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RAMACLE® SOFTWARE FEATURE Cosmic Ray Removal

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Automated removal of spectral artefacts

Ramacle® is a comprehensive, user friendly software package designed for the complete operation and control of Edinburgh Instruments' Raman systems. Among its many advanced data handling tools, Ramacle includes automatic cosmic ray removal, enabling fast and reliable elimination of unwanted spectral artefacts.

This feature is optimised for both single Raman spectra and large Raman datasets, including maps containing thousands of individual spectra. By removing cosmic rays efficiently and consistently, Ramacle helps ensure that your data accurately represents your sample and supports confident interpretation and downstream analysis.

What are cosmic rays?

Cosmic rays are high-energy particles originating from space that can interact with the CCD detector used in Raman spectrometers. When a cosmic ray strikes the detector during data acquisition, it produces an unwanted signal that appears in the spectrum.

These events are random and unavoidable. In Raman spectra, they typically manifest as sharp, high intensity spikes that do not correspond to any real chemical or structural feature of the sample. In some cases, cosmic rays may also appear as broader or more complex artefacts, making them harder to distinguish from genuine Raman bands.

When collecting large datasets, such as Raman maps, the likelihood of cosmic ray events increases significantly. Removing these artefacts at an early stage ensures cleaner data and more reliable results throughout your analysis pipeline.

Why is it important to remove cosmic rays?

Cosmic rays introduce false features into Raman spectra, which can obscure or distort real sample information. If left uncorrected, they can negatively impact both qualitative interpretation and quantitative analysis.

These can appear as spikes in the baseline of the spectrum or overlapping with a Raman band. They can also appear as broader, more structured features which may be mistaken for true Raman peaks (Figure 1).

Cosmic rays can:

- ➕ Mask real Raman features, particularly weak or narrow bands
- ➕ Complicate visualisation of Raman maps, such as intensity maps.
- ➕ Distort the shape and intensity of genuine Raman peaks, leading to misinterpretation.
- ➕ Introduce errors into data processing workflows, especially techniques that rely on the full spectrum, including multivariate and chemometric analyses.

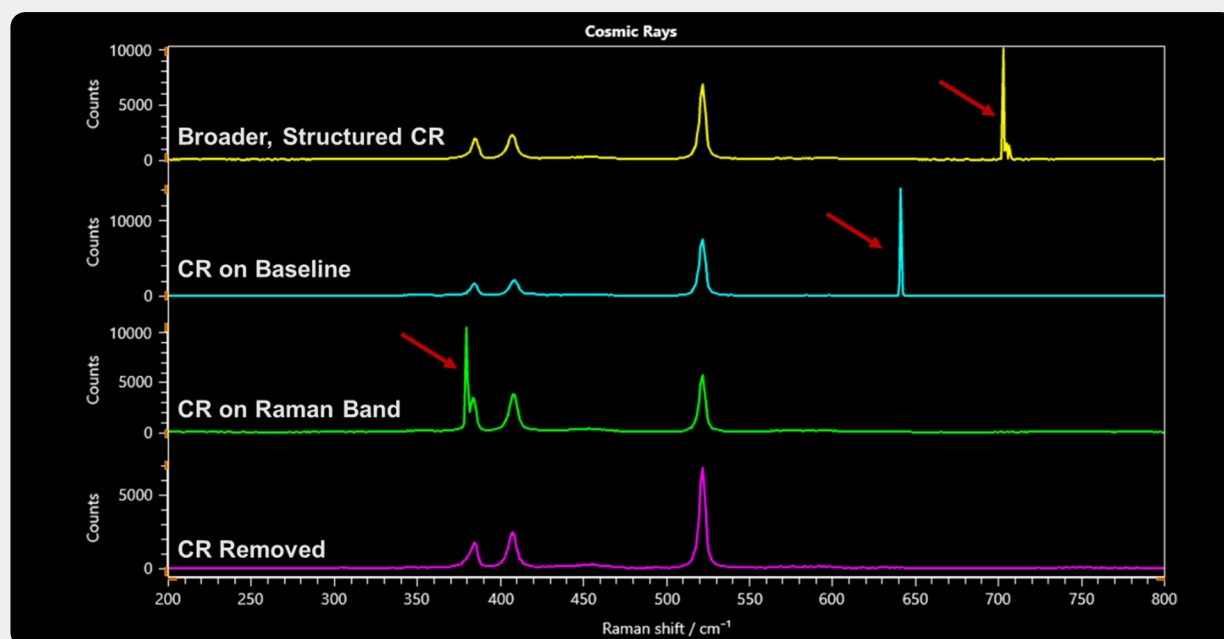


Figure 1. Example of cosmic ray (CR) artefacts appearing as sharp spikes and structured features in Raman spectra.

Automatic cosmic ray removal in Ramacle

Ramacle software includes automated cosmic ray removal functionality that eliminates cosmic rays from both individual spectra and entire Raman maps.

Cosmic rays are identified based on their characteristic intensity, width, and spectral profile, and are removed while preserving the underlying Raman signal. The process is fast and consistent, making it particularly effective for large datasets where manual correction would be impractical.

The impact of cosmic rays on a Raman map containing thousands of spectra is illustrated in Figure 2. Before cosmic ray removal, the map is dominated by these artefacts, that distort the image (Figure 2A). This skews colour intensity values and obscures genuine sample features.

After cosmic ray removal, the map no longer contains outliers or artefacts (Figure 2B). This improves visual clarity, enables spatial features to be resolved, and ensures that subsequent quantitative analysis accurately reflects the underlying data.

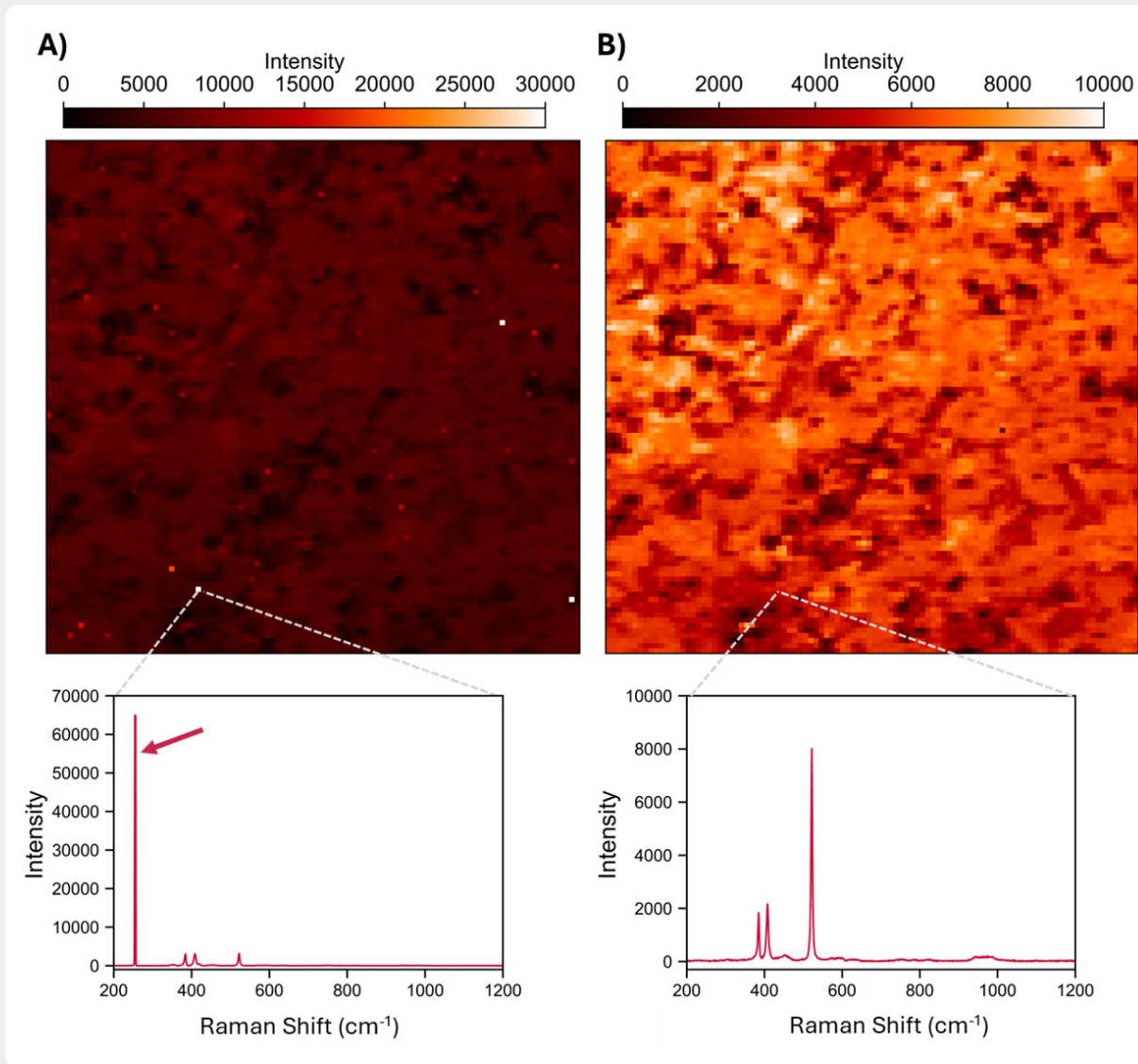
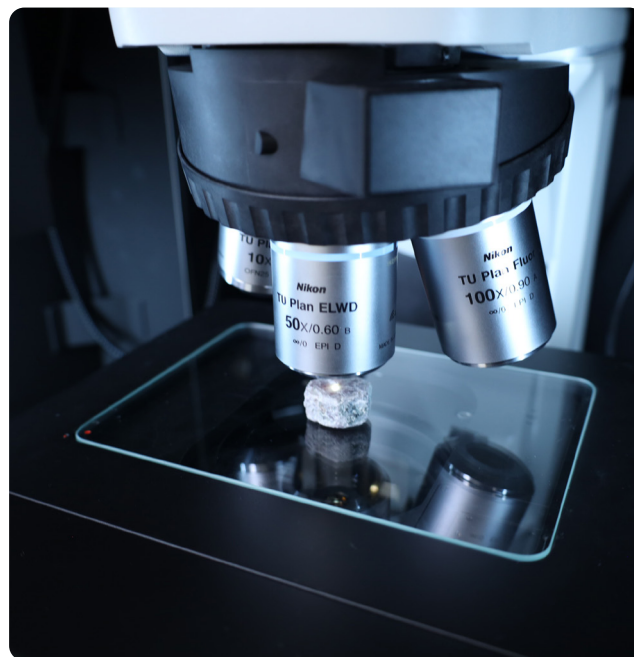


Figure 2. Raman map of molybdenum disulfide (MoS_2) on silicon wafer showing spatial signal intensity variation of whole spectrum A) Before cosmic ray removal, and B) After automatic cosmic ray removal with Ramacle.

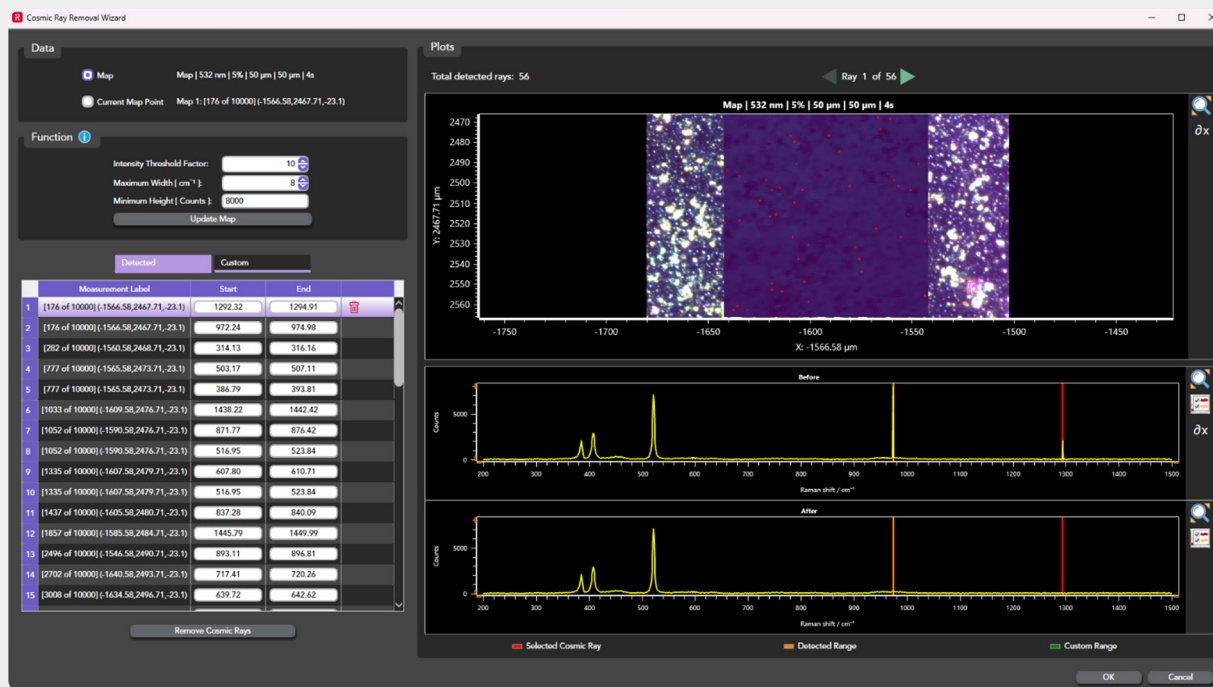


Figure 3. Cosmic Ray Removal in Ramacle software.

User adjustable parameters for optimal results

While Ramacle's default settings are suitable for most applications, the software also provides user adjustable parameters to accommodate different samples, acquisition conditions, and detector settings (Figure 3).

Users can fine tune the cosmic ray removal process by adjusting:

- + Intensity threshold factor - controls the sensitivity of cosmic ray detection
- + Maximum width - defines the widest feature considered to be a cosmic ray
- + Minimum height - filters out baseline noise so the software only processes significant intensity spikes

Once cosmic rays are automatically identified, users can review all detected events in the raw spectra and remove any false positives if required. Additionally, users can manually select cosmic rays via the 'Custom' tab for events that are not detected automatically.

This flexibility allows experienced users to optimise performance for challenging samples or specialised experiments, ensuring that all cosmic rays are removed without affecting genuine Raman features.

Clean data, confident analysis

Automatic cosmic ray removal in Ramacle simplifies Raman data processing and helps users focus on their true Raman features and results. By efficiently eliminating spectral artefacts from both small and large datasets, Ramacle delivers cleaner spectra, clearer maps, and more reliable analysis.

Whether you are performing routine measurements or advanced chemometric analysis, Ramacle's cosmic ray removal tools provide a robust foundation for high quality Raman spectroscopy.



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