end of the double-sided interferogram) increases the number of data points per resolution element to two. This process may be continued until the data point spacing in the calculated spectrum is so small that no information is lost visually [2].

Available options of zero padding are: 0,1,3,7 corresponding to

- 0: No zero padding is applied
- 1:  $N$  zeros are added to the interferogram
- 3:  $3N$  zeros are added to the interferogram
- 7:  $7N$  zeros are added to the interferogram

Details on how to adjust zero padding on SpectroMOST are explained in Chapter 6 - Section3.4.

### 2.4. Wavenumber correction

Wavenumber axis of the measured spectrum may drift with aging, so two correction techniques are available:

- 1- Self-Correction: system can be auto-corrected with a smart built-in algorithm. The auto-correction is done after measuring background reference white light i.e. no sample should exist in the light path.
- 2- Correction using Reference Material: user can use a standard reference material to correct wavenumber drifts in Neospectra. User should enter the reference absorption peaks positions that correspond to the selected resolution (8 nm or 16 nm at wavelength 1,550 nm).

Wavenumber correction should be applied regularly to maintain the good performance of the module. Depending on the environment, wavenumber correction can be performed every day, week, month or year. Details on how to perform wavenumber correction using SpectroMOST are explained in Chapter 6 - Section3.