DOWNLOAD PDF PHARMACEUTICAL APPLICATIONS OF RAMAN SPECTROSCOPY

Chapter 1 : Raman Applications - Pharmaceutical - HORIBA

Introduction. Raman spectroscopy is becoming one of the most popular analytical measurement tools for pharmaceutical applications ranging from verification of raw materials to process monitoring of drug production to quality control of products.

Similar to an infrared spectrum, a Raman spectrum consists of a wavelength distribution of peaks corresponding to molecular vibrations specific to the sample being analyzed see Figure 1B. Chemicals, such as drugs, can be identified by the frequency and quantified by the intensity of the peaks. In practice, a laser is focused into the sample, the inelastic scattered radiation Raman is optically collected and directed into a spectrometer , which provides wavelength separation, and a detector converts photon energy to electrical signal intensity. An attractive advantage to this technique is that samples do not have to be extracted or prepared, and the laser can simply be aimed at a sample to perform chemical measurements, which can often be accomplished in a minute or less. The first major breakthrough came with the development of the laser, which provided considerably more photons to generate Raman scattered photons and therefore improved sensitivity [4]. In the mids, array detectors were beginning to replace photomultiplier tubes that were used with scanning spectrometers [5]. These, as well as the 2-dimensional charge coupled device CCD detectors that soon followed, reduced the measurement time from hours to minutes. These detectors also allowed replacing strip-chart recorders with XY plotters. In the s, fiber optic probes were introduced [6, 7], which allowed the first process measurements [8]. Interferometer-based systems that employed nm lasers were also introduced during this time period [9]. Because very few chemicals have electronic absorptions at this longer wavelength, the generation of fluorescence that could obscure the Raman signal was virtually eliminated. This decade also saw the rapid development of the personal computer, which quickly became an important tool to analyze the spectra once collected. The s introduced two new optical elements that simplified Raman spectrometer optical designs. In addition, diode lasers that were developed for the telecommunication industry were introduced. The combination of diode lasers, optics, CCD detectors, and laptop computers led to the first truly portable systems, with nm laser excitation as the most popular [12]. The stability of these systems also allowed the development of the first dedicated process systems, while the size allowed development of Raman microscope systems [13]. During the present century, the miniaturization of Raman spectrometers continued as briefcase systems [12, 14], were replaced by handheld systems [15, 16]. Computing power also allowed the application of statistics to large spectra data sets, and during the last 25 years, chemometrics has become an important part of Raman spectral analysis [14, 17]. Spectrometer Designs As indicated, these technological advances have led to a variety of spectrometer designs, each with advantages that may be important for a particular application. For example, interferometer-based Raman spectrometers off er high resolution and an invariant x-axis, along with fluorescence-free spectra. A stable x-axis allows monitoring long chemical reactions without constant calibration and performing complex chemometrics without fear of model failure. Dispersive-based Raman spectrometers off er high sensitivity and simple optical designs. The use of nm lasers allow using Si detectors, which are much more efficient than the InGaAs detectors that are required when using nm lasers. The increased sensitivity allows measuring spectra in seconds not minutes, while the optical designs allow for light-weight, handheld spectrometers. Recently, several companies introduced dispersive-based Raman spectrometers that employ nm lasers and InGaAs array detectors. These spectrometers take advantage of both designs, in that the longer excitation virtually eliminates fluorescence interference, while the optics allow the production of handheld systems. During the past decade, Raman spectroscopy has been applied to a wide range of pharmaceutical applications []. These include optimizing polymorph or crystalline structure analysis [22, 23], the synthesis of new drugs, gaining process understanding through real-time monitoring of reactors, crystallizers, and blenders [], verifying raw materials [27] and assuring product quality [28]. Pharmaceutical companies are often reluctant to publish their results as it could

weaken their business position, so representative examples for several of these applications, as well as two emerging applications, verifying product authenticity and product shelflife are provided here. Drug Development Once a potentially new drug is identified, the method to synthesize the drug is developed. Raman spectroscopy is ideal for monitoring reactant, intermediate and product concentrations, determining pathways, kinetics, mechanisms, end-points, and yields for a variety of reaction types, such as Diels-Alder, Fischer esterification, Grignard, and hydrogenation. Fischer esterification is used in the synthesis of many drugs, such as benzocaine, but this reaction is more often used as an intermediate step to protect carboxylic acid groups, while functionalizing phenyl rings. As an example of this important pharmaceutical reaction, the esterification of benzoic acid was performed to produce methyl benzoate Figure 1A. The reactant and product have unique spectra, with peaks at and cm-1, respectively, which are ideal for real-time monitoring Figure 1B. A fiber optic coupled emersion probe inserted into a 3-neck flask was used to collect spectra every 45 seconds using 0. Crystallization, often the final step in drug synthesis, is used to separate a drug from a solvent matrix so that it is suitable for final form manufacturing. This process must also be optimized, not only to maximize separation, but, in many cases, to ensure that the correct polymorph is formed. For some drugs, various polymorphs exist with dramatically different solubilities that affect bioavailability, an important consideration in defining dosage. Process conditions, such as temperature, mixing rate, and concentrations can affect crystalline formation kinetics, and which polymorph dominates. Again, Raman spectroscopy is well-suited for understanding and optimizing process conditions. In fact, drug synthesis and crystallization are often carried out in a single batch reactor. Figure 2A shows the Raman spectra for the initial reactants and the final crystalline product proprietary. In this case, the product has a unique Raman peak at cm-1, suitable for monitoring formation, while the shift in the peak ar to cm-1 can be used to monitor crystallization. Although these spectral changes can be used, a chemometrics model that correlates these properties to the entire Raman spectrum allows monitoring both the synthesis and crystallization process with high accuracy and precision green trace, Figure 2B. As previously stated, FT-Raman analyzers provide the necessary x-axis stability for reactions that take hours, however, temperature controlled, temperature immune optics, or inclusion of an x-axis reference in dispersive-based Raman analyzers can also be used. The peak height is used to monitor product formation, while the shifts are used to follow chrystallization. B Plot of the cm-1 peak height and a chemometrics correlation to both product formation and crystallization onset initiated by a temperature drop. Drug Quality Quality-by-design in drug manufacturing begins with verification of the purity of raw materials and ends with the quality of the product. The latter requires assurance that the product, as a gel cap, tablet, etc. Raman spectroscopy has been used to monitor mixing in blenders [25], as well as to inspect individual products before shipment. Tablets are non-uniform and a single point measurement can produce misleading results. To overcome this inaccurate result, several approaches have been developed []. These include mapping the sample using a raster or pattern approach, spinning the tablet, employing a large spot size or transmission Raman. It is worth noting that the entire pill does not have to be mapped. Figure 3C shows the concentrations for 8 points forming a circle on the pill, while Figure 3D shows the running average for three 8-point concentric circles. Aspirin, Acetaminophen, and Caffeine. D Plot of running average of normalized intenisties for Aspirin, Acetaminophen, and Caffeine for 24 spots. The most innacurate spot was chosen as the starting spot to accentuate the capability of this approach. Product Authentication Counterfeit drugs have become a significant problem during the past decade. The availability of such drugs has been made possible largely through purchases from fraudulent websites. Counterfeit drugs range from those employing incorrect ingredients, no actives e. The latter are the most challenging since a simple compositional analysis may pass the sample as the genuine product. Authentic and counterfeit products have been examined by many analytical methods, including infrared, near-infrared, and Raman spectroscopies [36, 37]. A key consideration for Raman analysis is the blue dye, indigo carmine aluminum lake, used in the coating. Dye coatings are often used along with size and shape to provide product uniqueness for easy recognition by the pharmacist and consumer alike. This interference can be overcome by using nm excitation as shown in Figure 4A. However, this comes at

cost. The first measurement required 10 seconds, while the latter, which used an interferometer-based spectrometer, required 25 minutes. Fortunately, the introduction of dispersive-based Raman spectrometers using the longer laser wavelength provides an ideal compromise. Spectra with high signalto- noise ratios can be obtained in 20 seconds as shown in Figure 4B. The counterfeit drug spectra show additional peaks at and cm-1 that can be easily used to differentiate counterfeits from originals. Both at 8 cm-1 resolution. Product Shelf Life Drug formulations include additives and coatings to minimize degradation of the active ingredient due to heat, moisture and radiation, and thereby maximize product shelf-life. Most drugs fall into two categories, those that maintain potency for at least one year, and those that maintain potency for greater than two years from the time of manufacture. While most drug degradation products are benign and simply ineffective, acetaminophen, one of the most popular and effective drugs for pain relief, degrades into a poison, p-aminophenol, which can cause liver damage [38]. Acetaminophen is the number one over-the-counter drug associated with accidental overdose and death [39]. Although unproven, some of these accidents may be due to use of expired drugs. The primary method used today to determine drug degradation is high performance liquid chromatography HPLC [40]. The advantages of Raman spectroscopy, minimal or no sample preparation, non-destructive analysis and speed , suggest that it may also find value for this important application. Figure 5 - A Raman spectra of acetaminophen red and p-aminophenol black. B Raman spectra of pure epinephrine USP grade, top spectrum and injectable epinephrine product 0. C SERS of epinephrine product blue spectrum compared to prepared 0. Conditions for A and B: In fact, the active ingredient is undetectable in a Raman spectrum of a commercial 0. Surface-enhanced Raman spectroscopy SERS can be used to amplify the signal by as much as 6-orders of magnitude [41, 42]. The SERS effect has several requirements [43]. First, the materials used must have conducting electrons, such as copper, gold and silver. Second, the size of the material must be similar in magnitude to the wavelength of light used in measurements so that the electromagnetic wave, i. Third, the drug of interest must be within the plasmon field so that its Raman scattering can be generated by both the plasmon and electromagnetic fields. Since the intensity of Raman scattering is a function of the field strength squared, then the signal intensity is amplified to the fourth power. Also, certain relationships e. The last requirement, often overlooked, determines the extent that a vibrational mode is enhanced. The SER spectrum is dominated by the vibrations that include nitrogen, such as the CCN bending and secondary amine modes at and cm-1, while the Raman spectrum is dominated by the aromatic ring modes at and cm This is not surprising, since epinephrine is expected to interact with the silver particles through the nitrogen lone pair. More importantly, the degradation product, nor-epinephrine, in which hydrogen replaces a methyl group, produces a SER spectrum that is sufficiently different for identification and quantitation. Specifically, the CCN bending and secondary amine modes shift to and cm Conclusion Raman spectrometers will continue to decrease in size, integrate into other measurement apparatus, and provide incredible analyses through chemometrics. I hope this short review provides some insight into the capabilities of Raman spectroscopy for pharmaceutical applications. A review, J Pharma Biomed Anal, 48,

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Chapter 2 : What are the most common applications of Raman spectroscopy? - HORIBA

Description. Carefully organized with an emphasis on industry issues, Pharmaceutical Applications of Raman Spectroscopy provides the basic theory of Raman effect and instrumentation and then addresses a wide range of pharmaceutical applications.

Applications[edit] Raman spectroscopy is used in chemistry to identify molecules and study chemical bonding and intramolecular bonds. In solid-state physics , Raman spectroscopy is used to characterize materials, measure temperature , and find the crystallographic orientation of a sample. As with single molecules, a solid material can be identified by characteristic phonon modes. Information on the population of a phonon mode is given by the ratio of the Stokes and anti-Stokes intensity of the spontaneous Raman signal. Raman spectroscopy can also be used to observe other low frequency excitations of a solid, such as plasmons , magnons , and superconducting gap excitations. Distributed temperature sensing DTS uses the Raman-shifted backscatter from laser pulses to determine the temperature along optical fibers. In nanotechnology, a Raman microscope can be used to analyze nanowires to better understand their structures, and the radial breathing mode of carbon nanotubes is commonly used to evaluate their diameter. Raman active fibers, such as aramid and carbon, have vibrational modes that show a shift in Raman frequency with applied stress. Polypropylene fibers exhibit similar shifts. In solid state chemistry and the bio-pharmaceutical industry, Raman spectroscopy can be used to not only identify active pharmaceutical ingredients APIs , but to identify their polymorphic forms, if more than one exist. For example, the drug Cayston aztreonam , marketed by Gilead Sciences for cystic fibrosis , [10] can be identified and characterized by IR and Raman spectroscopy. Using the correct polymorphic form in bio-pharmaceutical formulations is critical, since different forms have different physical properties, like solubility and melting point. Raman spectroscopy has a wide variety of applications in biology and medicine. It has helped confirm the existence of low-frequency phonons [11] in proteins and DNA, [12] [13] [14] [15] promoting studies of low-frequency collective motion in proteins and DNA and their biological functions. Multivariate analysis of Raman spectra has enabled development of a quantitative measure for wound healing progress. This is a large advantage, specifically in biological applications. Raman spectroscopy is an efficient and non-destructive way to investigate works of art. It also gives information about the original state of the painting in cases where the pigments degraded with age. Raman spectroscopy has been used in several research projects as a means to detect explosives from a safe distance using laser beams. Raman4Clinic is a European organization that is working on incorporating Raman Spectroscopy techniques in the medical field. They are currently working on different projects, one of them being monitoring cancer using bodily fluids such as urine and blood samples which are easily accessible. This technique would be less stressful on the patients than constantly having to take biopsies which are not always risk free. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. Since it is a scattering technique, specimens do not need to be fixed or sectioned. Water does not generally interfere with Raman spectral analysis. Thus, Raman spectroscopy is suitable for the microscopic examination of minerals , materials such as polymers and ceramics, cells , proteins and forensic trace evidence. A Raman microscope begins with a standard optical microscope, and adds an excitation laser, a monochromator , and a sensitive detector such as a charge-coupled device CCD , or photomultiplier tube PMT. FT-Raman has also been used with microscopes. Ultraviolet microscopes and UV enhanced optics must be used when a UV laser source is used for Raman microspectroscopy. In direct imaging, the whole field of view is examined for scattering over a small range of wavenumbers Raman shifts. For instance, a wavenumber characteristic for cholesterol could be used to record the distribution of cholesterol within a cell culture. The other approach is hyperspectral imaging or chemical imaging , in which thousands of Raman spectra are acquired from all over the field of view. The data can then be used to generate images showing the location and amount of different components. Taking the cell culture example, a hyperspectral image could show the

distribution of cholesterol, as well as proteins, nucleic acids, and fatty acids. Sophisticated signal- and image-processing techniques can be used to ignore the presence of water, culture media, buffers, and other interference. Raman microscopy, and in particular confocal microscopy , has very high spatial resolution. Since the objective lenses of microscopes focus the laser beam to several micrometres in diameter, the resulting photon flux is much higher than achieved in conventional Raman setups. This has the added benefit of enhanced fluorescence quenching. However, the high photon flux can also cause sample degradation, and for this reason some setups require a thermally conducting substrate which acts as a heat sink in order to mitigate this process. Another approach called global Raman imaging [31] uses complete monochromatic images instead of reconstruction of images from acquired spectra. This technique is being used for the characterization of large scale devices, mapping of different compounds and dynamics study. It has already been use for the characterization of graphene layers, [32] J-aggregated dyes inside carbon nanotubes [33] and multiple other 2D materials such as MoS2 and WSe2. Since the excitation beam is dispersed over the whole field of view, those measurements can be done without damaging the sample. By using Raman microspectroscopy, in vivo time- and space-resolved Raman spectra of microscopic regions of samples can be measured. Sampling is non-destructive and water, media, and buffers typically do not interfere with the analysis. Consequently, in vivo time- and space-resolved Raman spectroscopy is suitable to examine proteins , cells and organs. In the field of microbiology, confocal Raman microspectroscopy has been used to map intracellular distributions of macromolecules, such as proteins, polysaccharides, and nucleic acids and polymeric inclusions, such as poly-B-hydroxybutyric acid and polyphosphates in bacteria and sterols in microalgae. Combining stable isotopic probing SIP experiments with confocal Raman microspectroscopy has permitted determination of assimilation rates of 13C and 15N-substrates as well as D2O by individual bacterial cells [34]. Using confocal Raman microspectroscopy essentially as a single-cell mass spectrometer is enabled by the fact that the vibrational frequency of any molecular bonds is a function of the masses of the bound atoms. Thus, incorporation of heavy isotopes will cause quantitative "red shifts" in diagnostic Raman peaks. YAG are especially common. The use of these lower energy wavelengths reduces the risk of damaging the specimen. Recently advances were made which had no destructive effect on mitochondria in the observation of changes in cytochrome c structure that occur in the process of electron transport and ATP synthesis. Raman microscopy of inorganic specimens, such as rocks and ceramics and polymers, can use a broader range of excitation wavelengths. While conventional Raman spectroscopy identifies chemical composition, polarization effects on Raman spectra can reveal information on the orientation of molecules in single crystals and anisotropic materials, e. Polarizationâ€”dependent Raman spectroscopy uses plane polarized laser excitation from a polarizer. The Raman scattered light collected is passed through a second polarizer called the analyzer before entering the detector. The analyzer is oriented either parallel or perpendicular to the polarization of the laser. Spectra acquired with the analyzer set at both perpendicular and parallel to the excitation plane can be used to calculate the depolarization ratio. Typically a polarization scrambler is placed between the analyzer and detector also. For isotropic solutions, the Raman scattering from each mode either retains the polarization of the laser or becomes partly or fully depolarized. If the vibrational mode involved in the Raman scattering process is totally symmetric then the polarization of the Raman scattering will be the same as that of the incoming laser beam. In the case that the vibrational mode is not totally symmetric then the polarization will be lost scrambled partially or totally, which is referred to as depolarization. Hence polarized Raman spectroscopy can provide detailed information as to the symmetry labels of vibrational modes. In the solid state, polarized Raman spectroscopy can be useful in the study of oriented samples such as single crystals. The polarizability of a vibrational mode is not equal along and across the bond. Therefore the intensity of the Raman scattering will be different when the lasers polarization is along and orthogonal to a particular bonds axis. This effect can provide information on the orientation of molecules with a single crystal or material. The spectral information arising from this analysis is often used to understand macromolecular orientation in crystal lattices, liquid crystals or polymer samples. Each mode is separated

according to its symmetry.

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Chapter 3 : Pharmaceutical Applications of Raman Spectroscopy

Pharmaceutical applications of Raman spectroscopy have developedsimilarly and this book will focus on those applications. Carefullyorganized with an emphasis on industry issues, PharmaceuticalApplications of Raman Spectroscopy, provides the basic theory ofRaman effect and instrumentation, and then addresses a wide rangeof pharmaceutical.

Recent progress has even enabled enantioselective measurements, which were previously believed to be impossible. The present article compares experimental approaches to polarization-resolved Raman spectroscopy and discusses them with regards to their pros and cons. Background Raman spectroscopy is an established analytical tool in the pharmaceutical sector. Beyond the analysis of products in the lab, Raman techniques find more and more applications as a means of process analytical technology PAT. However, the full potential is currently, by far, not tapped. A key feature that is rarely exploited in routine Raman analysis is the sensitivity of Raman scattering to the polarization properties of the incident light. If the laser is linearly polarized, the majority of the Raman signal will be polarized in the same way. A certain fraction of the scattered light, however, will be polarized orthogonally with respect to the incident light. This fraction is referred to as the depolarized signal. Its value ranges from zero for highly polarized signals to 0. The depolarization ratio allows deriving valuable information about the symmetry of a vibrational mode. Symmetric vibrations are usually highly polarized and anti-symmetric modes are depolarized. Consequently, acquiring both the polarized and the depolarized Raman spectrum permits an improved structural analysis and a more accurate assignment of the observed peaks. This is particularly true for overlapping vibrational bands. Another advantage of polarization-resolved detection is the determination of the isotropic and anisotropic Raman intensities. In the context of pharmaceutical analysis, however, the recent development of enantioselective Raman esR spectroscopy, which is based on polarization-resolved detection, is a promising tool. Four general concepts are illustrated in Figure 1. The main components, i. The simplest setup Figure 1a employs a polarization filter, either a thin film polarizer or a polarizing prism, in the signal collection path. To obtain the vertical or the horizontal signal component, the polarizer is oriented accordingly. This approach is experimentally simple, but it has two disadvantages, i. Such a scrambler may also reduce the signal intensity and hence calls for longer acquisition times. A different experimental option is depicted in Figure 1b. In order to avoid polarization-dependent effects in the spectrograph, the polarization direction of the laser is adjusted using a halfwave plate. However, again, the two spectra must be recorded in sequence. Schematic experimental setups for polarization-resolved Raman spectroscopy. For many process monitoring applications, however, temporal resolution is crucial. Therefore, recording the two spectra sequentially is not an option as the sample may have changed between the two measurements. Acquiring both the polarized and depolarized signal components simultaneously is possible using a polarizing beam splitter in the signal path and two spectrometers. This is illustrated in Figure 1d. Unfortunately, this approach is inherently expensive and requires significant alignment effort, and the detectors must be synchronized. A suitable alternative technique for acquiring both spectra at the same time has recently been demonstrated. The key components are the half-wave plate and the Wollaston prism. This means that half of the intensity of the beam is vertically and the other half is horizontally polarized. The Wollaston prism splits the two polarization components into two individual beams, see enlarged detail in Figure 1c. The lens focusses the two beams to two spatially separated spots in the sample. The resulting Raman scattering from both spots is imaged onto the entrance slit of an imaging spectrograph equipped with a two-dimensional detector, e. The camera eventually records both spectra simultaneously as they appear on separated parts on the chip. Basically, this concept makes use of the approach in Figure 1b, but enables the recording of the polarized and depolarized Raman signals at the same time. The disadvantage of the method is the spatial separation of the measurement volumes inside the sample. In other words, the sample must be homogenous on the length scale of this separation. This length scale can be

less than a millimeter, depending on the optical alignment of the setup. Comparison and Conclusion All the experimental approaches described above have their pros and cons. As mentioned before, temporal resolution is a main criterion in process monitoring. Further important points are experimental simplicity and robustness as well as cost. The setups in Figures 1a and 1b are experimentally simple but they share the disadvantage of requiring sequential acquisition of the two spectra. Moreover, one component needs to be adjusted between the measurements. The rotation of polarizers and half-wave plates can be made automatic, but it still means a source of error. The setups in Figures 1c and 1d are more complicated, but they do not need to be touched and hence are more robust. Only a few commercial Raman instruments are capable of recording both polarization components. Most devices on the market utilize fiber-optics, e. The fibers usually do not maintain the polarization. Hence, custom-made solutions are needed. Considering simple and cheap options, the four setups can be compared with each other. They all contain a laser and a minimum of three lenses. Setup 1a in addition exhibits two polarizers, a scrambler and a spectrograph with detector. The cheapest option would be to replace the spectrograph, camera, and scrambler by a fiber-coupled miniature spectrometer with an integrated backilluminated detector. The fiber will act as polarization scrambler. Setup 1b contains a half-wave plate and two polarizers. The spectrograph and camera can again be replaced by a fiber-couple spectrometer. This is not possible in setup 1c, as the concept is based on the functionality of an imaging spectrograph and a two-dimensional detector. In addition, a Wollaston prism is necessary. Setup 1d, on the other hand, requires two spectrographs and detectors. Both can be implemented as fiber-coupled spectrometers. The pros and cons of all four setups are compared in Table 1. The costs underlying the ratings have been estimated on the basis of current catalog prices. Setups 1a and 1b are almost identical in price, while the costs for setup 1d is almost the double amount as the spectrometers incl. The recently proposed setup 1c places itself in between and thus represents a true alternative, in particular when temporally resolved measurements are needed. In conclusion, polarization-resolved Raman spectroscopy is an emerging analytical technique and has great potential in the field of pharmaceuticals. The enantioselective Raman esR method is of particular interest in this context. The present article evaluated the current experimental possibilities for acquiring the polarized and depolarized Raman spectra. Four concepts were compared with respect to experimental simplicity, alignment effort, temporal and spatial resolution as well as cost. The recent development of an approach3 that allows the recording of both spectra simultaneously turns out to exhibit experimental as well as economic advantages. Thus, its further development towards a robust analytical tool will open up Raman spectroscopy for new applications in monitoring pharmaceutical processes. Pros and cons of the different setups. Noack, Universal enantiomeric discrimination by Raman spectroscopy, Analyst , Kiefer, Enantioselective Raman Spectroscopy â€" A new tool for process monitoring in the pharmaceutical industry? Kiefer, Simultaneous acquisition of the polarized and depolarized Raman signal with a single detector, Analytical Chemistry 89, His research interests are the areas of developing and applying spectroscopic techniques for the characterization of advanced materials and processes.

Chapter 4 : An Overview: Application of Raman Spectroscopy in Pharmaceutical Field | BenthamScience

Raman Spectroscopy is a robust and widely adopted analytical technique in the pharmaceutical market. The non-destructive technique provides versatile chemical identification rapidly within a small footprint benchtop instrument.

Chapter 5 : Raman applications

RA Raman spectroscopy of pharmaceutical ingredients under humidity controlled atmosphere RA Raman Spectroscopy to Study the Distribution of Compounds in a Pharmaceutical Drug Product For a list of all available application notes please click here.

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Chapter 6 : Pharmaceutical | Kaiser Optical Systems, Inc. | An Endress+Hauser Company

As Raman spectroscopy enables rapid, non-destructive measurements, the technique appears a most promising tool for on-line process monitoring and analysis in the pharmaceutical industry. This article gives a short introduction to Raman spectroscopy and presents several applications in the pharmaceutical field.

Chapter 7 : Pharmaceutical Applications of Raman Spectroscopy - Google Books

As Raman spectroscopy enables rapid, non-destructive measurements, the technique appears a most promising tool for on-line process monitoring and analysis in the pharmaceutical industry.

Chapter 8 : Raman spectroscopy - Wikipedia

Raman spectroscopy is now becoming widely utilized in the pharmaceutical sciences, too. Conventional applications of vibrational spectroscopy include the identification of drugs, excipients, and raw materials; quality control; as well as characterization of polymorphs, salts, and hydrates.