AVANTES
MEMBER OF THE NYNOMIC GROUP

TECHNICAL NOTE
RESOLUTION

TECHNICAL NOTE

RESOLUTION

Keywords:
Resolution, FWHM, Pixel, Peak

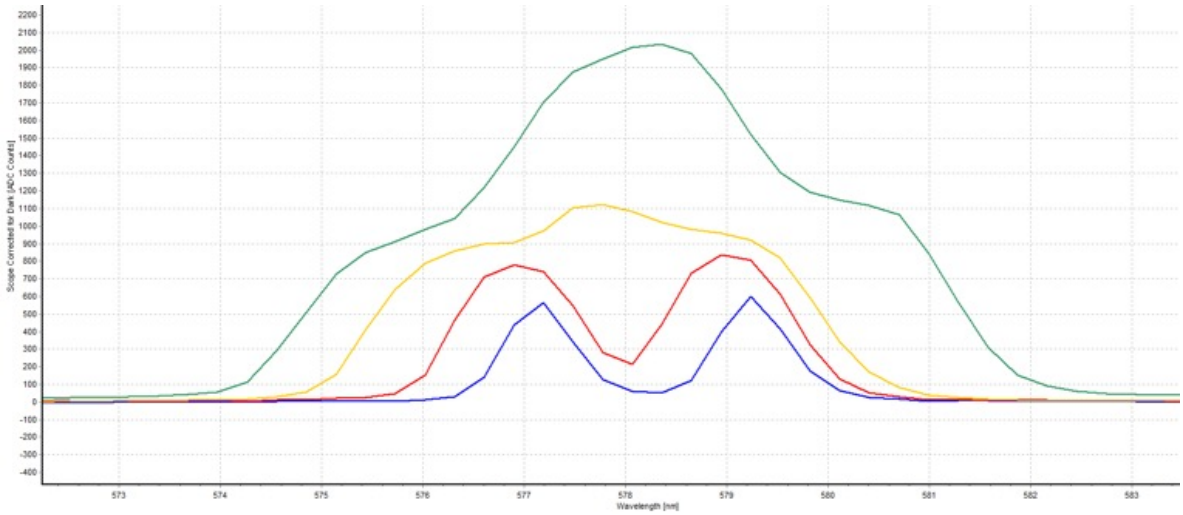
Description:

Resolution is one of the key specifications discussed in a spectrometer purchase decision. This being said, resolution specifications are often overstated by manufacturers, as the proper means of measuring resolution is not well understood by many customers. Furthermore, maximizing resolution is often not recommended for specific applications and can actually impede performance. The purpose of this technical note is to clarify resolution, how it is measured and which elements you should check when evaluating the resolution of a spectrometer for your application.

WHAT IS RESOLUTION?

Among the many applications of spectroscopy, we encounter different types of resolution ranging from temporal, spatial and spectral resolution. When evaluating a spectrometer instrument, the optical resolving power of the instrument is key. This is known as spectral resolution and is normally defined as the minimum spectral separation between peaks that the instrument can resolve. Depending on the application, resolution can be an important parameter. For a lot of standard applications range and sensitivity are the main parameters, but as soon as peaks contain the application information (LIBS, Raman, plasma, laser, etc.) resolution becomes an important parameter. Basically, resolution states how well peaks can be seen, distinguished and separated from each other.

In the example below we see the effect on an image when the resolution is changing.



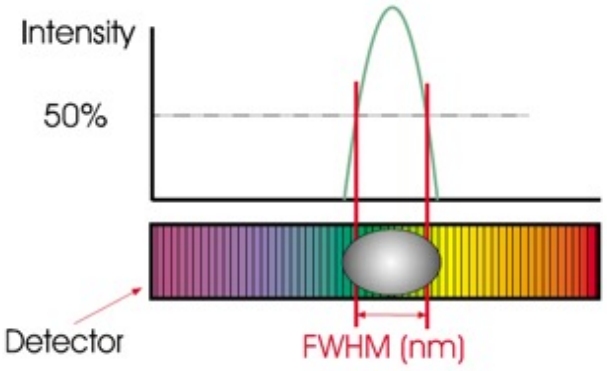
The resolution for this example is changed by using different slit sizes. This can easily be done by using the replaceable slit option (–RS option) for Avantes' spectrometers. The following slits are used:

- Blue line = 10um slit
- Red line = 25um slit
- Yellow line = 50um slit
- Green line = 100um slit

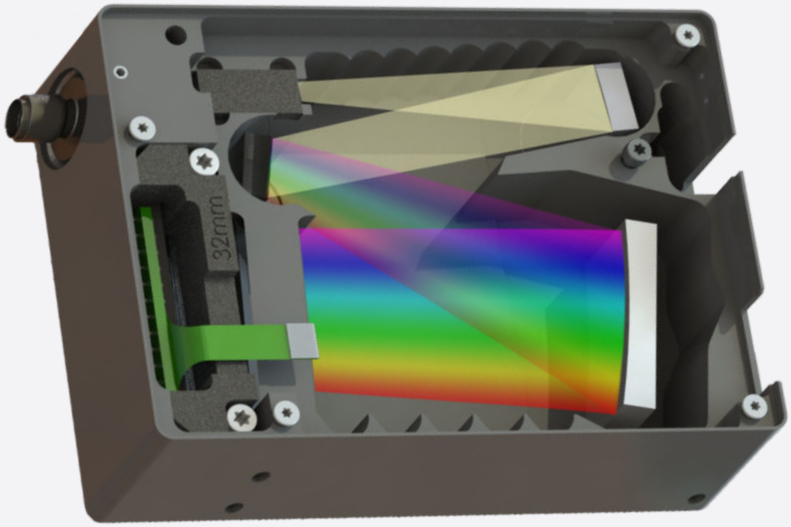
With the small slit, the resolution is higher and the 2 peaks can clearly be distinguished. With a lower resolution, the shape of the peaks will get wider. This will, in the end, lead to 1 "smeared" pulse build up by the overlapping peaks, where one can not distinguish the separate peaks anymore.

WHAT IS RESOLUTION?

Therefore, measurements with spectra based on peaks need a higher resolution spectrometer (think about Plasma, LIBS, Raman). The resolution value is determined by measuring the Full Width Half Maximum (FWHM). This is done by measuring the width of the peak at the half of the maximum peak intensity:



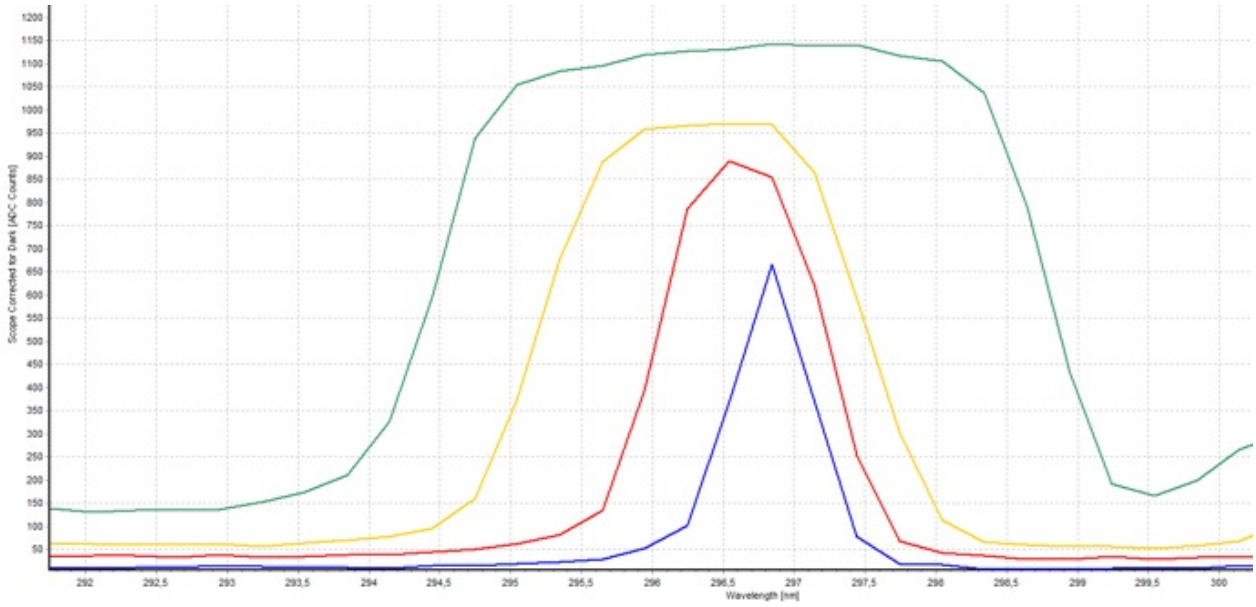
For further understanding of resolution in a spectrometer we need to look deeper into the spectrometer. For explanation purpose we look at a spectrometer based on our popular 75mm Czerny Turner design. In this spectrometer there is 1 to 1 projection of the image of the slit, onto the detector. So if the slit size is 50um, a small light bar of 50 um will be projected on the detector (but for each color/wavelength on a different position). When we take a basic spectrometer for color measurements (range from 360-780nm) the range of 420 nm will be projected on 2048 pixels, so each pixel will cover 0.21nm. This also called the pixel dispersion and should not be confused with resolution. The pixel width of this detector is 14um. When 50 is divided by 14, the image is projected on 3.6 = 4 pixels. With 4 pixels, the theoretical resolution is: 4x0,21= 0.84nm. However, since we don't want to have 2 peaks next to each other overlap, it is better to add 1 pixel for separation. So we calculate the theoretical resolution with 1 extra pixel (4 for the image and 1 for the separation), the theoretical resolution will be 5x0,21= 1,05 nm.



RESOLUTION VALUES

Due to alignment, aberrations and tolerances on optics, the FWHM value can be slightly different. For the example mentioned above, the catalog value is 1.17nm, which we can achieved in realistic measurements for our customers. Stated values on the website and in the catalog of Avantes are based on measured data of built spectrometers (not the theoretical results which will be more optimistic than real life). The average values are between 1,10 – 1,20nm. By stating realistic values we ensure that our customers will not be disappointed about the instrument afterwards.
A small slit will project light on only a few detector pixels. With a larger slit is wider there are more pixels illuminated. Using a larger slit will increase the amount of light entering the spectrometer. However it will not increase the intensity on 1 pixel, it will illuminate the pixels next to it. Using a slit smaller than the pixel width will decrease the intensity on that pixel. In the example below we can see the differences for the following slit widths:

- Blue line = 10um slit
- Red line = 25um slit
- Yellow line = 50um slit
- Green line = 100um slit

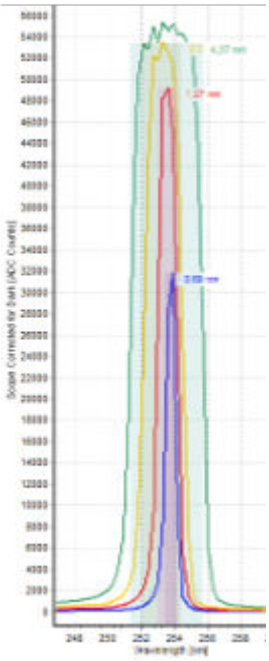


When the peaks are measured it depends where most of the light is projected. In the blue spectrum you see that the most of the light is projected on 1 pixels which gives the best performance from a resolution perspective. When the peak covers multiple pixels it is difficult to find the exact position of the peak. In that situation a cubic spline interpolation method can be used. In that situation the peak position can be determined more accurate but it affects the FWHM.

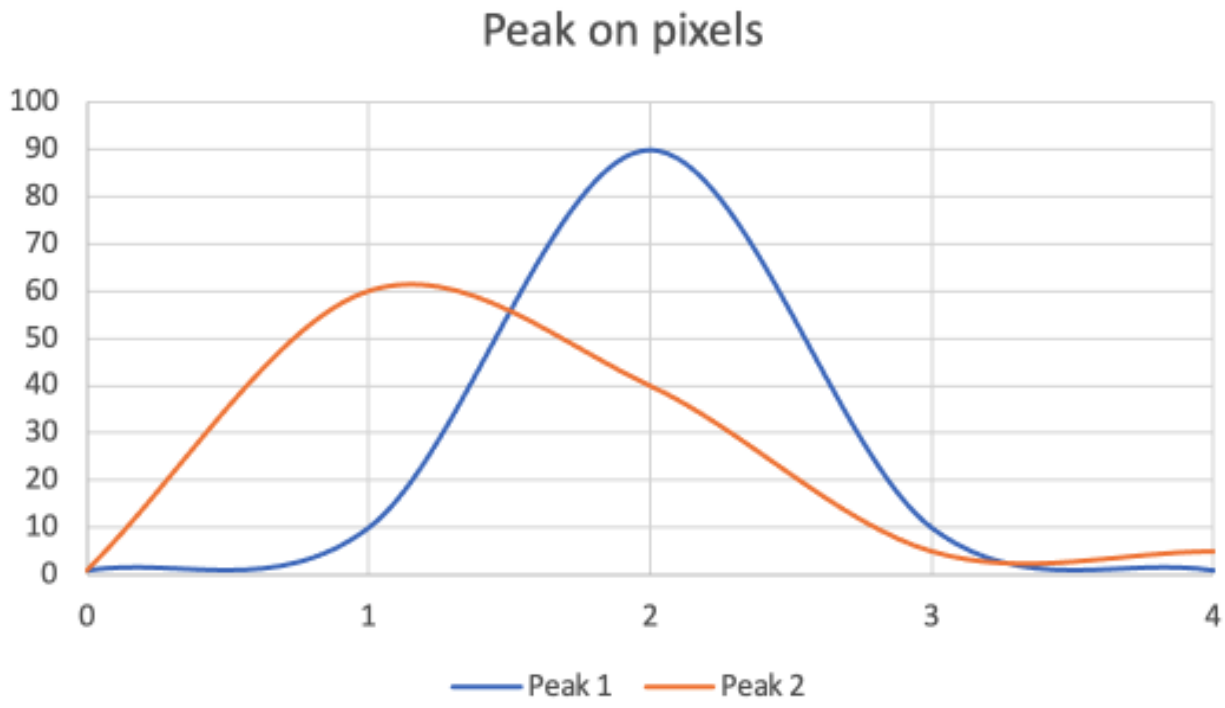
RESOLUTION VALUES

For the peak of 253nm we see, for example, the following resolutions compared to the theory and specification:

Resolution (nm)	Theory	Specification	Measured
Slit 10	0,44	1	0,69
Slit 25	0,88	1,4	1,27
Slit 50	1,76	2,5	2,3
Slit 100	3,52	4,8	4,37



In the table multiple resolution specifications are depicted.
Theory represent the best possible theoretical resolution (in that case 2 peaks cannot be clearly separated). Specification is the value that is mentioned in our datasheets, these values can realistically be reached (for the average of the peaks). Measured values (this is an example measurement) show that we can reach the specification stated in our catalogue and website easily.
In the raw data spectrum there might be shape differences between peaks. The main
reason for this is that it depends if the main intensity is located at a pixel. When all intensity is projected at 1 pixel, a nice peak is showed. When the signal is projected on multiple pixels, the intensity is lower and the peak is broader. With wide slits the projection covers multiple pixels and a different peak shapes / FWHM can be observed:



TECHNICAL NOTE

DIFFERENCES IN RESOLUTION

Most manufacturers of spectroscopy instruments work with the best possible theoretical values and in some cases even with the pixel dispersion. So the measured resolution does not match the specified resolution values. For Avantes spectrometers, the resolution will always be realistic. It is one of the main specifications that is checked for every spectrometer we manufacture.

For more information about this subject, please contact our Technical Support.

AVANTES
MEMBER OF THE NYNOMIC GROUP

CONTACT

WE'RE HAPPY TO HELP

Curious how spectroscopy can help you reveal answers by measuring all kind of materials, in-line, at your production facility, in a lab or even in the field? Please visit our website or contact one of our technical experts, we're happy to help you.

Avantes Headquarters
Phone: +31 (0) 313 670170
Email: info@avantes.com
Website: www.avantes.com

Avantes Inc.
Phone: +1 (303) 410 8668
Email: infoUSA@avantes.com
Website: www.avantesUSA.com

Avantes China
Phone: +86 10 845 740 45
Email: info@avantes.com.cn
Website: www.avantes.cn

Follow us on social media: