

# Raman spectroscopy explained



### Raman spectroscopy explained

Renishaw has been supplying Raman spectroscopy systems since the early 1990s. One of the most frequent questions our staff are asked is "What is Raman spectroscopy?"

This booklet answers this question, and related questions such as "How are Raman images generated?" and "What is SERS?" We hope you find it useful.

If you would like any additional copies, or if you have any comments or suggestions for how we can improve it, please contact us.

Renishaw plc New Mills, Wotton-under-Edge Gloucestershire GL12 8JR United Kingdom

raman@renishaw.com www.renishaw.com/raman



### Contents

1.	What Raman spectroscopy can tell you	4
2.	What Raman images can tell you	8
3.	Why we use Raman spectroscopy	11
4.	Raman spectroscopy: important considerations	15
5.	A basic overview of Raman spectroscopy	18
6.	Raman spectroscopy in more detail	21
7.	Raman spectra explained	24
8.	Raman bands explained	27
9.	Photoluminescence explained	30
10.	Raman images explained	33
11.	SERS/TERS.	38
12.	Renishaw's key technologies	41
13.	Renishaw's Raman products	44

## 1. What Raman spectroscopy can tell you





Raman spectroscopy produces chemical and structural information to help us understand more about the material being analysed. This page details some of the benefits of Raman spectroscopy.

### Identify unknown materials

We can identify unknown materials from their unique Raman spectral fingerprints, typically using databases 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 erectile dysfunction tablet.

### What Raman spectroscopy can tell you

### **Differentiation of materials**

You can determine if materials are the same or different 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 (polymorphic) of the same chemical.



Spectra of three different polytypes of SiC



### Quantification of material composition and properties

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

- the relative amount of material
- · layer thickness from monolayer up to hundreds of nanometers
- crystallinity
- whether it is under compression or tension
- temperature



Raman shift / cm-1

Raman spectra of two polyethylene samples showing a difference in crystallinity

## 2. What Raman images can tell you





We can use Raman spectroscopy to obtain chemical and structural information that helps us understand more about the materials we analyse. This information can be collected from an array of points on—or in—a sample, and visually represented as images (1D, 2D or 3D) depicting any of the parameters which can be revealed using Raman.

### Spatial analysis of material

You can determine:

- · if a specific material or species is present
- · if any unknown materials are present in the sample
- the variation in a parameter of a material, such as crystallinity or stress state
- · the distribution of the material or species
- · the size of any particles or domains
- the thickness and composition of layered materials, such as polymer laminates, from micrometres to millimetres thick
- · the relative amounts of materials or species



StreamLine Raman image of tablet used for the treatment of Parkinson's disease.

### What Raman images can tell you

### Revealing the science from the image

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 species or parameters at the same time.

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



Raman image of montelukast sodium



## 3. Why we use Raman spectroscopy



### Why we use Raman spectroscopy

### Advantages of Raman spectroscopy

### Chemical composition and structure of materials

Raman spectroscopy can differentiate chemical structures, even if they contain the same atoms in different arrangements.

### Non-contacting and non-destructive

Analyse your sample multiple times without damage.

### Typically no sample preparation

If you can use an optical microscope to focus onto the analysis region, you can use a Raman microscope to collect its Raman spectrum.

# You can choose how much, or little, of the sample you want to analyse

The best Raman microscopes provide flexibility in controlling collection volumes, ranging from minute amounts of material (<1  $\mu$ m in size) to samples centimetres across.

#### Analyse through transparent containers and windows

Most Raman analyses use visible or near-visible light. It is, therefore, simple to collect the content-rich information even when the sample is sealed within a transparent container (e.g. vial or capillary tube), or within a cell with a viewing window (e.g. temperature or pressure cell).

### Sensitive to small changes in material structure

Raman bands result directly from molecular vibrations. These vibrations are very sensitive to changes in chemistry and structure, so you can spot subtle differences in molecular environment. The direct relationship between vibrations and Raman bands also makes interpretation easier.

#### You can analyse samples in water

You can analyse samples in aqueous solutions, such as suspensions or biological samples.



There is no need for time-consuming extraction or drying, which may also alter the chemistry of your samples.

### It works on almost all materials

Almost all materials exhibit Raman scattering. The only exception is pure metals, which just reflect light. (However metallurgists use Raman spectroscopy because carbides, nitrides and oxides do Raman scatter).

### It uses light

Scientists and engineers can apply the tricks they already know about manipulating light to Raman spectroscopy. For example:

- fitting a powerful microscope to a Raman spectrometer enables the analysis of micrometresized particles of material.
- fibre optics can be used to make Raman measurements remote from the Raman system. This is perfect for applications where very large samples need analysing, or where remote *in situ* measurements are needed (such as when Raman analyses are being undertaken on a synchrotron beamline or in a process reactor).

### **Other benefits**

High resolution Raman systems reveal numerous well-defined Raman bands, enabling not only unambiguous material identification but also the determination of sample stress.

### Why we use Raman spectroscopy

### **Combine Raman spectroscopy with other techniques**

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

- Scanning probe microscopy (SPM) / atomic force microscopy (AFM)
- Scanning electron microscopy (SEM)
- Confocal laser scanning microscopy (CLSM)

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



inVia with Bruker Nano Surfaces Innova atomic force microscope



## 4. Raman spectroscopy: important considerations



### Raman spectroscopy: important considerations

### Getting the best from your Raman system

While Raman spectroscopy has many advantages, it can present some challenges. There are ways we can address some of the issues encountered during its use.

### Raman is a weak effect

Renishaw's Raman systems overcome this by using highly efficient optical designs and ultrasensitive detectors.

# Photoluminescence (PL) is a strong effect that can mask Raman information

By using a multiple laser system you can switch to a different excitation wavelength. This maximizes your chances of producing spectra whose Raman features are not masked. For example, switching from a visible to a near-infrared laser (e.g. 785 nm) usually reduces PL.

# Chemical glassware, such as glass cuvettes or microscope slides, can mask the Raman signals of your samples

You can avoid this by using a metal microscope slide rather than a glass one. When you have to use a transparent vessel, you can select a glass type with a weak Raman signal (e.g. quartz is weaker and less intrusive at 785 nm than standard glass). In some cases, you can use replacement materials such as  $CaF_2$  or  $MgF_2$ . These produce a few narrow Raman bands, typically located in a different part of the spectrum to those of the material you are studying.

The inVia is a confocal Raman microscope. This enables the sampling volume to be minimised, helping to counteract any unwanted contributions from substrate or container materials.

### Renishaw is leading the way in avoiding sample damage

Lasers are used to generate Raman scattering. The Raman signal is typically proportional to the amount of laser power, so more power usually means a stronger signal. All samples have a laser power density threshold beyond which structural or chemical modification may occur.



Renishaw's Raman systems provide unrivalled laser control performance; you can be confident your sample has not changed. inVia confocal Raman microscopes do this by using 16 or more repeatable and software-controlled power levels, combined with multiple focus modes such as spot focus, line focus, and enlarged spot focus. Together with inVia's market-leading sensitivity, these produce the highest Raman signals at the lowest possible power densities. Sample integrity is maintained and data collection speeds are fully optimised.

### Control the volume of sample analysed

Renishaw's Raman systems use powerful microscope lenses to collect the Raman scattered light. These have high numerical apertures and efficiently collect the light scattered, over a wide range of angles, from a tiny region of the sample. This is in comparison with bulk analysis systems which typically use lower magnification lenses and sample larger volumes.

Renishaw's systems are fully configurable, enabling both bulk analysis and confocal microscopy operation, without compromise. This is achieved using integrated fibre probe options and fast averaging modes incorporated within the StreamLine<sup>™</sup> Slalom option. Averaging is performed on the detector and readout noise is minimised.

## 5. A basic overview of Raman spectroscopy





### Spectroscopy and light

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'. Which parts of the visible spectrum enter our eyes determines which colours we perceive.

A substance might appear blue, for example, if it absorbs the red parts of the spectrum of light falling upon it, only reflecting (or scattering) the blue parts into our eyes.



The different fundamental light processes during material interaction

### Raman spectroscopy looks at the scattered light

If you were to shine blue light—from just one part of the spectrum—onto the material, you might expect to just see blue light reflected from it, or no light at all if it is completely absorbed (i.e. a black material).

However, by using a Raman spectrometer, you can see that often a very tiny fraction of the scattered light has a different colour. It has changed frequency because, during the scattering process, its energy changed by interacting with molecular vibrations. This is the Raman scattering process, named after its discoverer, the famous Indian physicist C.V. Raman. He was awarded the 1930 physics Nobel Prize for this great discovery.

### A basic overview of Raman spectroscopy

By studying the vibration of the atoms we can discover the chemical composition and other useful information about the material.

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.

#### **Raman spectrometers**

These systems consist of:

- · one or more single coloured light sources (lasers)
- · lenses (both to focus the light onto the sample and to collect the scattered light)
- filters (to purify the reflected and scattered light so that only the Raman light is collected)
- a means of splitting the light into its constituent colours (normally a diffraction grating or prism)
- · a very sensitive detector (to detect the weak light)
- a device such as a computer to control the whole system, display the spectrum and enable this information to be analysed

Raman scattering offers significant advantages for the investigation of materials over other analytical techniques, such as x-raying them or seeing how they absorb light (e.g. infrared absorption or ultraviolet absorption).



## 6. Raman spectroscopy in more detail



### Raman spectroscopy in more detail

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

### Raman scattering

Raman scattering occurs when light interacts with molecular vibrations. This is similar to the more widely known infrared absorption spectroscopy, but different rules apply. A change in molecular polarisability is required during the vibration for the Raman effect to occur.

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 is superb for studying the carbon atoms that make up the structure of diamond, unlike infrared absorption spectroscopy.

### Scattered light

The first step in producing a Raman spectrum is to illuminate your sample with a monochromatic light source, such as a laser.

Most of the light that scatters off is unchanged in energy ('Rayleigh scattered'). A minute fraction—perhaps 1 part in 10 million—has lost or gained energy ('Raman scattered'). This Raman shift occurs because photons (particles of light) exchange part of their energy with molecular vibrations in the material.

Where energy is lost the Raman scattering is designated as 'Stokes'; where energy is gained the Raman scattering is designated as 'anti-Stokes'. We rarely use anti-Stokes Raman light as it is less intense than the Stokes, however it does represent equivalent vibrational information of the molecule.





Rayleigh and Raman scattering energy diagram.  $S_{q'} S_{r}$ ,  $S_{2}$  are electronic energy levels, with higher energy vibrational levels.

### **Vibrating atoms**

The change in energy depends on the frequency of vibration of the molecule. If it is very fast (high frequency)—light atoms held together with strong bonds—the energy change is significant. If it is very slow (low frequency)—heavy atoms held together with weak bonds—the energy change is small.

### **Raman spectrometers**

Renishaw inVia systems consist of:

- single or multiple lasers, from UV (244 nm) to IR (1064 nm) switch with a single click
- high quality objective lenses, from high confocal 100× to long working distance and immersion options
- · custom designed motorised spectrometer lenses automatically align for each configuration
- · laser-line-specific Rayleigh filters with a dual filter arrangement to optimise sensitivity
- · highest quality master diffraction gratings provide exceptional dispersion and longevity
- thermoelectrically cooled (-70 °C) CCD detector stable and sensitive
- · high specification multi-core PC for data collection and analysis

## 7. Raman spectra explained





### Raman spectra

We graphically depict the results of our measurements as Raman spectra. We plot the intensity of the scattered light (y-axis) for each energy (frequency) of light (x-axis). The frequency is traditionally measured in a unit called the wavenumber (number of waves per cm, cm<sup>-1</sup>).

We plot the x-axis frequencies relative to that of the laser as it is the shift in energy of the light that is of particular interest.



Raman spectrum of polystyrene

### How do I get the information I want from my spectrum?

You can tell a great deal about a material from its Raman spectrum, with different features relating to different aspects of the material.

The key features are:

The Raman shifts and relative intensities of all of the Raman bands of the material With this, we can identify the material.

#### Individual band changes

A band may shift, narrow or broaden, or vary in intensity. These changes can reveal information about stresses in the sample, variations in crystallinity, and the amount of material respectively.

### Raman spectra explained

### Variations in spectra with position on the sample

This will reveal changes in the uniformity (homogeneity) of the material. You can analyse at several arbitrary points, or systematically measure an array of points (enabling the production of images of composition, stress, crystallinity, etc).



## 8. Raman bands explained



### **Raman bands explained**

### 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 configuration (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.





### **Vibration frequencies**

28

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.

We see the high frequency carbon-hydrogen (C-H) vibrations in the polystyrene spectrum at about 3000 cm<sup>-1</sup>. The low frequency carbon-carbon (C-C) vibrations are at around 800 cm<sup>-1</sup>. The C-H vibrations have a higher frequency than the C-C vibrations because hydrogen is lighter than carbon.



We see the vibrations of two carbon atoms linked by strong double bonds (C=C) at around 1600 cm<sup>-1</sup>. This is at a higher frequency than two carbon atoms lined by a weaker single bond (C-C, 800 cm<sup>-1</sup>).

You can use these simple rules to explain many of the features of Raman spectra.

### **Vibrations in detail**

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 in two bands, at approximately 2900 cm<sup>-1</sup> and 3050 cm<sup>-1</sup>. The carbons in the former are part of carbon chains ('aliphatic'), whereas the carbons in the latter form part of carbon rings ('aromatic').

You can view the vibrations of a complex molecule as partly consisting of many simple diatomic vibrations. However the full richness of the Raman spectrum can only be understood by considering the vibrations of larger groups of atoms, (such as the expanding/contracting 'breathing mode' of the aromatic carbon ring that appears at 1000 cm<sup>-1</sup> in polystyrene).

### Low frequency vibrations

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

### The big picture

A Raman spectrum therefore 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 database for identification.

## 9. Photoluminescence explained





When a sample is illuminated by a laser, both Raman scattering and photoluminescence (PL) can occur. The latter can be many times stronger than the former and can prevent successful Raman analysis.

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 interference can normally 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.

### **Photoluminescence explained**

### What PL can tell us

In many cases photoluminescence carries useful information that can facilitate sample analysis and augment the Raman data. inVia confocal Raman microscopes are suited to the analysis of both Raman scattering and PL.

Fluorescence imaging (a type of PL) is often employed in the biological sciences, where fluorescent tags are used to reveal the presence and distribution of molecular species. However, this approach is more invasive than Raman analysis, which is typically tag-free. Renishaw's inVia confocal Raman microscope can be used to generate images of fluorescent tags, but more commonly provides valuable tag-free chemical information.

You can also use PL to study crystal defects, such as atomic vacancies and substitutions. This is of particular importance for materials such as diamond and silicon carbide (SiC). Not only can you identify the defect, but you can also tell if the crystal has internal stresses.



Stress image generated from the ruby R2 PL band position

### How to avoid PL backgrounds

32

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

Ideally, a Raman instrument should be able to switch rapidly and easily between different laser wavelengths, so that you can select or avoid PL features, depending on your requirements.



## 10. Raman images explained



### **Raman images explained**

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 it from a more complicated analysis of the whole Raman spectrum.

The two main methods of collecting the spectral data to generate these images are Raman mapping and Raman imaging.



White light and Raman images of washing powder



### Raman mapping

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

There are several Raman mapping methods, such as:

#### Point-by-point mapping

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 are Renishaw's StreamHR<sup>™</sup> and StreamHR Rapide.

#### · Line focus mapping

This is similar to point-by-point mapping, but 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 laser powers without damaging the sample (reducing exposure times). Renishaw's StreamLine<sup>™</sup> is a sophisticated modern implementation of this concept.

It is important to consider the potentially undesirable effects of undersampling when mapping. This is most clearly illustrated when point-by-point mapping: parts of the sample will be 'missed' if the laser spot is smaller than the spacing between acquisition points. Renishaw has solved this problem through the use of the StreamLine<sup>™</sup> Slalom mode.

#### Generating Raman images from map data

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

#### · Intensity at one frequency in the spectrum

This produces an equivalent image to that from Raman imaging. These are quick to generate but may be misleading because it is not possible to differentiate between intensities arising from a Raman band of interest and those associated with a broad background fluorescence.

### **Raman images explained**

#### · Curve fit parameters

All the spectra in the set have a theoretical curve fitted to one of the Raman bands. Images are then made based on the theoretical curve parameters for each spectrum. Images are often made using the centre frequency of the curve (band), or the full width at half maximum (FWHM), as this is sensitive to stresses and crystallinity within the sample respectively.

#### Multivariate parameters

Images can be generated using chemometric tools, such as generic principal component analysis (PCA), or Renishaw's Empty Modelling<sup>™</sup>, which is optimised for Raman data. The Empty Modelling 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 the need for prior knowledge of what is present within the sample, which greatly simplifies the analysis process. Multivariate analysis is very powerful because it uses information from the entire spectrum, not just one part of it (intensity at one frequency) or one curve-fitted band. This typically results in higher quality Raman images.

### Raman imaging

Raman imaging is analogous to taking a photograph; spectral intensity values are collected simultaneously from the entire area of interest. The laser illuminates a square or circular region on the sample. The light is filtered so that the intensity of just one narrow part of the spectrum is recorded on the detector.

The single image collected contains limited information, just the intensity of the light at that frequency. However, these images can be acquired rapidly. This is especially true if you have a high power laser; because the light is spread over an area, you can use all the power without damaging your samples, with correspondingly short exposure times.

Two-dimensional images are typically produced using this method. Renishaw's True Raman Imaging is an example of Raman imaging.

Note that it is possible to collect intensity values covering multiple points of the spectrum by using multiple and/or tuneable filters.



### **Spatial resolution**

#### Point-by-point Raman mapping

Spatial resolution is determined by a combination of the laser spot size and the spacing between acquisition points on the sample.

#### · Laser spot size

This is a function of the objective magnification and the laser wavelength (higher magnification and shorter wavelengths produce smaller spot sizes)

#### · Spacing between acquisition points on the sample (sampling)

This is a function of the sample stage (ideally stages should have a large travel range while still enabling a step size down to 100 nm, smaller than the smallest spot size)

#### Raman imaging

Spatial resolution is determined by the magnification of the optics in the system and the size of the elements in the detector. Ultimately this is limited, by the inherent wavelike nature of light, to a little under a micrometre.

## **11. SERS/TERS**





### **Boosting Raman**

SERS (surface-enhanced Raman scattering) and TERS (tip-enhanced Raman scattering) both involve the use of metallic particles 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 (SERS) and resolve very small features (TERS). These techniques are therefore exciting areas of Raman spectroscopy.





AFM image of a graphene flake



AFM image of a graphene flake with Raman spectra from far-field and TERS measurements.

### 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/TERS**

### SERS

SERS normally uses either a colloidal suspension of metal (e.g. silver) or a roughened metal surface. These enhance the Raman scattering from molecules adsorbed onto the metal surfaces. SERS enables new applications, such as the analysis of 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 gives a much higher spatial resolution than normal Raman scattering (nanometre-scale, rather than about 0.2  $\mu$ m).

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



## 12. Renishaw's key technologies



### Renishaw's key technologies

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

The Spectroscopy Products Division reflects this with its innovations in Raman spectroscopy. The following core technologies are widely used in our products.

### SynchroScan™

Continuous scanning for seamless wide-range spectra.

### StreamLine™

Uses line illumination for rapid, 2D mapping of samples.

### StreamLine<sup>™</sup> Slalom

Uses a zig-zag motion with line illumination for 100% coverage over large areas.

### **StreamHR**<sup>™</sup>

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

### True Raman imaging<sup>™</sup>

Rapid snapshots of large areas without sample movement.

### High definition Raman images:

Collect and analyse large datasets.

### **EasyConfocal**<sup>™</sup>

Confocal, chemical and structural information in 3D.

#### Surface

Collect Raman data over predefined surfaces.



### LiveTrack<sup>™</sup>

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

### **Cosmic ray remover**

Quick and easy removal of cosmic ray artefacts from your spectra.

### Automatic intelligent background removal

Removes fluorescent backgrounds from spectral data.

### Empty modelling<sup>™</sup>

Chemometric method for extracting chemical information from Raman data.

### High speed encoded stage (HSES)

For accurate and repeatable positioning of your samples.

### **Full automation**

Simplifies instrument operation.

### **Kinematic mounts**

Makes it easy to remove and replace components precisely.

## 13. Renishaw's Raman products





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

Renishaw is 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 confocal Raman microscopes



### inVia<sup>™</sup> Basis confocal Raman microscope

Our entry-level research-grade Raman microscope.



### inVia<sup>™</sup> Reflex confocal Raman microscope

Simple to operate yet delivers outstanding performance and reliable results, for even the most challenging experiments.



### inVia<sup>™</sup> Qontor<sup>®</sup> confocal Raman microscope

Renishaw's most advanced Raman microscope. With the addition of LiveTrack<sup>™</sup> focus tracking technology, you can analyse samples with uneven, curved or rough surfaces.

### **Renishaw's Raman products**

### **Benchtop Raman analysers**



### Pharmaceutical Analyser – RA802

A dedicated, high-speed Raman imaging system designed for pharmaceutical analysis.



### **Biological Analyser – RA816**

A compact benchtop Raman imaging system designed exclusively for biological and clinical research.

### Bespoke systems



### **Combined/hybrid Raman systems**

Couple inVia to other systems, such as atomic force microscopes and scanning electron microscopes.



### **Custom Raman solutions**

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



### Four ways to get trained

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:

- Raman Revealed workshops
- · bespoke training
- · 'start-up' training
- · how-to guides

Visit www.renishaw.com/RamanTraining for more information about the range of training options available.

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

#### Renishaw plc

New Mills, Wotton-under-Edge, Gloucestershire GL12 8JR United Kingdom T +44 (0) 1453 524524 F +44 (0) 1453 524901 E raman@renishaw.com

www.renishaw.com/raman



### **Renishaw. The Raman innovators**

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

Offering the highest levels of performance, sensitivity and reliability across a diverse range of fields and applications, the instruments are designed to meet your needs, so 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 its customers.

Please visit www.renishaw.com/raman for more information.

RENISHAW HAS MADE CONSIDERABLE EFFORTS TO ENSURE THE CONTENT OF THIS DOCUMENT IS CORRECT AT THE DATE OF PUBLICATION BUT MAKES NO WARRANTIES OR REPRESENTATIONS REGARDING THE CONTENT. RENISHAW EXCLUDES LIABILITY, HOWSOEVER ARISING, FOR ANY INACCURACIES IN THIS DOCUMENT.

BR009-02-A February 2021 © 2021 Renishaw plc. All rights reserved.

Renishaw reserves the right to change specifications without notice.

RENISHAW, the probe symbol used in the RENISHAW logo, and Qontor are registered trade marks of Renishaw plc in the United Kingdom and other countries. apply innovation and names and designations of other Renishaw products and technologies are trade marks of Renishaw plc or its subsidiaries.

All other brand names and product names used in this document are trade names, trade marks or registered trade marks of their respective owners.