The "New" Raman: Streamlined, Flexible and Powerful

A White Paper by Dr Giorgia Marucci, Dr Nick Barnett (Pro-Lite Technology) & Cicely Rathmell (Wasatch Photonics)

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Introduction

It has been over 90 years since C.V. Raman received the Nobel Prize in Physics for the discovery which bears his name. Since that time, successive improvements in measurement systems have enabled Raman spectroscopy to become a powerful and versatile analytical tool that is applied in a vast array of applications from material science to medical diagnostics.

The development of Raman spectroscopy throughout the years has depended largely on the availability of suitable technology. In his earliest experiments, Raman used filtered sunlight as a radiation source and observed the scattered light visually using a set of coloured filters. The invention of the laser in 1960, and its application as a source of monochromatic illumination, transformed the quality of Raman spectra. Other developments with detectors, sharp cut-off filters, high-efficiency gratings and fibre optic probes have all accelerated the evolution of the optical instrumentation at the core of spectroscopy. As a result, a new generation of compact and affordable Raman spectrometers is now available with the sensitivity and flexibility to serve a range of applications.

Even so, the assumption remains that there must be a trade-off between spectrometer size and performance. How could a compact Raman device provide comparable sensitivity or signal quality to a larger, more expensive bench-top instrument?

Wasatch Photonics is closing this performance gap with a line of streamlined spectrometers based on a low f-number optical bench design incorporating high-efficiency holographic transmission gratings (see Figure 1). This results in compact Raman spectrometers far faster and more sensitive than typical compact spectrometers.

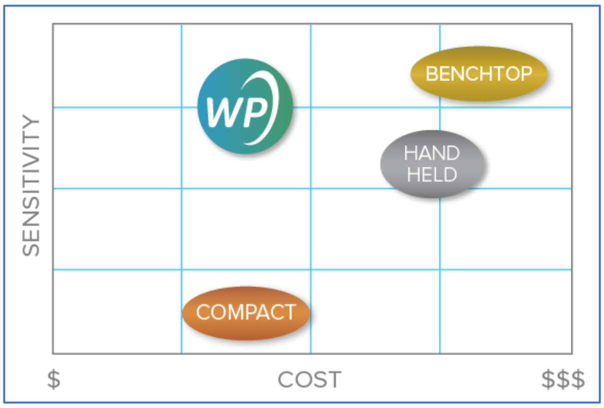

Figure 1: Position of Wasatch Photonics spectrometers in the market

Getting on the Right Wavelength

The sensitivity of a Raman spectrometer is important, but is not always enough to guarantee the success of a measurement. There are many other factors to consider, including the laser wavelength, measurement range, and the interface between the instrument and the sample.

The choice of the excitation wavelength can be critical to a Raman measurement, and will depend on the sample material and matrix components. Laser wavelength options for Raman range from the UV through NIR, each with their own preferred applications. Though shorter wavelengths generate more Raman signal, they also generate more background fluorescence that can degrade the signal to noise ratio (SNR) for organic samples. Savvy Raman vendors like Wasatch Photonics have developed a range of Raman products to span 248 through 1064nm (see Figure 2), allowing each user to balance signal, fluorescence background, size and cost for their unique application. This allows a diverse range of applications to be served by one platform, from materials and gas analysis to pharmaceuticals, biological samples, foodstuffs and dyes/black powders.

Figure 2: Wasatch Photonics offer of spectrometers for different excitation wavelengths

Fluorescence, for example, is a factor in the use of Raman spectroscopy in the food and beverage industry, where it can be applied for quality control and authentication purposes. The availability of Raman systems at NIR wavelengths expands the technique's potential for rapid, non-invasive, and unambiguous analysis in the sector. Figure 3 compares Raman spectra of coconut oil excited with three different laser sources; use of 1064nm excitation virtually eliminates fluorescence background and offers the greatest SNR. Likewise, 1064nm Raman has proven to be an effective tool for other food product investigations: for the discrimination of intact meat[1]; the authentication of extra virgin olive oil[2]; the detection of adulteration in goat milk[3]; and many others.

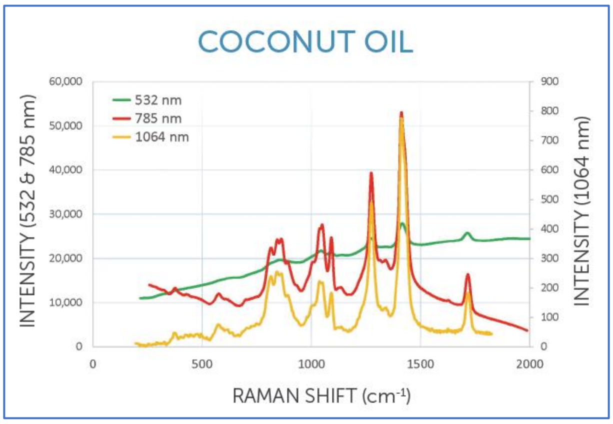

Figure 3: Raman spectrum of coconut oil compared using different excitation wavelengths: 532 nm (green line), 785 nm (red line) and 1064 nm (yellow line)

Bringing Answers in Range

The optimal choice of spectral range and resolution when using Raman depends on the functional groups under analysis. Many applications are well served by the detection of Raman peaks within the so-called fingerprint region extending out to 1800 cm^{-1}. However, it can sometimes be useful to detect molecular bands beyond the fingerprint region, from stretching modes of groups such as O-H and N-H, or highly saturated bonds (see Figure 4). Wasatch Photonics spectrometers offer the

1 Chima, Robert, et al. "Rapid discrimination of intact beef, venison and lamb meat using Raman spectroscopy." Food Chemistry 343 (2021): 128441.
2 Aykas, Didem Peren, et al. "Non-targeted authentication approach for extra virgin olive oil." Foods 9.2 (2020): 221.

3 Yaman, Hülya. "A rapid method for detection adulteration in goat milk by using vibrational spectroscopy in combination with chemometric method s." Journal of Food Science and Technology (2020): 1-8.

possibility to explore and extend the range of interest up to 3600 cm^{-1} using the WP 785 ER spectrometer and to 5000 cm^{-1} for the WP 532 EXR. As an example, the extended range of the WP 785 ER has found successful application in the identification of microplastics and bulk polymers [4,5].

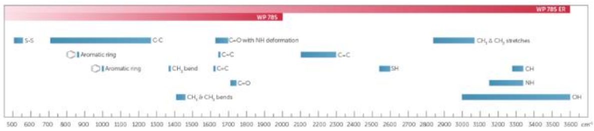

Figure 4: Raman functional groups by frequency, as compared to the operating range for a fingerprint (WP 785) and extended range (WP 785 ER) spectrometer

Adapting Raman to Your Sample

While bulky benchtop Raman systems strive to accommodate samples of every type, compact Raman streamlines the sample interface with configurations that meet various user needs. One application may require direct sample coupling in free space to maximise throughput, while another could benefit from a Raman probe for greater flexibility. The Wasatch Photonics portfolio offers a variety of options: fully integrated; semi-integrated; and modular systems. A fully integrated system can deliver the smallest footprint and greatest collection efficiency by combining the spectrometer, laser and coupling optics into one box. A semi-integrated system provides greater set-up versatility in the form of a spectrometer with integrated laser, matched to a Raman probe connected with flexible fibre optics to the main unit. Finally, a fully modular system consisting of separate spectrometer, laser, flexible fibres and a Raman probe can appeal to users that already own a laser or who require an adaptable system.

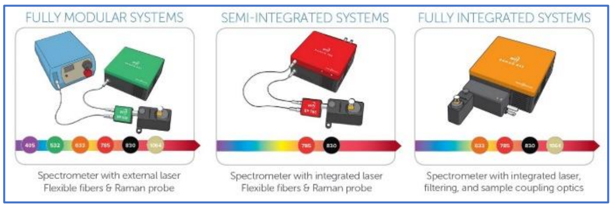

Figure 5: Wasatch range of Raman spectrometers, from modular through semi-integrated to fully integrated

This philosophy of user-configurability has been extended to the Raman probe through an interchangeable tip that allows the probe to be reconfigured for different sample types and working distances. With a thread designed to host many commercially available off-the-shelf optic accessories, this provides a degree of versatility to address different measurements with the same unit by simply changing the front-end optics (see Figures 6-9).

Process analytical technology (PAT) is one such application. Raman spectroscopy is widely used for monitoring chemical and biological processes like fermentation of microorganisms, a process used in many industrial fields such as energy, food and pharmaceuticals. The WP 785 RP Raman probe with interchangeable tip has proved to be an efficient tool in the monitoring of fermentation of glucose with yeast when coupled with an immersion probe[6]. The same immersion probe has also found application in the detection of microplastics in water[7]. In that application, the ball lens within the probe behaved as a reflector in an

[4] *Takahashi, Tomoko, et al. "Identification of microplastics in a large water volume by integrated holography and Raman spectroscopy." Applied Optics 59.17 (2020): 5073-5078.*
[5] *https://wasatchphotonics.com/applications/plastic-identification-extended-range-raman/*
[6] https://wasatchphotonics.com/applications/raman-process-monitoring/
[7] Radel, Samantha, et al. "In Situ Enhancement of Microplastic Raman Signals in Water Using Ultrasonic Capture." (2020). https://www.spectroscopyonline.com/view/situ-enhancement-microplastic-raman-signals-water-using-ultrasonic-capture

ultrasonic resonator, where the plastic microparticles agglomerated at the nodes of the ultrasonic waves and were analysed by Raman spectroscopy (Figure 8).

Figure 6: WP Raman probe with BallProbe® Tip for Contact or Immersion

Figure 7: Probe Tip with Custom Lens Adapter to modify sample spot size and working distance

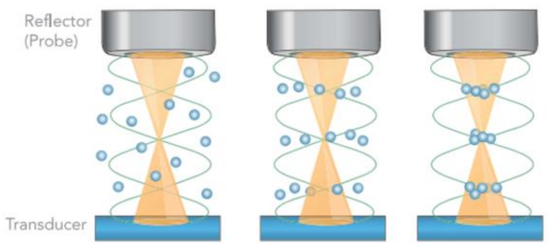

Figure 8: An ultrasonic standing wave formed between a piezo transducer and a Raman probe used as the reflector captures small particles in the nodes

Figure 9: Wasatch Raman probe coupled with a microscope objective

A Sum Greater Than its Parts

Taken together, these innovations of the optical bench, platform, and sampling optics to maximise flexibility and performance, the "new" compact Raman spectrometers have become a very attractive option for an increasing number of applications. These sleek optical benches are proving to deliver remarkable sensitivity in a fraction of the size of larger benchtop systems, liberating the technique for use in new settings, fields, and industries.

However, are the problem-solving capabilities of Raman compromised by evolution beyond the benchtop? We think not. The availability of multiple wavelength-specific optical benches enables users to select the best laser to maximise the Raman signal while minimising fluorescence. Meanwhile, modular designs and streamlined spectrometer platforms provide the flexibility to measure different samples by simply interchanging a few components according to the requirements of the application.

By retaining Raman's power and versatility while shedding the weight that once kept it in the lab, the 'new' compact Raman is poised to take on new domains.

Further Information

For further information on Wasatch spectrometers, please see: https://www.pro-lite.co.uk/File/raman_spectroscopy.php

About Wasatch Photonics

Wasatch Photonics is a manufacturer of VPH transmission gratings, compact spectrometers, and solutions for optical coherence tomography. Their low f-number spectrometers are designed for low light applications, allowing them to bridge the performance gap between high-end analytical spectrometers and cost-effective, portable devices. For more information, please visit www.wasatchphotonics.com

About Pro-Lite

Pro-Lite is the European channel partner for Wasatch Photonics in Germany, Spain, Portugal, France, UK and Ireland. Pro-Lite is a supplier of specialist equipment and services with a technical focus in the following areas of photonics: instruments for measuring light and the optical properties of materials; photometry; lasers and laser safety equipment; opto-mechanics and nano-positioning equipment; optics and optical materials; and spectroscopy and spectral imaging. Pro-Lite Technology Ltd is part of the Pro-Lite Group of Companies, which includes Photometric & Optical Testing Services, SphereOptics Germany, Pro-Lite France and Pro-Lite Iberia.