miniRaman 785 nm spectrometer: determination of signal-to-noise ratio

Key words

miniRaman, handheld Raman spectrometer, signal-to-noise ratio, signal, noise.

Introduction

This technical note describes the procedure of determining a signal to noise ratio of a Raman spectrometer on an example of Lightnovo ApS miniRaman 785 nm spectrometer.

Signal-to-noise ratio (SNR) is a critical parameter in Raman spectroscopy, directly impacting the reliability and interpretability of spectral data. As Raman signals are inherently weak due to the low probability of inelastic scattering events, optimizing and understanding SNR is essential for achieving accurate chemical identification, quantitative analysis, and high spatial resolution. This technical note explores the factors influencing SNR in Raman spectroscopy, including instrumentation, experimental conditions, and data processing techniques. By providing a practical framework for evaluating and improving SNR, this note aims to support researchers and practitioners in obtaining high-quality Raman spectra across diverse applications.

Measuring system: miniRaman spectrometer

Figure 1. Lightnovo miniRaman Power 785 nm spectrometer.

Lightnovo ApS miniRaman is a compact and fully handheld Raman spectrometer designed to deliver high performance in a portable format. Despite its small size, the device offers high sensitivity, excellent signal-to-noise ratio, and good spectral resolution, making it suitable for both qualitative and quantitative Raman analysis. These capabilities are typically associated with larger benchtop systems, but miniRaman achieves them through advanced optical design and efficient detection technology.

The versatility of miniRaman makes it suitable for a wide range of applications. In field settings, it enables rapid, on-site identification of substances such as illicit drugs, explosives, minerals, and raw materials without the need for sample preparation. Its portability and ease of use are especially valuable in environments where time, mobility, or space are limited. At the same time, its high performance makes it equally well-suited for use in R&D laboratories, where precise spectral information is needed for material characterization, process development, or academic research. Whether deployed in the field or in a controlled lab setting, miniRaman provides a robust, user-friendly solution for high-quality Raman spectroscopy.

Experimental

The Raman spectrum of a polystyrene reference sample was recorded utilizing the Lightnovo ApS miniRaman spectrometer, equipped with a 785 nm excitation laser. Spectral acquisition was performed under optimized measurement conditions, specifically an exposure time of 250 milliseconds, 10 accumulations (repetitions) per scan, and a laser power output of 50 milliwatts. These parameters were carefully selected to balance signal intensity and spectral clarity while minimizing potential sample degradation or fluorescence interference. The resulting Raman spectrum exhibited distinct and well-resolved vibrational peaks characteristic of polystyrene, confirming both the material identity and the high spectral performance of the miniRaman device. The clarity and reproducibility of the spectrum underscore the instrument's suitability for routine material analysis in both laboratory and field settings. The representative Raman spectrum of the polystyrene reference sample is presented in Figure 2, illustrating the system's capability to capture detailed molecular information with high precision.

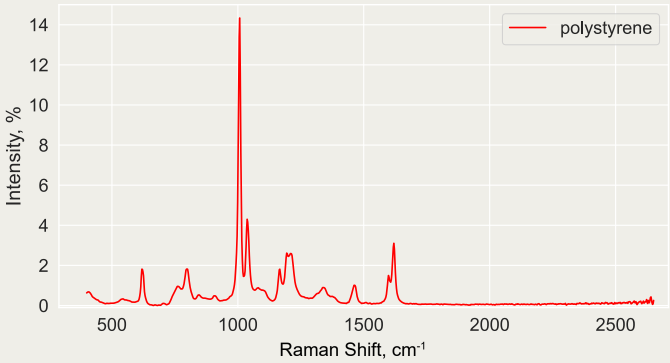

Figure 2. Raman spectrum of a polystyrene reference sample acquired with 785 nm laser, 250 ms exposure, 10 repetitions.

The signal intensity was quantitatively assessed by measuring the peak height of the prominent polystyrene Raman band located at approximately 1001 cm^{-1}, which corresponds to the symmetric ring breathing mode and is widely recognized as a standard reference feature in polystyrene spectra. This peak was selected due to its sharpness and high signal-to-noise ratio, making it a reliable indicator of overall spectral signal strength.

To characterize the noise level, a baseline region devoid of significant Raman features was chosen in the spectral range between 1700 cm^{-1} and 2100 cm^{-1}. This region is typically free from strong Raman bands in polystyrene and thus serves as an appropriate window for estimating the inherent noise of the spectrometer under the given acquisition conditions. The extracted noise spectrum within this range is depicted in Figure 3, providing a visual representation of the baseline fluctuations.

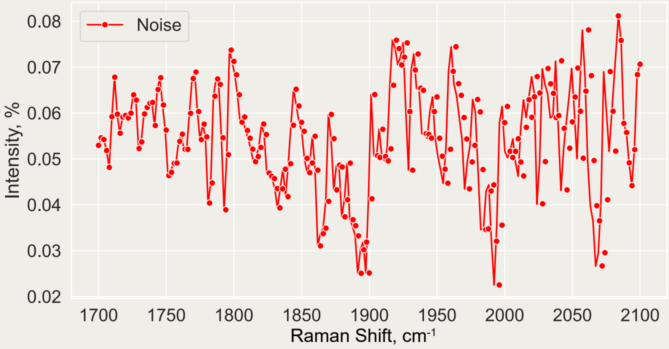

Figure 3. Noise in polystyrene Raman spectrum in the spectral range 1700..2100 cm^{-1}, acquired with 785 nm laser, 250 ms exposure, 10 repetitions.

Furthermore, a statistical analysis of the noise distribution was performed. A histogram of the intensity values within the 1700–2100 cm^{-1} range was generated to evaluate the nature of the noise. As shown in Figure 4, the resulting distribution closely approximates a Gaussian (normal) distribution, indicating that the noise is primarily stochastic and consistent with typical detector and electronic noise behavior. This analysis supports the reliability of the instrument for quantitative Raman measurements under the described experimental conditions.

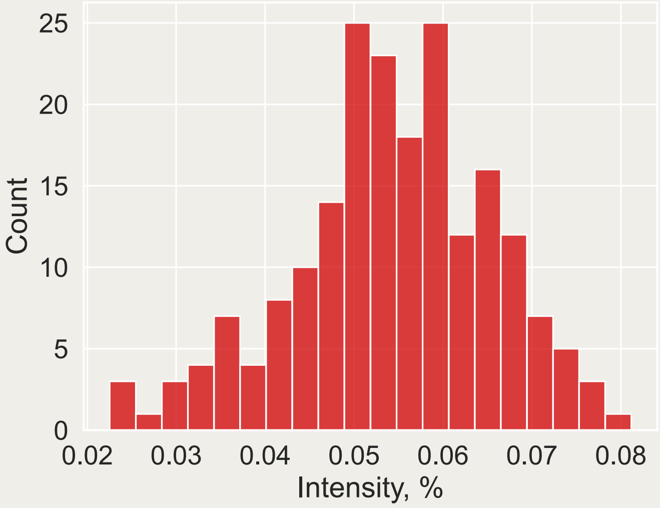

Figure 4. Histogram plot of noise in polystyrene Raman spectrum in the spectral range 1700..2100 cm^{-1}.

Results

The baseline level was determined by calculating the average (mean) intensity of the Raman signal over a specified spectral range from 1700 cm^{-1} to 2100 cm^{-1}. This region was selected because it is generally free of Raman peaks associated with polystyrene or other interfering vibrational modes, providing a clean and representative measurement of the underlying baseline noise or fluorescence. By averaging the signal over this range, a reliable and consistent baseline level can be established, which serves as a reference point for accurately quantifying the amplitude of the 1001 cm^{-1} Raman peak. This baseline correction approach helps minimize the impact of background variations, improving the accuracy and reproducibility of the measured signal.

$$\mathit{baseline} = \mathit{mean}(\mathit{polystyrene}[1700..2100\ \mathit{cm}^{-1}])$$

The noise level was determined as a standard deviation of the signal in the range 1700..2100 cm^{-1}.

$$\mathit{noise} = \mathit{std}(\mathit{polystyrene}[1700..2100\ \mathit{cm}^{-1}])$$

The signal level was determined by measuring the amplitude of the prominent 1001 cm^{-1} Raman peak, which corresponds to the symmetric ring-breathing mode of polystyrene. This amplitude was calculated as the difference between the peak intensity at 1001 cm^{-1} and the baseline intensity.

$$\mathit{signal} = (\mathit{polystyrene}) - \mathit{baseline}$$

Signal to noise ratio was determined as follows:

$$\mathit{SNR} = \mathit{signal} / \mathit{noise}$$

The following values were obtained as a result of calculations:

$$\mathit{baseline}=0.0543$$

$$\mathit{noise}=0.0114$$

$$\mathit{signal}=14.3540$$

$$\mathit{SNR}=1255.8572$$

This gives signal to noise ratio of a miniRaman spectrometer as 1256:1 for an exposure time of 250 ms, 10 averages. Note that signal to noise ratio can be improved by increasing the exposure time and/or the number of repetitions.

Conclusion

In conclusion, the miniRaman system demonstrates an impressive signal-to-noise ratio (SNR) performance, especially considering its compact, handheld form factor. Despite the inherent challenges of miniaturization—such as reduced optical throughput and limited thermal stability—the instrument delivers high-quality spectral data that rivals larger, benchtop systems in many applications. This makes miniRaman a reliable and efficient tool for field-based Raman spectroscopy, enabling accurate chemical identification and material analysis outside of the laboratory. Its strong SNR performance expands its usability across diverse environments, from industrial quality control to on-site geochemical and forensic investigations.

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