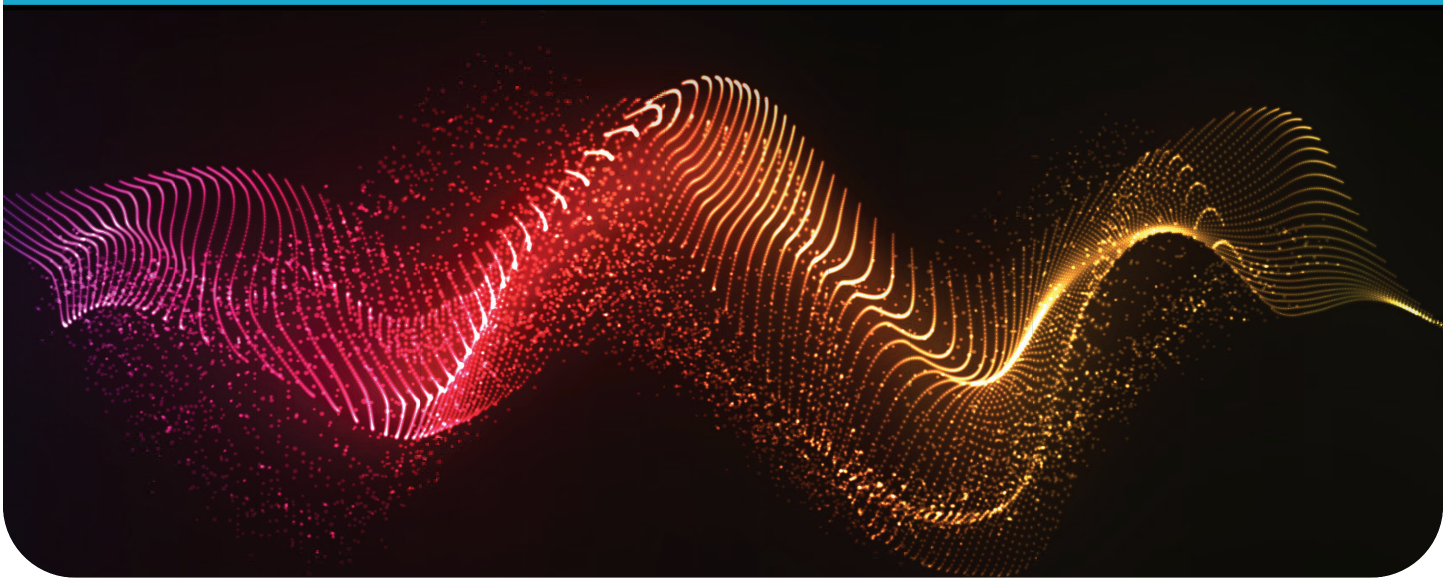
Tech Tip: Understanding High Gain Mode



High gain mode (HGM) is a spectrometer feature that electronically increases the responsivity of the spectrometer with the goal of boosting sensitivity. It is particularly beneficial for low intensity spectroscopy measurements. Read on to learn more about high gain versions of our NR spectrometers and how they enhance sensitivity for low-light measurements.

What is High Gain Mode?

High gain mode increases spectrometer responsivity by amplifying the electrical signal produced by the detector when it receives light. When light hits the detector, it generates an electrical signal. With high gain mode, an electronic amplifier is then used to make low intensity signals large enough to process and analyze. Applying electronic gain increases the strength of the signal coming from the detector, making the detector appear more responsive to low levels of light.

When gain is increased:

- Spectrometer becomes more responsive to low intensity light signals.
- Signal levels are boosted before analog-to-digital conversion.
- Apparent sensitivity improves, making it easier to detect low signal levels.

This signal amplification makes high gain versions of the NR1.7 and 2.2 spectrometers ideal for low intensity measurements. A comparison of the key features for high gain and standard gain spectrometers is shown in the table below.

Feature	High Gain (HGM)	Standard Gain (SGM)
Sensitivity	Increased sensitivity for detection of low-intensity signals	Standard sensitivity for applications with strong intensity signals
Applications	Ideal for weak signal detection	Used for routine measurements with high light levels
Signal-to-Noise Ratio	Lower SNR due to increased noise	Better SNR offering stable results
Stability	May be less stable due to noise	More stable and consistent results for long-term measurements

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Considerations for Using High Gain

It is important to note that the electronic amplification used in high gain spectrometers increases responsivity without increasing the maximum signal the detector can produce. This electronic amplification can also increase some forms of noise. The increase in responsivity without increasing the maximum signal output decreases the signal-to-noise ratio (SNR) for a single spectral acquisition. This occurs because the maximum SNR for a single scan is primarily determined by photon shot noise which depends on how many photons you can collect before you have to read the signal from the detector. Higher responsivity means you reach the maximum signal output with less photons and therefore a lower single scan SNR. Additionally, high gain amplifies baseline noise, which decreases the overall range of signals the spectrometer can accurately measure in a single scan. The good news is that the noise does not increase as much as the responsivity increases which is why the true sensitivity does increase with high gain mode.

Users should balance the need for increased sensitivity against the noise level they can tolerate for their specific application. High gain mode is recommended when measuring low signal levels using short integration times. Standard gain mode is the best option when making high-intensity measurements or using longer integration times. Standard gain is also preferred when maximum dynamic range is needed. The table below highlights the key considerations for using high gain mode along with potential impacts.

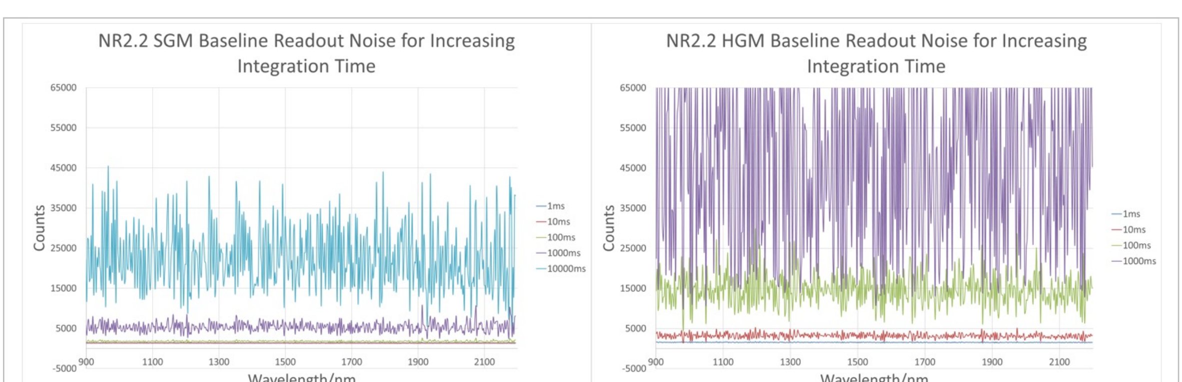
Factor	Impact
Noise amplification	High gain also amplifies noise reducing SNR
Lower saturation threshold	Strong signals will saturate more easily, limiting dynamic range
Signal level	Optimal in low-light conditions — not for use with high-intensity sources

The impact of increased noise with high gain mode is demonstrated in the table below showing the dynamic range, baseline noise, and signal-to-noise ratio (SNR) specifications for standard gain and high gain versions of the NR spectrometers. These values illustrate how the increased sensitivity of high gain mode also amplifies noise, leading to a reduction in both dynamic range and SNR.

	NR1.7 SGM	NR1.7 HGM	NR2.2 SGM	NR2.2 HGM
Dynamic Range (single Scan)	21000	12000	17510	10323
Baseline Noise /Counts	3.1	5.5	3.3	3.7
SNR	10000	2800	9700	2788

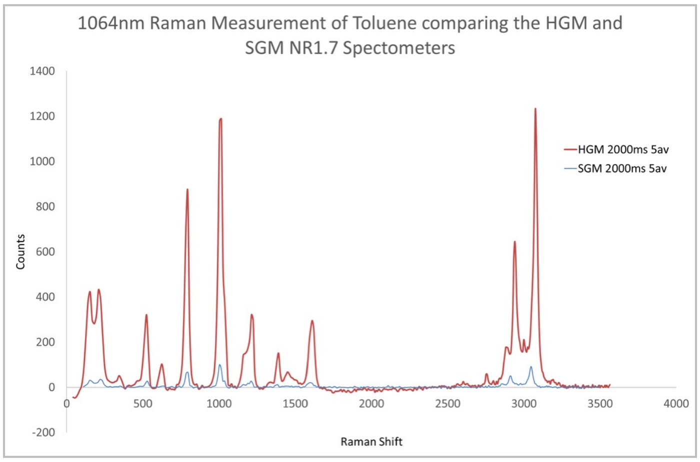
Practical Use of the High Gain NR Spectrometer

High gain mode is recommended for low intensity measurements with the assumption that amplification of the signals of interest will outpace the associated increase in noise. Fortunately, the increased sensitivity that comes with high gain mode also enables the use of significantly reduced integration times relative to standard gain mode. With lower integration times, the noise is also reduced. This is demonstrated in the plots below showing readout/electronic noise as a function of integration time. These plots show that shorter integration times yield less readout noise for both the high and standard gain spectrometers. The plots also show that with standard gain mode, longer integration times up to 10 seconds in this specific case do not saturate the detector providing a wide dynamic range for the measurements. In high gain mode, detector saturation occurs much more quickly at 1 second significantly limiting the maximum integration time and dynamic range for the measurements. For this reason, high gain mode should only be used with shorter integration times to avoid detector saturation.

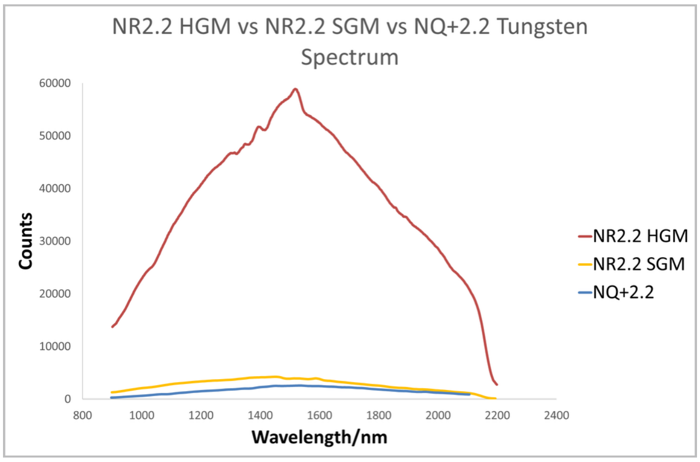


Comparing High Gain and Standard Gain Measurements

High gain spectrometers excel at making low intensity measurements like low reflectivity, low intensity emission, and even NIR Raman. In the case of NIR Raman, already low signal levels are further decreased with 1064 nm laser excitation. This makes the high gain version of the NR1.7 ideal for NIR Raman. This is demonstrated in the plot below showing 1064 nm Raman spectra for toluene collected with high and standard gain NR spectrometers. The dramatic increase in signal intensity measured with the high gain NR spectrometer illustrates the power of high gain mode. Both spectra were collected with the same laser, setup and acquisition parameters. These spectra demonstrate how the enhanced responsivity of the high gain version of the NR enables detection of peaks not observed with a standard gain NR.



In the graph below, a raw responsivity comparison of standard and high gain spectrometers is shown using a tungsten halogen light source. Raw responsivity measured with the high gain version of the NR2.2 is compared to a standard gain NR2.2. Through detector amplification in high gain mode, the intensity measured with the high gain NR is higher than the intensity measured with the standard gain NR. This makes the high gain version faster than the standard gain version of the spectrometer enabling the use of shorter integration times for lower noise.



Conclusions

High gain mode increases a spectrometer's sensitivity by amplifying low intensity light signals, making it ideal for low intensity applications. Users must balance the benefits of increased sensitivity with potential increases in noise and reduced dynamic range. Selecting the appropriate gain setting is critical for maintaining optimal signal-to-noise performance across a wide range of applications.

High gain mode:

- Increases signal amplification: Weak light signals detected by the spectrometer are boosted for more accurate measurements.
- Improves sensitivity: Useful when measuring low-light intensity or low-concentration samples.
- Amplifies both signal and noise: While helping to detect weak signals, high gain also increases background noise, reducing the signal-to-noise ratio (SNR).
- Reduces dynamic range: With signal amplification, the detector may saturate more quickly with stronger signals limiting the range of intensities that can be accurately measured.

By understanding the differences between these modes, you can select the performance of the NR spectrometer specific for your application, whether it is for detecting low intensity signals or achieving high precision in routine analyses.