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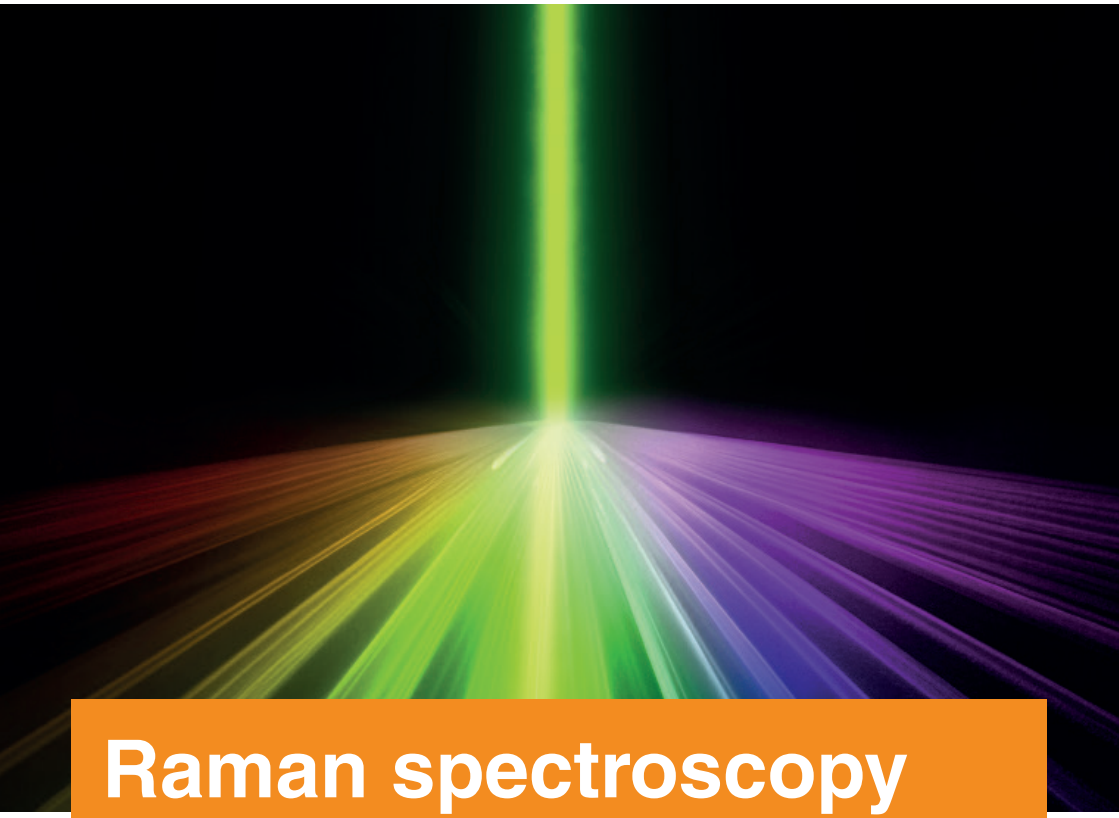

Raman spectroscopy explained

Raman spectroscopy can help us to understand our material world. Across research laboratories, industrial manufacturing environments and clinical diagnostic laboratories. Raman spectroscopy is a form of vibrational spectroscopy. Raman analysis probes materials with a beam of light to reveal detailed chemical and structural information. This technique is non-destructive and requires no sample preparation.

Learn the principles of Raman spectroscopy, and how it could be a powerful tool for you.

www.renishaw.com/raman

#renishawraman

Contents

What Raman spectroscopy can tell you 3

What Raman images can tell you 7

Why we use Raman spectroscopy 10

Challenges and solutions 14

Parts of a Raman spectrometer 16

The Raman effect 18

Raman bands explained 21

Photoluminescence explained 26

Raman images explained in detail 30

SERS/TERS 36

Renishaw's key technologies 38

Renishaw's Raman products 40

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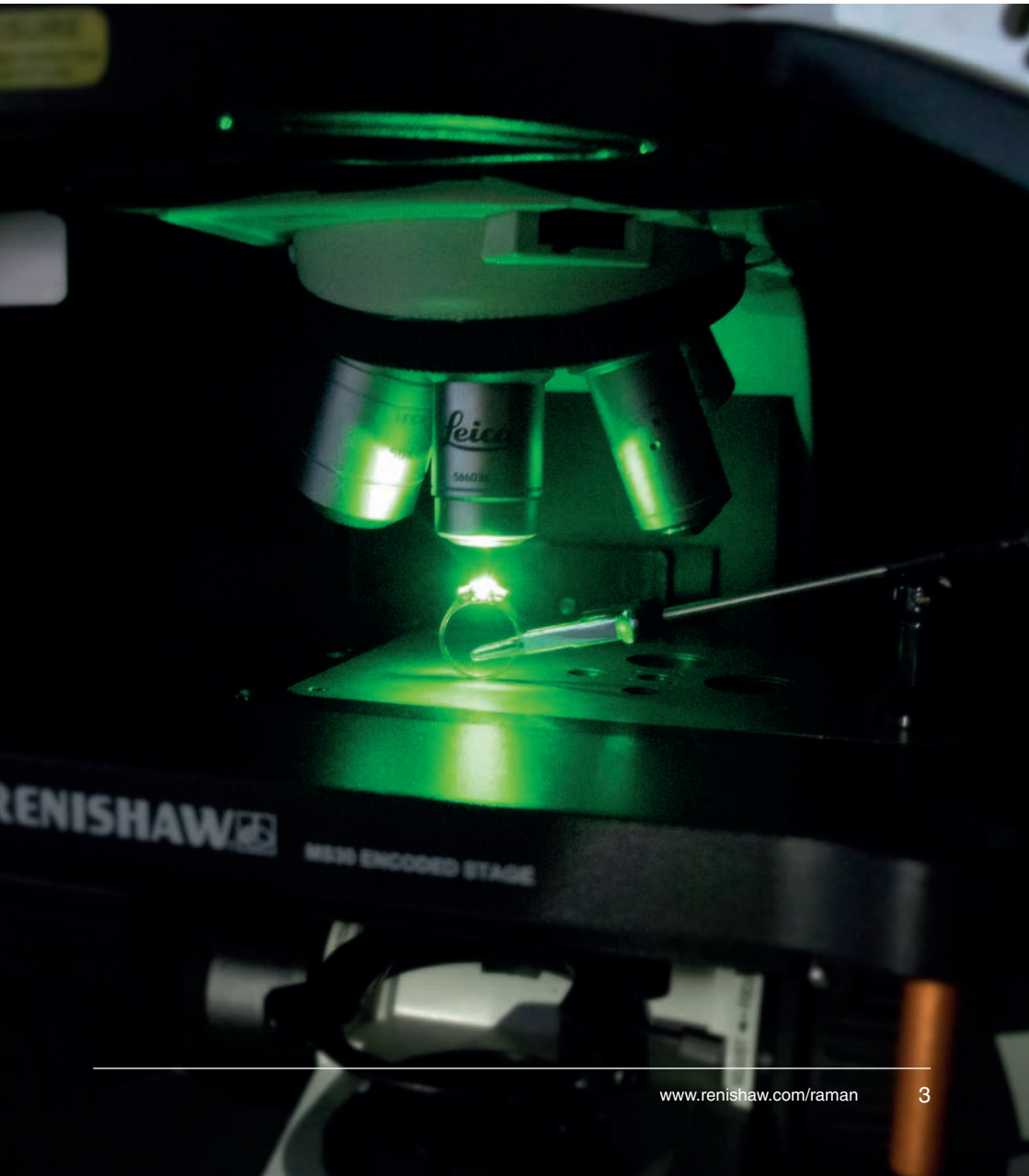
What Raman spectroscopy can tell you

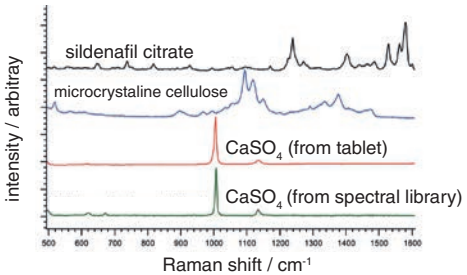


Raman spectroscopy produces chemical and structural information to help us understand more about the sample being analysed. This section details some of the uses of Raman spectroscopy.

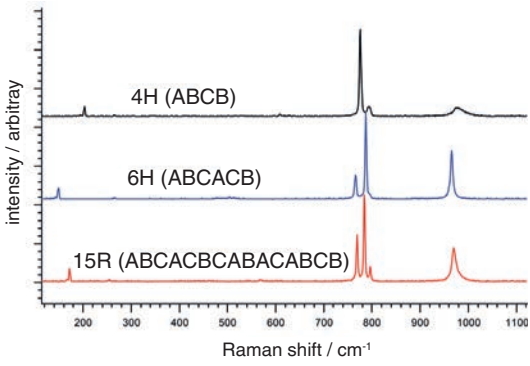
Identify unknown materials

We can identify unknown materials from their unique Raman spectral fingerprints, typically using library of known spectra.

Ideally you would use a Raman instrument with high spectral resolution across the whole Raman range. This gives you better chemical specificity. You can then identify, differentiate and investigate a wider range of materials.



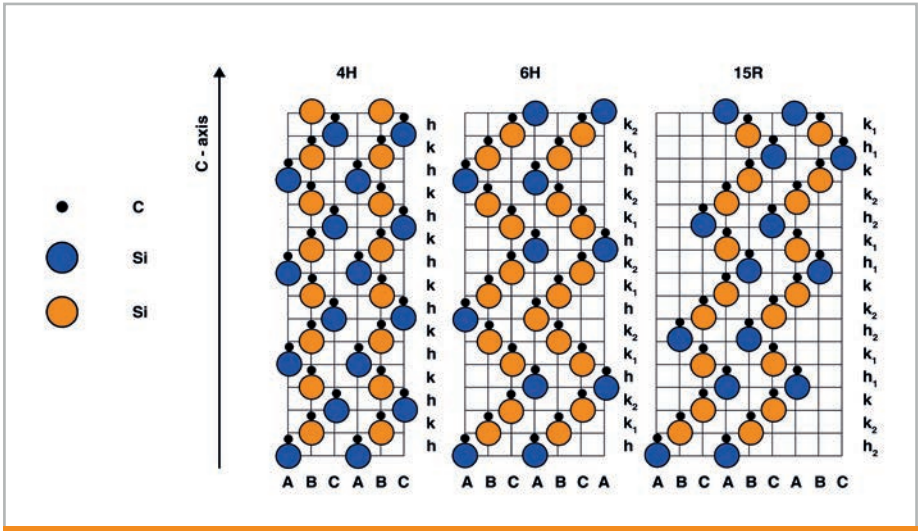
Raman spectra showing some of the species present within a suspected counterfeit tablet. The spectrum shown in red was identified as $CaSO_4$ by searching against Renishaw's inorganic materials and minerals library.



Spectra of three different polymorphs of silicon carbide (SiC), an important semiconductor material.

Differentiate materials by structure

You can study differences in materials by comparing their Raman spectra. A high spectral resolution system, such as Renishaw's inVia™ confocal Raman microscope enables you to distinguish even very similar crystal forms (polymorphism) of the same chemical.



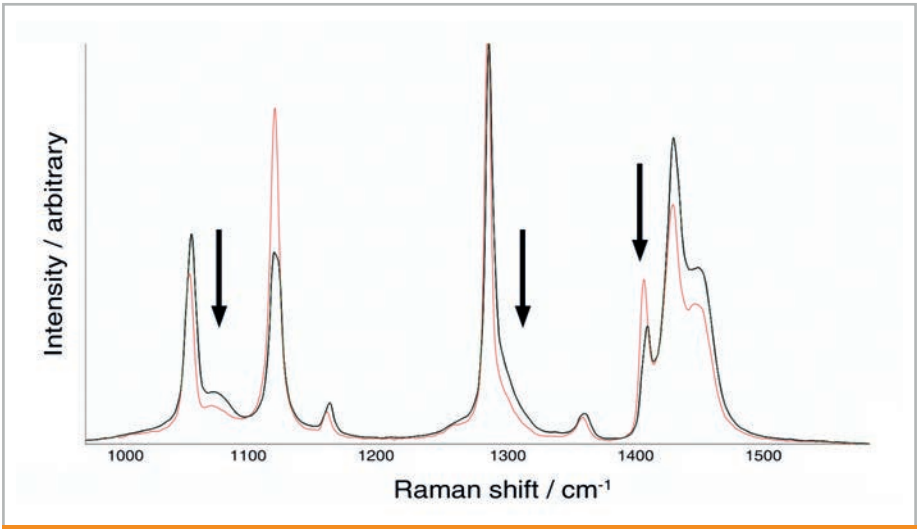
Crystal structure of SiC polymorphs: 4H-SiC; 6H-SiC and 15R-SiC.

Investigating structural properties

You can study changes in the Raman spectrum such as the height, width or position of the Raman bands and determine things like:

- the quantity of material
- crystallinity
- whether it is under compression or tension
- temperature
- layer thickness

Raman bands contain information about molecular and crystal lattice vibrations. These vibrations are very sensitive to changes in chemistry and crystal structure, so you can identify subtle differences in your sample. The direct relationship between vibrations and Raman bands also makes interpretation easier.



Raman spectra of two polyethylene samples showing differences in intensities and band widths. These spectral differences are due to varying degrees of crystallinity.

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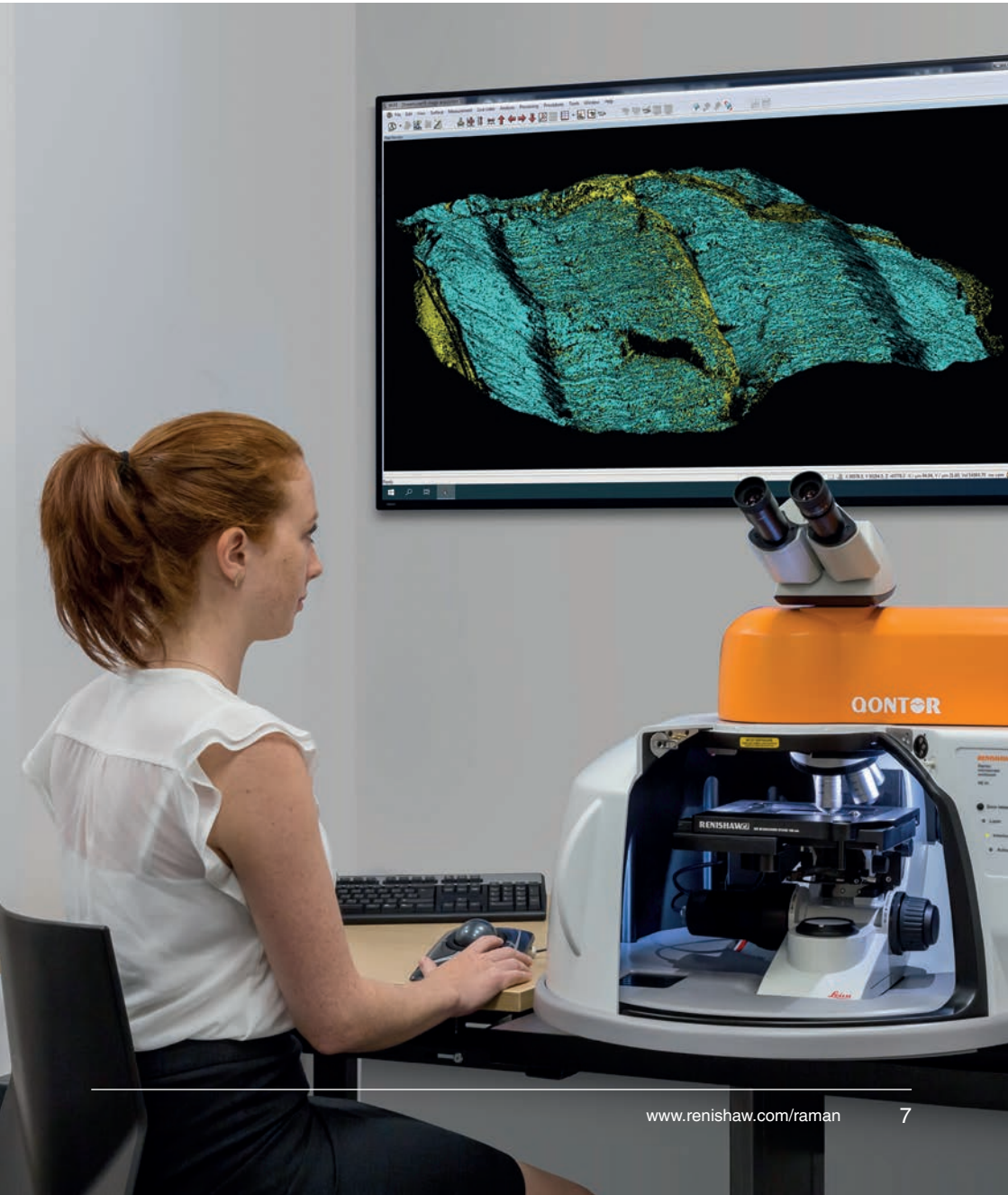
What Raman images can tell you

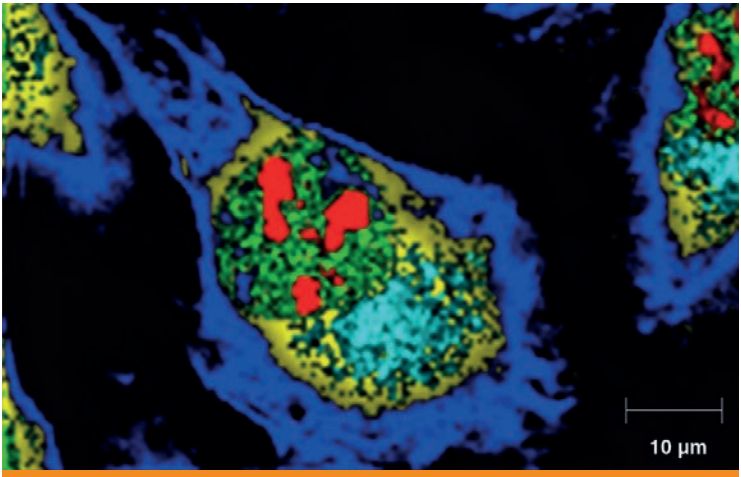


We can use Raman spectroscopy to obtain chemical and structural information that helps us understand the samples we analyse. Raman information can be collected from an array of pointson, or in, a sample, and visually represented as 1D profiles, 2D images or 3D volumes.

Spatial analysis of samples

You can determine:

- if a material or chemical species is present
- if any unknown materials are present
- the distribution of the materials or species
- the size and morphology of any particles or domains
- the relative amounts of materials or species
- variations in structural properties within a sample
- the thickness and composition of layered materials, such as polymer laminates, from micrometres to millimetres thick

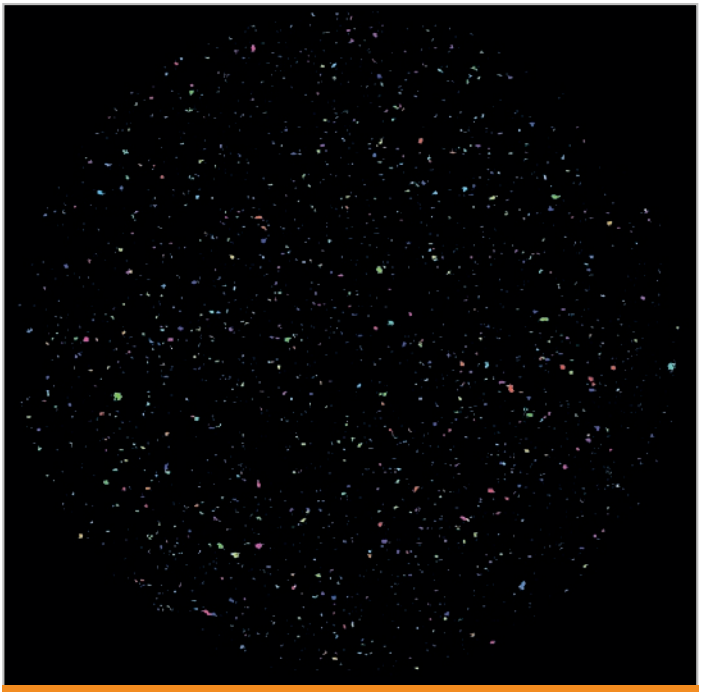


Raman image of human osteosarcoma cells. The colours represent the nuclei (green), nucleoli (red), membrane bound organelles (cyan) and the cell body (yellow – thick region, blue – membranous area).

Quantification of sample composition and structural properties

Images are a powerful way to convey the science of the sample. The brightness, contrast and colour of the image can all be used to emphasise key information. By overlaying or combining individual images, you can display multiple chemical species or parameters at the same time.

Quantitative data can also be extracted from Raman images, such as particle statistics (number of particles/domains, shape or size metrics, etc.). These provide objective metrics from which image information can be confidently quantified, making comparison simple.



Binarised Raman image of talc within a pharmaceutical tablet (10 µm step size producing 672,500 spectra/pixels). Different colours indicate neighbouring particles/domains are separated. Number of domains = 2,524; average equivalent circle diameter = 20.0 µm; average domain area = 411 µm^2.

Why we use Raman spectroscopy

Advantages of Raman spectroscopy

1. Get chemical composition and structural properties of samples

Raman spectroscopy can be used to differentiate and identify chemical groups and crystal structures, enabling chemicals and their polymorphs to be identified.

2. It is widely applicable

All non-metals have active Raman spectra. This is why Raman spectroscopy is ideal for the analysis of unknown samples. Note that metal compounds do provide Raman spectra and Raman analysis is excellent for characterising metal oxides and understanding corrosion.

3. Little sample preparation

If you can use an objective lens to focus light onto your sample, you can collect its Raman spectrum without any sample preparation.

4. Label-free biochemical detection

You don't need any stains or dyes to differentiate between biological tissues and cells.

5. Non-contact and non-destructive analysis

Analyse your sample without changing it.

6. Analyse even trace amounts

The best Raman microscopes can spatially resolve minuscule amounts of material (<1 µm in size) like contaminants, nanodiamonds and monolayer graphene. Such systems have high numerical aperture lenses to efficiently illuminate and collect the Raman-scattered light from a tiny region of the sample.

7. Analyse large samples and bulk chemicals too

Fibre-optic Raman probes can be used for remote chemical analysis. This is perfect for analysing very large samples that cannot be moved to the Raman system. Sometimes, remote in-situ measurements are needed (e.g. at a synchrotron beamline or in a chemical reactor).

8. Analyse through transparent containers and windows

Most Raman instruments use visible or near-visible light. This allows you to perform Raman spectroscopy even when the sample is sealed within a container.

9. Analyse samples in water

You can analyse samples in aqueous solutions, such as colloidal suspensions, living cells or biochemical reaction mixtures. There is no need for time-consuming extraction or drying, which may also alter the chemistry of your samples.

Combine Raman spectroscopy with other techniques

You can combine Renishaw's Raman systems with many other complementary analysis methods, such as:

- Scanning electron microscopy (SEM) using the Renishaw inLux™ SEM Raman interface
- Scanning probe microscopy (SPM) / atomic force microscopy (AFM)
- Photocurrent imaging using the Raman laser
- Photoluminescence (PL) and fluorescence lifetime imaging (FLIM)
- Medium wavelength infrared thermography (MWIR)
- Nanoindentation

Together, these techniques can provide you with a more complete understanding of your samples.

Combine Raman spectroscopy with a wide range of analytical techniques to better understand the science behind your samples.

The inLux SEM Raman interface brings in-situ Raman imaging to scanning electron microscope (SEM) chambers.

Challenges and solutions

Despite the many advantages of Raman spectroscopy, we sometimes need to overcome some practical challenges that are applicable to all Raman instruments. We have solutions so that you can get the best results from your Raman system.

1. Raman is a weak effect

Renishaw's Raman systems overcome this by using cutting-edge, highly efficient optical designs and ultra-sensitive detectors.

2. Background fluorescence from the sample can obscure Raman data

Renishaw Raman systems can be equipped with multiple excitation lasers. This allows you to change to a measurement region that is free from sample fluorescence. For more information see page 29.

3. Many sample surfaces are not flat

In the past, Raman imaging on uneven samples was difficult. Now, with LiveTrack™ focus-tracking technology, Renishaw's Raman microscopes automatically stay in focus throughout data collection. You can investigate how chemistry and structure vary across interesting topographical features.

4. High laser powers can damage samples

Lasers are used to generate Raman-scattered light. Typically, the Raman spectral intensity increases proportionally with increasing laser power. However, at high laser powers, all samples can undergo structural or chemical changes. Here are our solutions:

a. High-throughput spectrometer design; you can produce the highest Raman signals with very low laser powers.

b. Laser power is software controlled and repeatable. In this way, you can be sure that your sample has not changed.

c. Spread the incident laser power over a larger area using line focus mode. You can do this with an inVia microscope, an RA802 Pharmaceutical analyser and an RA816 Biological analyser.

5. Containers and substrates can contribute to your Raman spectrum

You can control the degree of confocality on the inVia™ confocal Raman microscope and the Virsa™ Raman analyser. Combine a high numerical aperture (NA) microscope objective with a highly confocal instrument setting to minimise the sampling volume. This helps to counteract any unwanted contributions from substrate or container materials.

If you wish to analyse a bulk sample in a transparent container, you could use a low NA objective to focus into the vessel. This is another way of maximising the Raman signal from the material of interest and minimising spectral contributions from the container.

6. The background from glass cuvettes or glass microscope slides can obscure the Raman signals of your samples

There are many options for reducing the spectral contribution from substrates and containers:

a. Replace glass microscope slides with stainless steel slides.

b. For biological cells, you can use mirror polished stainless steel, CaF_2 or MgF_2 microscope slides.

c. Replace standard glass containers with quartz, which produces a lower background at 785 nm than standard glass.

7. Cosmic ray features can cause errors in automated data analysis

Cosmic rays are high-energy particles from beyond the Earth's atmosphere. If cosmic rays impact a detector during data collection, high-intensity spikes are recorded in the spectra. Large Raman images often contain thousands of cosmic ray artefacts.

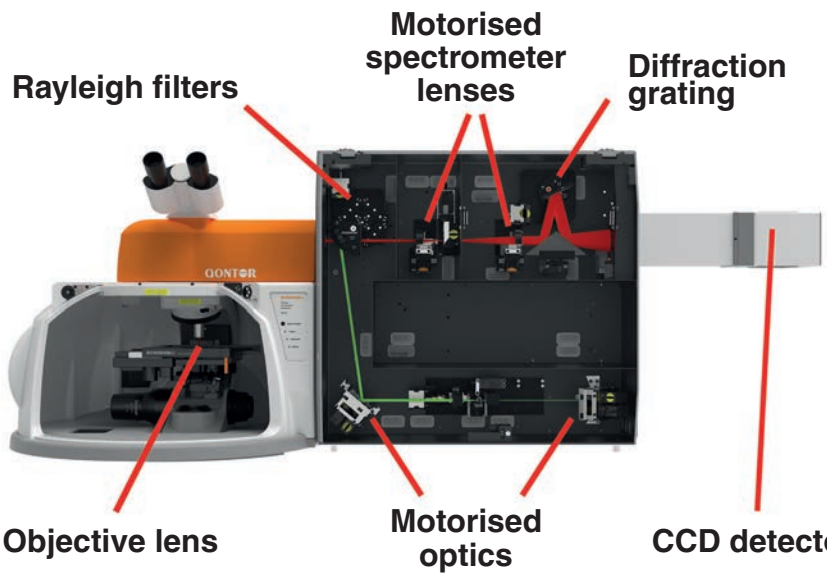
WiRE™ software can automatically remove cosmic rays from very large Raman images, containing up to 50 million spectra. This ensures that an automated workflow can produce reliable results.

Parts of a Raman spectrometer

The Raman effect is very weak; only about 1 part in 10 million of the scattered light has a shifted colour. This is too weak to see with the naked eye, so we analyse the light with a highly sensitive spectrometer.

Renishaw's inVia Raman microscopes consist of:

1. single or multiple lasers from ultraviolet (UV 244 nm) to infrared (IR 1064 nm) with motorised optics. You can change laser wavelength with a single click in the software, without any manual realignment of the optics.
2. high-quality objective lenses to focus the light onto the sample, including highly confocal 100×, long working distance and immersion options
3. motorised spectrometer lenses which are automatically optimised for each laser excitation wavelength
4. Rayleigh filters to separate the reflected and scattered light so that only the Raman light is collected by the spectrometer
5. diffraction gratings with high dispersion to separate the light into its constituent colours
6. a stable and sensitive thermoelectrically cooled (-70 °C) CCD detector
7. a PC for automated system control, data collection and analysis



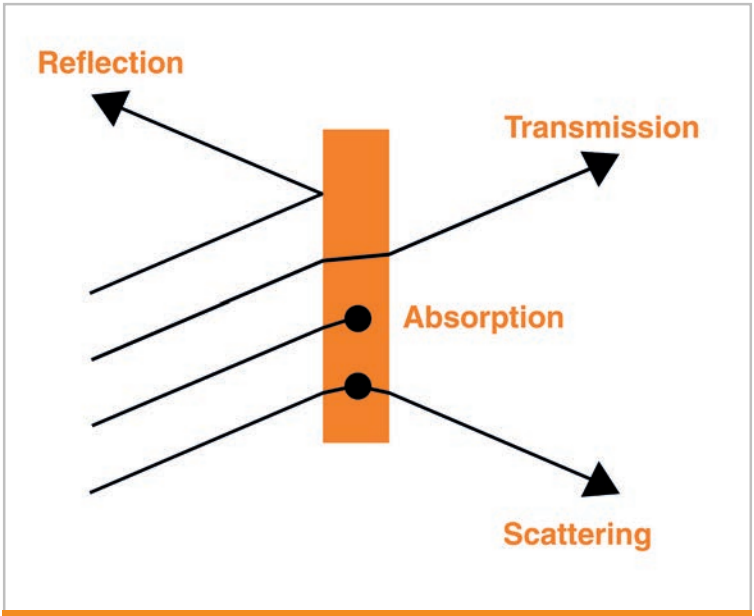
A typical optical layout for an inVia™ confocal Raman microscope.

The Raman effect

What happens when light interacts with matter?

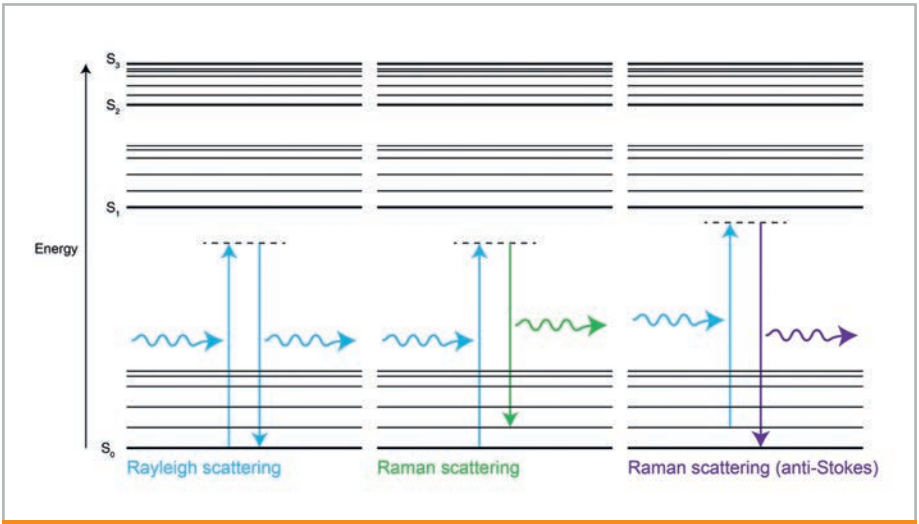
Light interacts with matter in different ways: transmitting through some materials, while reflecting or scattering off others. Both the material and the colour (wavelength) of the light affect this interaction. We call the study of this light 'spectroscopy'.

The parts of the visible spectrum that enter our eyes determine the colours we perceive. For example, a substance might appear blue if it absorbs the red parts of the spectrum of light that fall upon it. Only the blue parts of the visible spectrum are reflected, or scattered, into our eyes.



The different fundamental light processes during material interaction.

Raman spectroscopy looks at the inelastically scattered light. When energy is lost, the Raman scattering is designated as 'Stokes'; where energy is gained, it is designated as 'anti-Stokes'. We rarely use anti-Stokes Raman light as it is less intense than the Stokes, however it does provide equivalent vibrational information.



The change in energy that occurs during Rayleigh and Raman scattering are shown on a Jablonski diagram. S_0, S_1, S_2 are typical electronic energy levels, with higher energy vibrational levels.

Raman spectroscopy is similar to infrared (IR) absorption spectroscopy, but different selection rules apply. For the Raman effect to occur, a change in molecular polarisability is required during vibration. You will see some vibrations in the Raman spectrum that are not visible in the infrared spectrum, and vice-versa, because of the different selection rules. For example, Raman spectroscopy can be used to study the carbon bonds in diamond, unlike infrared absorption spectroscopy.

The Raman shift

By studying molecular vibrations, we can discover the chemical composition and other useful information about the material. The change in energy, or the Raman shift, depends on the frequency of vibration of atoms in a molecule or crystal. The energy change is large (and the vibrational frequency is fast) when there are light atoms held together by strong bonds. The energy change is small (and the vibrational frequency is slow) when there are heavy atoms held by weak bonds.

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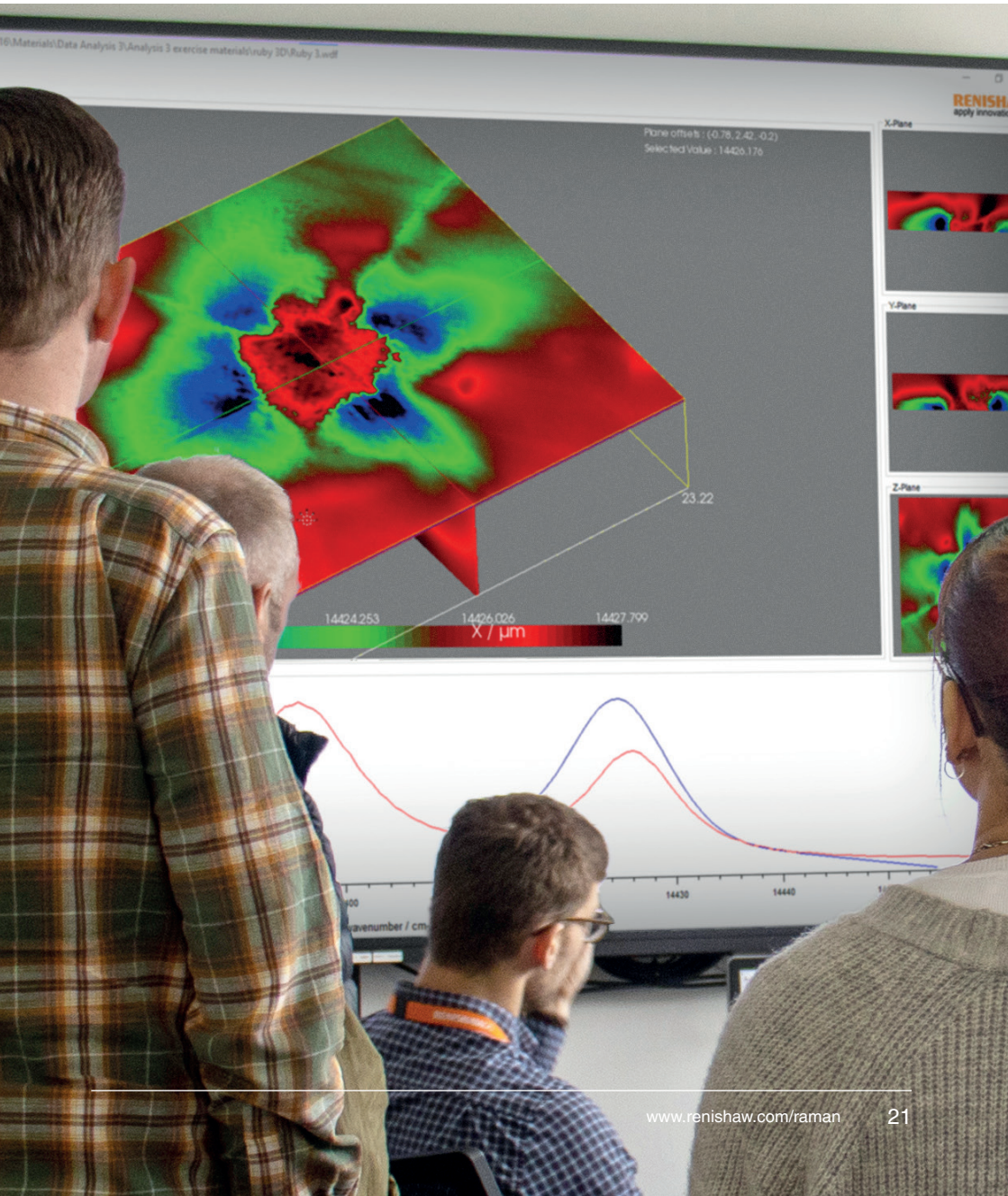
Raman bands explained



How does a Raman spectrum show the chemistry and structure of a sample?

Raman spectroscopy reveals the chemical and structural composition of samples. Generally, all materials produce Raman spectra, except for pure metals.

We graphically display the results of our measurements as Raman spectra. We plot the intensity of the scattered light on the y-axis against the energy (frequency) change of light on the x-axis.

We plot the x-axis frequencies relative to that of the laser because we are interested in the shift in frequency of the Raman-scattered light. Therefore, the x-axis is labelled the Raman shift (shown by the units cm^{-1}).

What do the Raman bands represent?

It is easy to understand the Raman spectrum of crystals with a regular array of identical atoms, all in the same arrangement (such as the carbon atoms in diamond). In these cases, you often see just one dominant Raman band (because there is just one molecular environment of the crystal).

The Raman spectrum of polystyrene, however, is much more complex because the molecule is less symmetric and has hydrogen atoms in addition to carbon atoms. There are also different bond types connecting the atoms.

Characteristic vibrational frequencies

The frequencies of vibration depend on the masses of the atoms involved and the strength of the bonds between them. Heavy atoms and weak bonds have low Raman shifts. Light atoms and strong bonds have high Raman shifts.

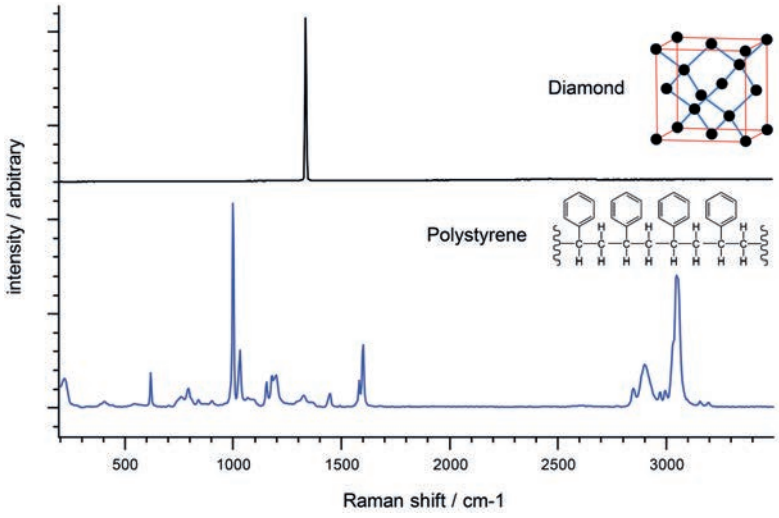
In the polystyrene spectrum, we see the high frequency carbon-hydrogen (C-H) vibrations at about 3000 cm^{-1}. The low frequency carbon-carbon (C-C) vibrations are at around 800 cm^{-1}. The C-H vibrations have a higher frequency than the C-C vibrations because hydrogen is lighter than carbon.

Similarly, we see the vibrations of two carbon atoms linked by strong double bonds (C=C) at around 1600 cm^{-1}. This is at a higher frequency than two carbon atoms linked by a weaker single bond (C-C, 800 cm^{-1}). You can use these simple rules to explain many of the features of Raman spectra.

Raman shifts are sensitive to neighbouring bonds

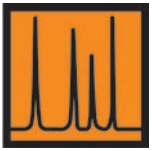
You can see more subtle effects if you inspect spectra closely. The strength of bonds also affects their vibration rates. For example, the C-H vibrations of polystyrene appear as two bands, at approximately 2900 cm^{-1} and 3050 cm^{-1}. The carbons in the former band are part of carbon chains ('aliphatic'), whereas the carbons in the latter band form part of carbon rings ('aromatic').

You can view the vibrations of a complex molecule as partly consisting of many simple diatomic vibrations. However, you can only get a complete understanding of the Raman spectrum by considering the vibrations of larger groups of atoms, such as the expanding/contracting 'breathing mode' of the aromatic carbon ring in polystyrene (at 1000 cm^{-1}).

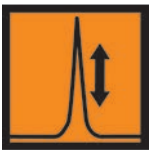


Raman spectra of diamond and polystyrene.

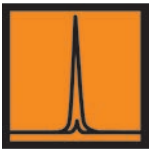
Key features of a Raman spectrum



Characteristic frequencies → **Identify the material using the spectral fingerprint**



Variation in intensity → **Concentration or amount of material**



Variation in intensity with changing laser polarisation → **Crystallographic orientation**

Variation in band position → **Compressive or tensile stress/strain**

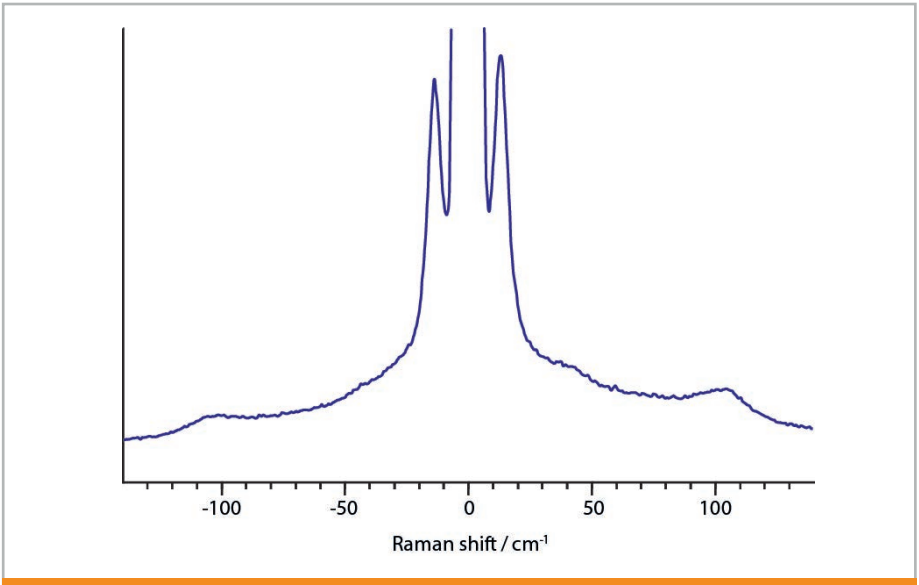
Variation in band width → **Uniformity of bond lengths e.g. crystallinity**

Low-frequency vibrations

You can also study Raman bands with low Raman shifts, below 100 cm^{-1}. These originate from very heavy atoms or very large-scale vibrations, such as the whole crystal lattice vibrating. Renishaw's Raman systems enable you to study these modes. You can explore a wide range of materials and crystals, easily distinguishing between different crystalline forms (polymorphs) and layered structures.

The big picture

A Raman spectrum consists of a range of features, each associated with a vibrational mode. The spectrum is unique to the material and enables you to identify it. It is important to note that, although a full understanding of the vibrational modes is of interest, you rarely need this as you can use a reference library for identification.



A low-frequency Raman spectrum showing both Stokes and anti-Stokes Raman bands due to longitudinal acoustic modes in polyethylene. These Raman bands can be used to measure the long-range order and the degree of crystallinity in polymer samples.

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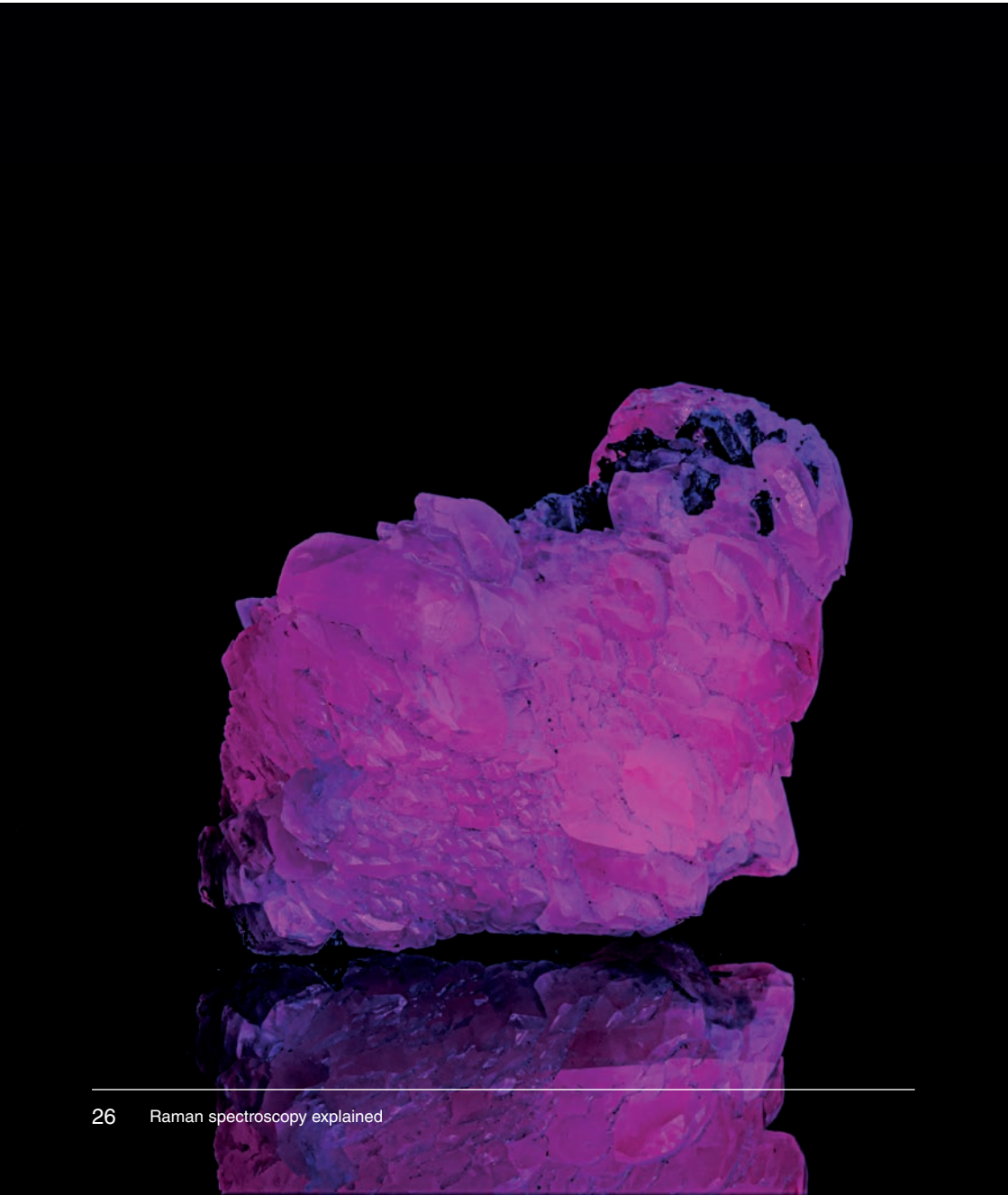
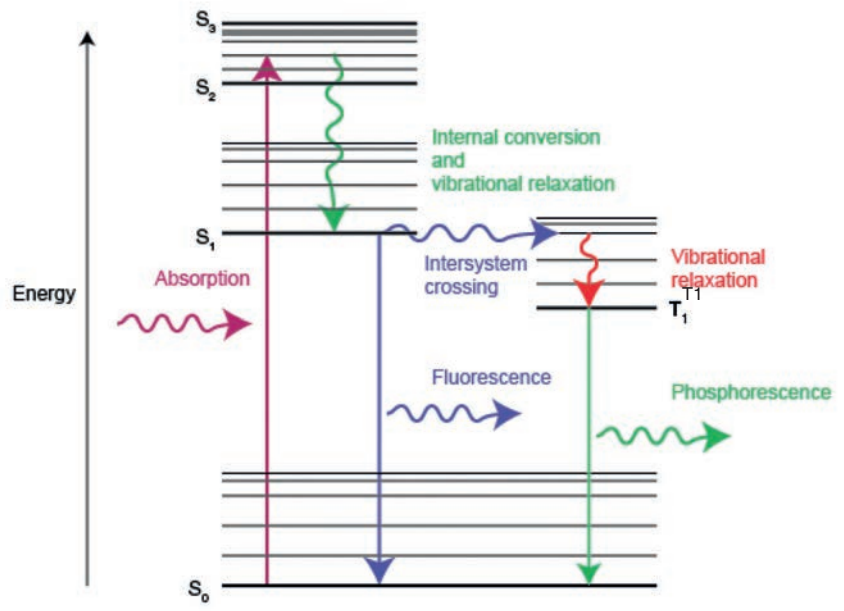
Photoluminescence explained



When a sample is illuminated by a laser, both Raman scattering and photoluminescence (PL) can occur. PL can be many times stronger than Raman scattering and can obscure Raman features.

PL comprises both fluorescence and phosphorescence processes and originates from an absorption/emission process between different electronic energy levels in the material. The amount and type of PL depends on which material you are studying and which laser wavelength you are using. Unwanted fluorescence backgrounds can often be avoided by choosing an appropriate laser wavelength.



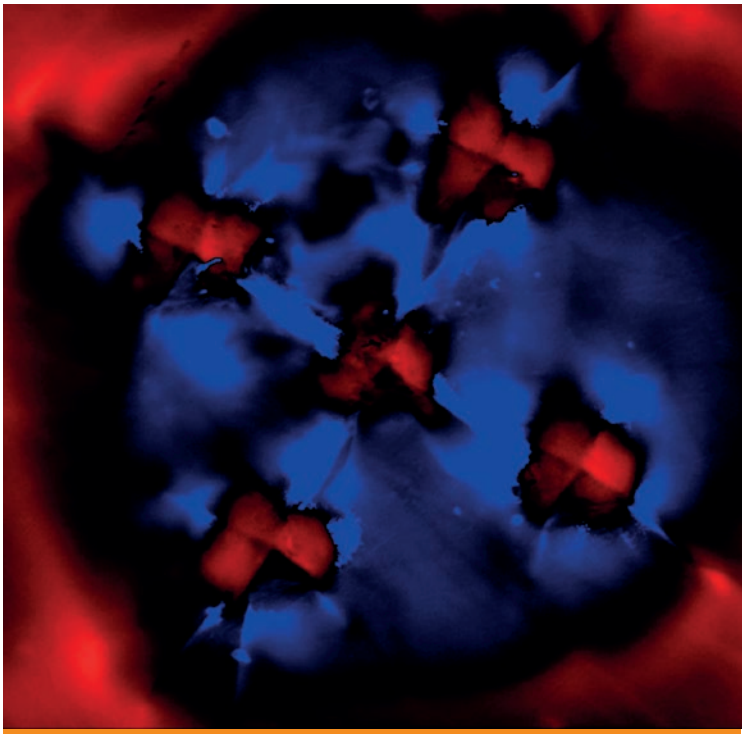
Energy diagram showing absorption of light and the processes involved in the emission of light as fluorescence and phosphorescence.

What photoluminescence (PL) can tell us

In many cases photoluminescence carries useful information that can facilitate sample analysis and augment Raman data. Renishaw Raman systems are suited to the analysis of both Raman scattering and PL. PL spectroscopy can be used to study the electronic properties of materials. It is of vital importance for semiconductor analysis, where it provides information on the band structure of the material and any defects.

Fluorescence imaging (a type of PL) is often employed in the biological sciences, where fluorescent tags (labels) are used to reveal the presence and distribution of molecular species. However, this approach is more invasive than Raman analysis, which is typically label-free.

Renishaw's Raman systems can be used to generate images of fluorescent tags, but more commonly provides valuable label-free chemical information.

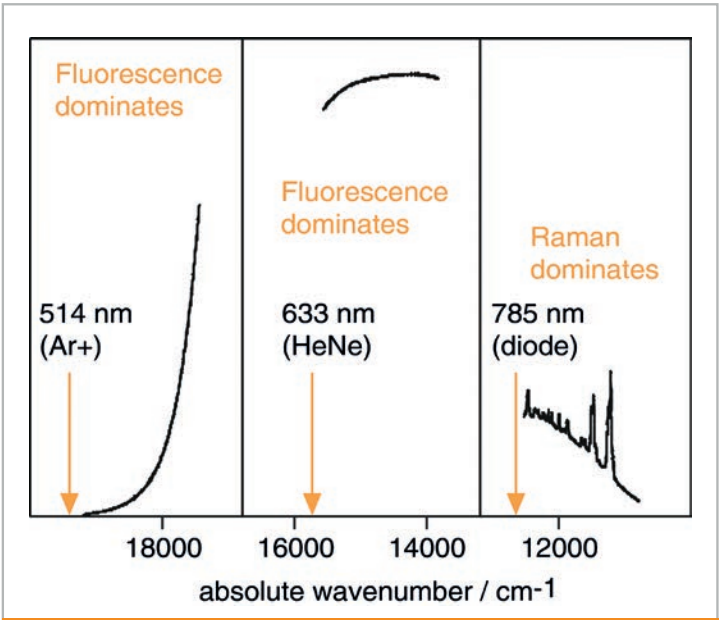


Stress image generated from the ruby R2 PL band position.

How to avoid fluorescence backgrounds

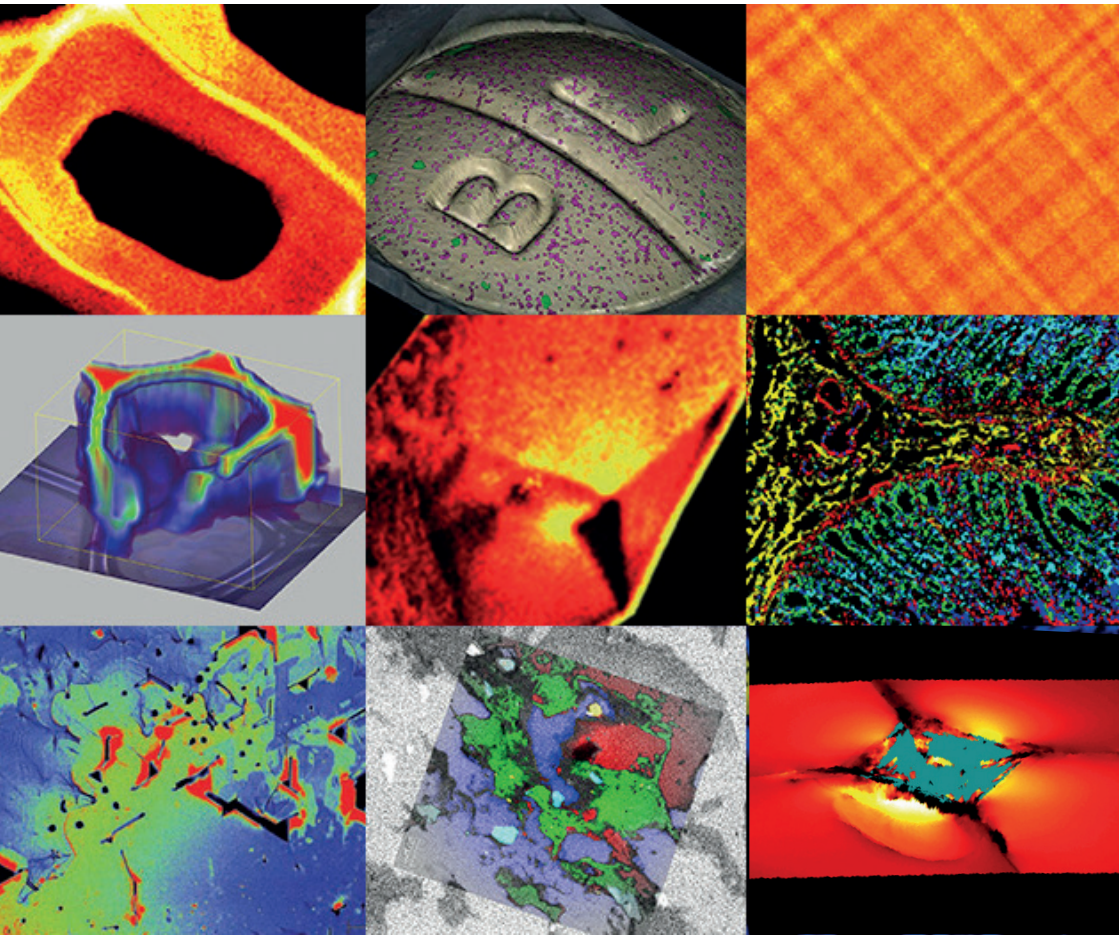
Occasionally, fluorescence bands are strong and broad, masking Raman information. You can avoid this by using a different laser wavelength. This can move the Raman bands away from the peak emission of the fluorescence band and may even avoid generation of the fluorescence entirely.

If you wish to analyse a wide range of materials, your ideal Raman instrument should be able to switch between different laser wavelengths and measure the same sample volume with just one click. Changing excitation laser wavelength can help to avoid unwanted fluorescence features so that the Raman bands are clearly detected. The inVia microscope, the Virsa analyser and the inLux SEM Raman interface feature fully automated switching between laser wavelengths.



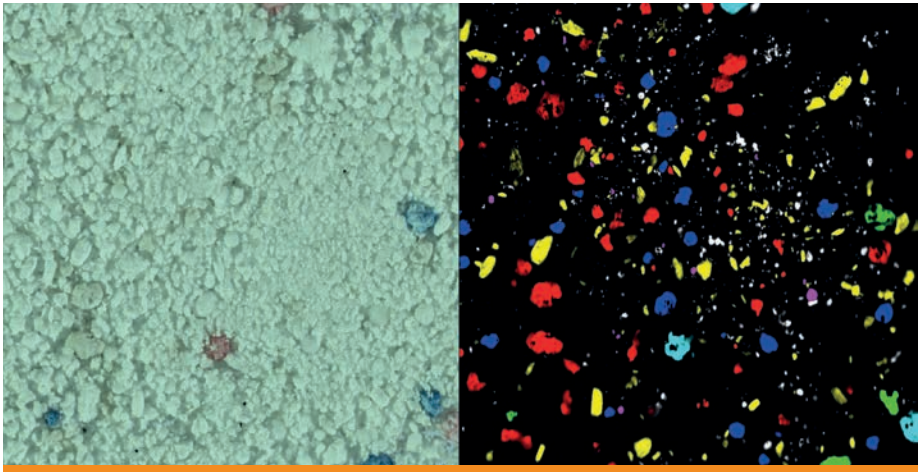
Spectra from a conducting polymer. Raman bands are clearly detected using near infrared laser excitation at 785 nm. When visible laser excitation at 514 nm and 633 nm are used, the spectra are dominated by strong fluorescence. The vertical axes have been scaled for clarity.

Raman images explained in detail

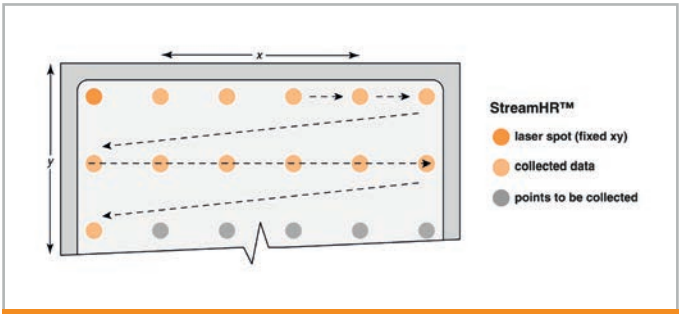


Raman images (sometimes referred to as maps) depict a variation in spectral information from different points on, or in your sample. They can take the form of one-dimensional profiles, two-dimensional images or three-dimensional rendered volumes. With them, you can rapidly see how a Raman parameter alters with position.

The parameter could be as simple as the intensity of a particular Raman band, or you could derive from it a more complete analysis of the whole Raman spectrum.



White light and Raman image of washing detergent. The coloured domains within the Raman image show the distribution of 8 different chemical species. The Raman image was generated by comparing the Raman spectrum from each point against a series of reference spectra. The colour of each pixel is based on the best match.



Schematic diagram of data collection using StreamHR™ rapid imaging technology.

How do we collect Raman images?

We collect a spectral dataset (a Raman spectrum from each position on the sample) in a single data file, rather than a simple intensity image. The resulting spectral hypercube is analysed to produce Raman images.

There are several Raman mapping methods, such as:

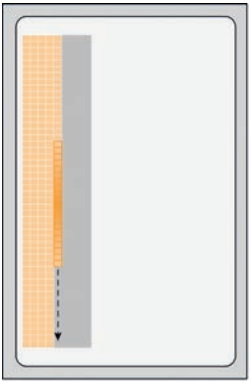
- **Point**

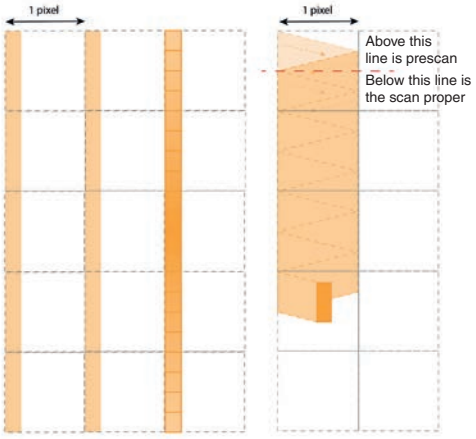
  The laser is focused to a spot. A motorised stage moves the sample under the laser. Spectra are sequentially acquired from an array of sample points spanning the defined region of interest. Fast versions of this method are Renishaw's StreamHR™ and StreamHR™ Rapide imaging technologies. These methods can collect over 1000 spectra per second.

- **Line**

  The laser illuminates a line on the sample, rather than a spot. This enables you to simultaneously collect spectra from multiple positions on the sample, saving time. With this method you can use higher total laser powers without damaging the sample (reducing exposure times). Renishaw's StreamLine™ imaging technology is a sophisticated modern implementation of this concept.

When imaging, it is important to consider the potentially undesirable effects of undersampling. Undersampling occurs if the laser spot or line is smaller than the spacing between acquisition points. Renishaw has solved this problem using StreamLine technology with Slalom mode.





StreamLine technology for fast, yet gentle, Raman imaging

The laser line is scanned across the sample along the y-axis. Data is collected from multiple rows on the CCD detector simultaneously.

The step size in x is equal to the width of the laser line. Complete coverage is achieved.

Undersampling without Slalom mode

If the step size in x is greater than the width of the laser line, some areas of the sample will not be analysed. In this illustration, data is collected from ~20% of the sample.

For fast and complete coverage

The zig-zag motion of the laser line enables a step size in x that is larger than the width of the laser line.

Data is collected from 100% of the sample at the fastest speeds.

Streamline imaging technology with Slalom mode ensures complete sample coverage when using large step (pixel) sizes to achieve the fastest Raman imaging of large samples.

Generating Raman images

Once all the Raman spectra are collected from the mapping experiment, they can be analysed to produce 1D profiles, 2D images or 3D rendered volumes. Analysis options in Renishaw's WiRE software include:

- **Intensity at one frequency in the spectrum**

  These images are quick to generate but may be misleading. Intensity variations may be due to a Raman band of interest. However, changes in spectral intensity can also be caused by background fluorescence or a non-flat sample going out of optical focus.

- **Curve fit parameters**

  All the spectra have a theoretical curve fitted to one or more of the Raman bands. Images are then made based on the calculated curve parameters for each spectrum. Raman images often show the Raman shift of the curve (the band's position), or the full width at half maximum (FWHM), as this is sensitive to stresses and crystallinity within the sample respectively.

- **Multivariate parameters**

  Multivariate analysis is very powerful because it uses information from the entire spectrum, not just one part of it (e.g. intensity at one frequency or one curve-fitted band). This typically results in better chemical specificity and higher quality Raman images.

  If you have pure reference spectra for the materials within your sample, you can create Raman images showing their distribution using Component Analysis methods (i.e. least squares fitting such as non-negative least squares, (NNLS)).

  If you don't have pure reference spectra, images can be generated using cluster analysis (k-means or hierarchical), principal component analysis (PCA), or Renishaw's Empty Modelling™ software feature. The Empty Modelling feature is a user-friendly implementation of the multivariate curve resolution-alternating least squares (MCR-ALS) method. This method reveals systematic variations between the Raman spectra and highlights the distribution of these variations across the sample as an image. This is achieved without prior knowledge of what is present within the sample, which is particularly useful for unknown materials and biological specimens. These advanced analysis features are all part of WiRE software's chemometrics package.

Spatial resolution

Spatial resolution of a Raman image is determined by a few factors:

- **Laser spot size**

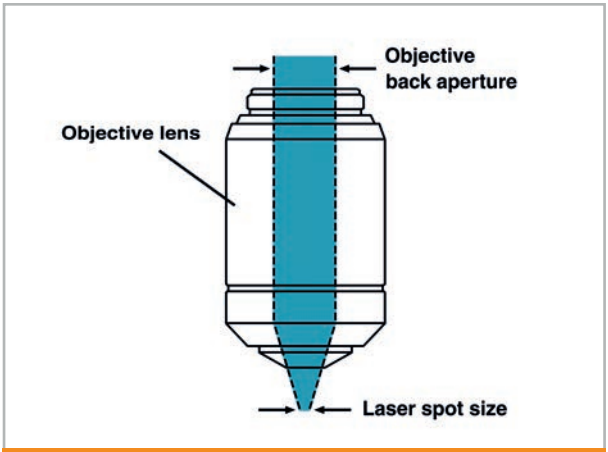
  This is a function of the objective's numerical aperture (N.A.) and the laser wavelength (higher N.A. and shorter wavelengths produce smaller spot sizes)

- **Spacing between spectral acquisition points on the sample (sampling)**

  This is a function of the sample stage. Renishaw's MS30 high speed encoded stage has a large travel range with small step sizes down to 50 nm, which is smaller than the smallest laser spot size.

- **The magnification of the optics in the spectrometer and the size of the CCD pixels.**

  Ultimately this is limited, by the inherent wavelike nature of light, to a little under one micrometre.



Diffraction-limited spot size = 1.22 $\frac{\lambda}{NA}$

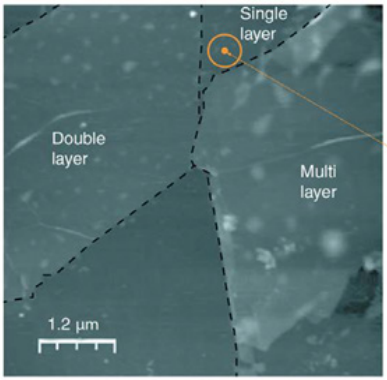
Theoretical resolution limit = 0.61 $\frac{\lambda}{NA}$

SERS/TERS

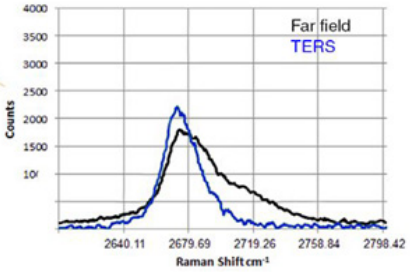
Enhancing Raman

Surface-enhanced Raman scattering (SERS) and tip-enhanced Raman scattering (TERS) both involve the use of metallic nanoparticles or layers to boost the amount of Raman scattering from molecules very close to them. The enhancement can be over a billion times in some cases.

You can detect very low concentrations of material using SERS, and resolve very small features using TERS. These techniques are therefore exciting areas of Raman spectroscopy. It should be noted that the enhancement from these techniques only applies to a small range of sample types. In addition, the samples typically require specialist sample preparation.



AFM image of a graphene flake



Raman spectra from far field and TERS measurements

AFM image of a graphene flake with Raman spectra from far-field and TERS measurements. The TERS Raman spectrum easily resolves the small region of single-layer graphene, while the far-field spectrum has a broader 2D band showing some contribution from the double-layer graphene.

The enhancement mechanisms

Two effects cause the enhancement to the Raman scattering from molecules close to the metal:

- The metal can amplify the electric fields of the incoming laser light and the outgoing Raman scattered light
- The metal can alter the distribution of charges within adsorbed molecules, causing stronger scattering

SERS

SERS normally uses either a colloidal suspension of metal (e.g. silver or gold) or a patterned metal surface. These enhance the Raman scattering from molecules adsorbed onto the metal surfaces. SERS enables new applications, such as the detection of very low concentrations of material in medical applications.

TERS

TERS uses a metallic-coated tip—typically on a scanning probe / atomic force microscope—to enhance the Raman signal from molecules within a few nanometres of the tip. You can determine the spectrum originating from molecules solely in the small volume close to the tip. This is done by comparing the spectrum from the surface with and without the tip present. This can give a much higher spatial resolution than normal Raman scattering (nanometre-scale, rather than about 0.2 µm).

Renishaw's combined Raman-SPM/AFM systems are available with TERS options.

Renishaw's key technologies

Since its establishment in 1973, Renishaw has been strongly committed to research and development. With numerous awards throughout our product lines, we are recognised as a world leader in devising novel mechanical, electronic, and optical technologies.

We use innovative technologies in our Raman spectroscopy products, including:

SynchroScan™ extended scanning technology

Continuous scanning for artefact-free extended spectra

High-definition Raman images

Collect and analyse millions of spectra in a single data file

StreamLine™ imaging technology

Uses laser line illumination for fast Raman imaging

EasyConfocal™ method

Confocal chemical and structural information in 3D

StreamHR™ imaging technology

Uses a laser spot for the fast generation of high spatial resolution confocal 2D and 3D images

LiveTrack™ focus-tracking technology

Maintain focus automatically in real time during data collection and white-light video viewing

Automatic cosmic ray remover

Quick and easy removal of cosmic ray artefacts from your spectra

MS30 high speed encoded stage

For accurate and repeatable positioning of your samples

Automatic intelligent background removal

Removes fluorescent backgrounds from spectral data

Full instrument automation

Simple and intuitive workflows for routine operation

Empty Modelling™ software feature

Chemometric method for extracting chemical information from Raman data

Kinematic mounts

Fast swap between optical components without any manual alignment

Renishaw's Raman products

Scientists and researchers use Raman spectroscopy to analyse a wide range of samples.

We are a recognised leader in Raman spectroscopy and our systems offer the highest levels of flexibility and performance.

With a range of products, we can help you get the best Raman spectroscopy solution for your needs.

inVia™ Qontor® confocal Raman microscope

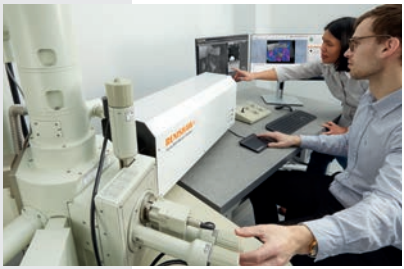
Our most advanced Raman microscope. The inVia microscope is a best-selling research-grade confocal Raman microscope which boasts ultimate flexibility, speed and sensitivity.

Virsa™ Raman analyser

The Virsa analyser is optimised for conducting research-grade analysis outside the laboratory. It has different configurations suited for process analysis, in-situ measurements and remote measurement of large objects.

inLux™ SEM Raman interface

The inLux SEM Raman interface brings Raman imaging to your scanning electron microscope (SEM) chamber. Now you can collect 2D and 3D Raman images whilst simultaneously imaging in SEM.

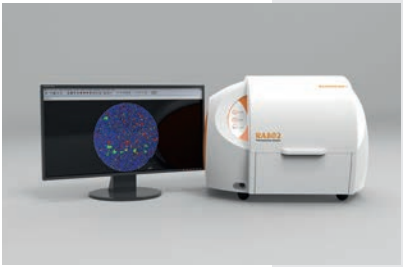


Custom Raman solutions

If our standard products don't match your exact needs, our Special Products Team can develop a custom solution to meet your requirements.

Combined/hybrid Raman systems

Couple an inVia microscope or a Virsa analyser to other analytical instruments, such as atomic force microscopes.



RA802 Pharmaceutical analyser

A dedicated, high-speed Raman imaging system designed for pharmaceutical analysis. Speed up drug development or perform root cause analysis.

RA816 Biological analyser

Identify and assess biochemical changes associated with disease formation and progression. Integrated performance qualification ensures stable and repeatable analysis.

Learn how to use your Renishaw system

We want you to realise the full potential of your Raman system and make use of all its features and capabilities. We offer a range of training options to help you achieve this:

‘Start-up’ training

On system installation, we provide two-days of personalised ‘start-up’ training. We demonstrate the Raman system’s data collection, processing and analytical capabilities. This training includes operation, preventive maintenance, calibration and alignment routines that are needed to ensure reliable results.

Online how-to guides and videos via our dedicated portal

Access our comprehensive online library of training modules and videos.

Raman Revealed workshops

A hands-on training course. You will learn how to optimise measurements on an inVia microscope. Our applications scientists will take you step-by-step through the powerful data processing and analysis tools available in WiRE software.

Bespoke training

We can provide training tailored specifically for your application needs. This is delivered by our applications team either at your site, or at a Renishaw site.

Visit www.renishaw.com/RamanTraining for more information.

Renishaw. The Raman innovators

Renishaw manufactures a wide range of high-performance optical spectroscopy products. These include confocal Raman microscopes for high-speed chemical imaging, dedicated Raman analysers, interfaces for scanning electron and atomic force microscopes, solid-state lasers for spectroscopy and state-of-the-art cooled CCD detectors.

We design instruments with the highest levels of performance, sensitivity and reliability for a diverse range of fields and applications. With a Renishaw Raman spectrometer, you can tackle even the most challenging analytical problems with confidence.

A worldwide network of subsidiary companies and distributors provides exceptional service and support for our customers.

If you have any questions about how Renishaw can help with your Raman analysis, please send an email to **raman@renishaw.com**

www.renishaw.com/raman

#renishawraman

+44 (0) 1453 524524 **raman@renishaw.com**

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