Multi-wavelength Excitation Raman Spectroscopy for In-situ Characterization of Real-world Samples

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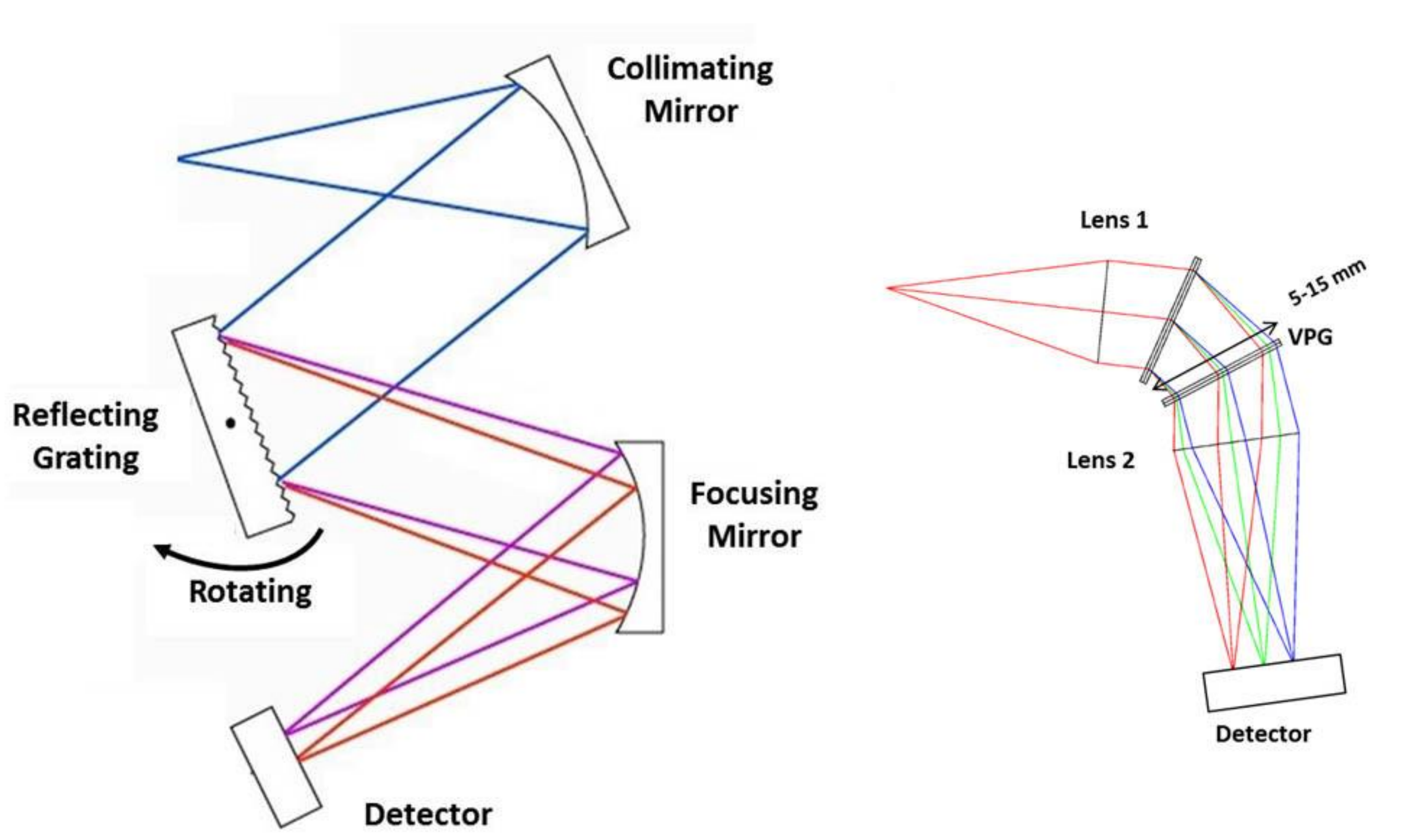
Background

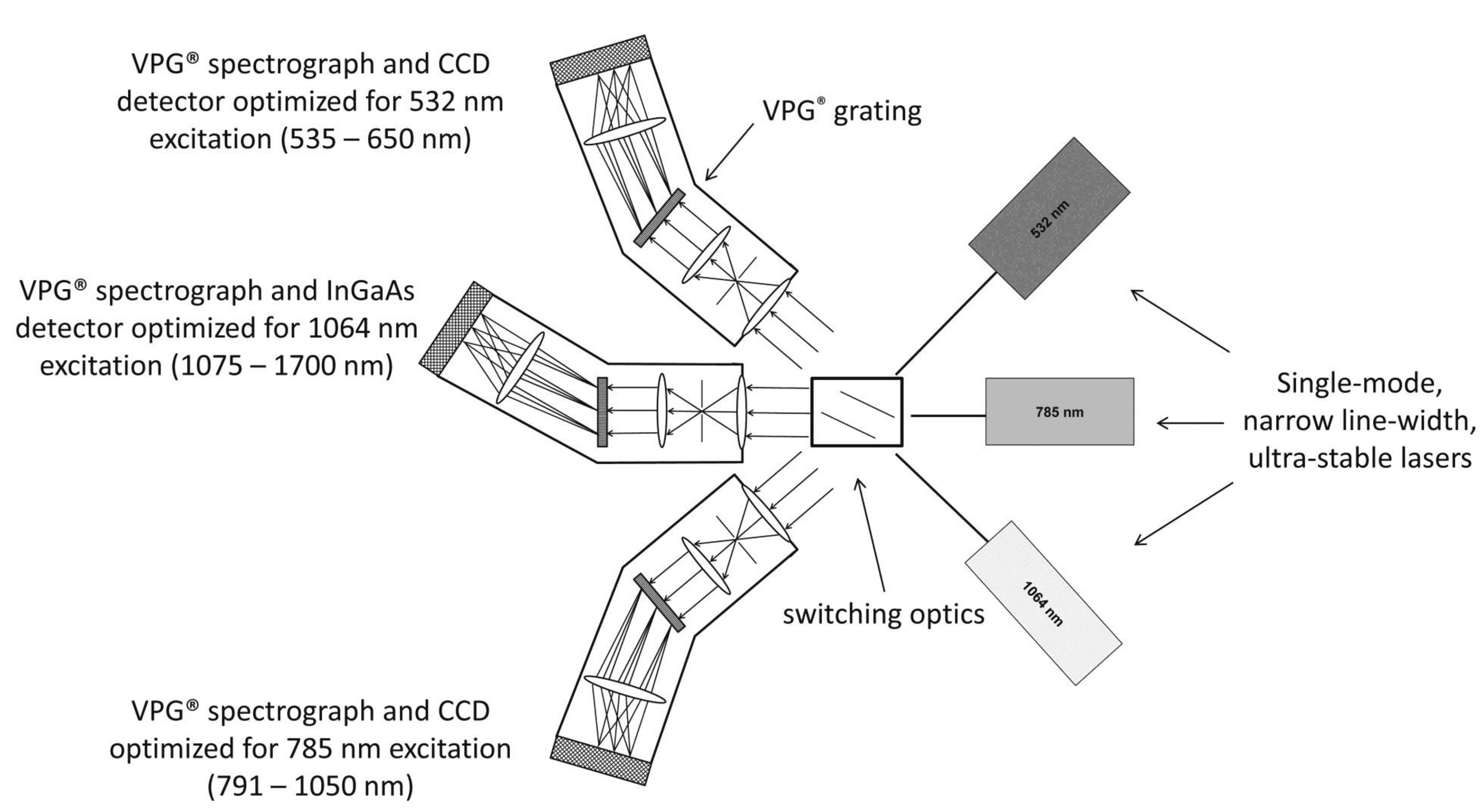
Having multiple wavelength excitations, particularly 1064 nm, in one Raman spectrometer/microscope offers extreme flexibility and convenience to investigate a great variety of real-world samples. In real-world Raman measurements, fluorescence is the biggest obstacle which significantly reduces the quality of the Raman spectra. 1064-nm Raman spectroscopy provides maximum fluorescence suppression and is best suited for most real-world samples, such as colored materials, plants and their derivatives, petroleum, fuels, lubricants, explosives, blood, animal tissues (stained or unstained), fabric, ink, unknown contaminants, food, drugs, pharmaceuticals, and so on. A few examples are demonstrated here.

Instrumentation Approaches

- ❑ CCD detectors for VIS excitations such as 488, 532, 632, and 785 nm, deep-cooled InGaAs detector for 1064-nm excitation.
- ❑ Volume Phase Gratings (VPG®) are high-throughput and low-footprint, making multi-gratings/spectrographs integration much easier.
- ❑ Each excitation has its own detector and spectrograph with VPG optimized for its Raman wavelength range to ensure maximized performance.



Left, schematic diagram of a traditional spectrograph based on a reflecting grating. Adapted from James B. Kaler, Stars and their Spectra: An Introduction to the Spectral Sequence Cambridge University Press (March 28, 1997). ***Right***, VPG design allows high compactness and no moving parts in the system.

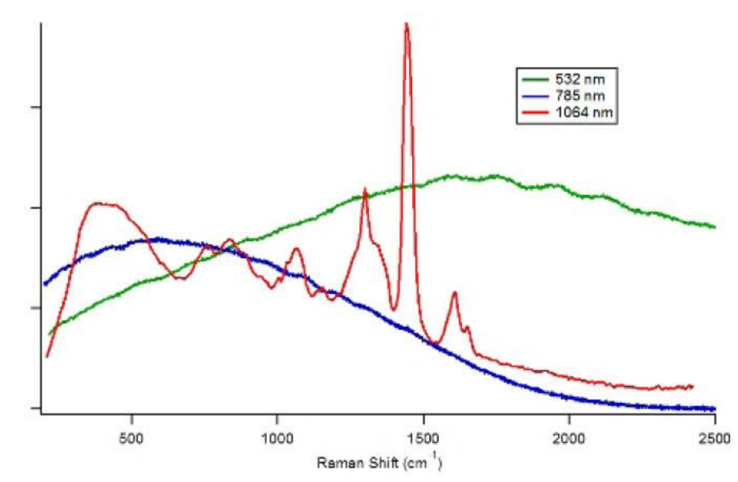


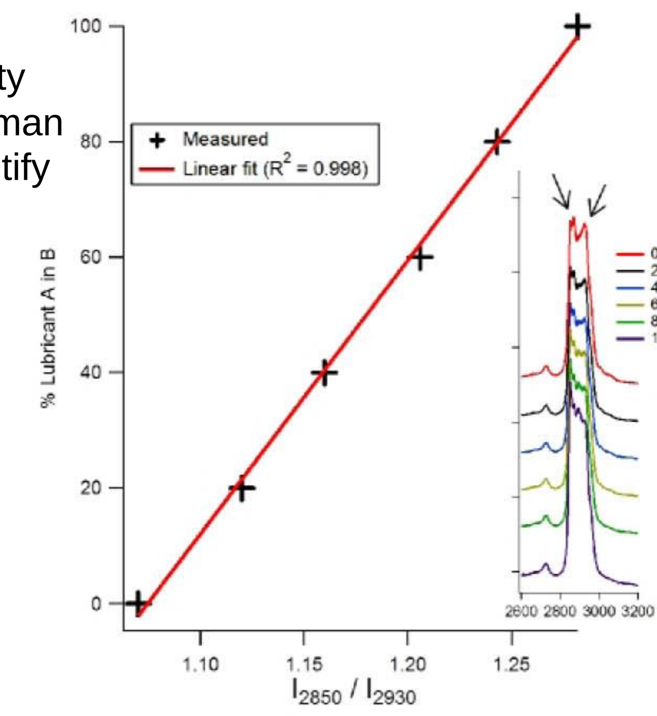
A simple design of three-excitation (532, 785, and 1064 nm) laser Raman system which can be a stand alone spectrometer or integrated into Raman microscopes. In this design, as each spectrograph/detector is only used for its unique wavelength band (no sharing), the system can maintain high response for an extended range of wavelengths (e.g., from UV to NIR).

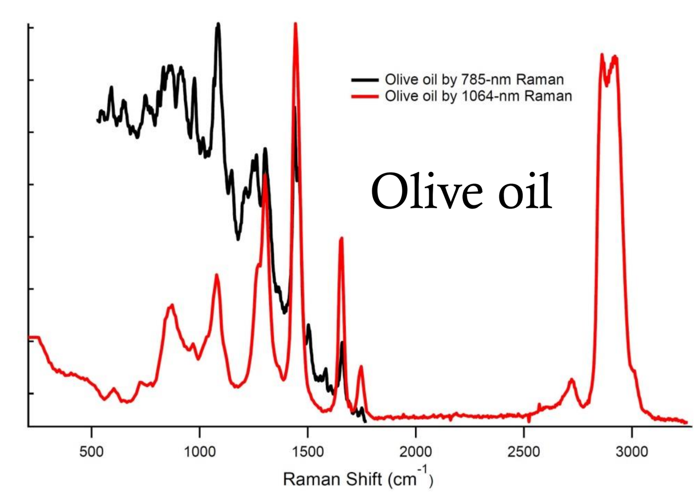
Examples of Real-world Samples

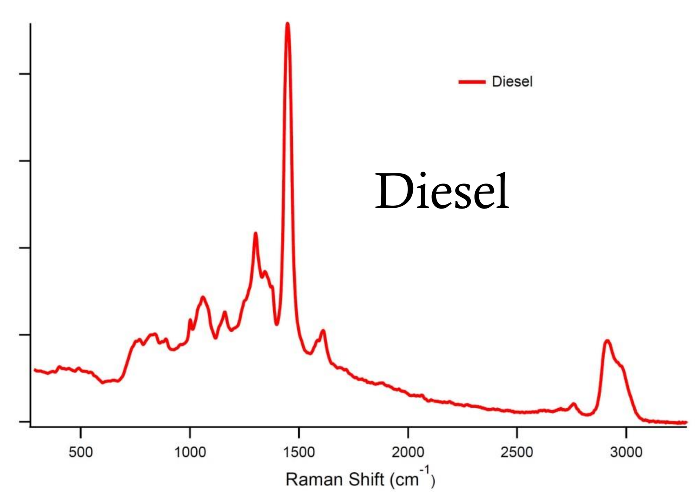
Petroleum and plants derivatives

Left, Only 1064-nm excitation produces high-quality Raman spectra for most lubricants. **Right**, two Raman makers *2850 cm⁻¹* and *2930 cm⁻¹* can be used to quantify the mixing percentage of two types of lubricants.

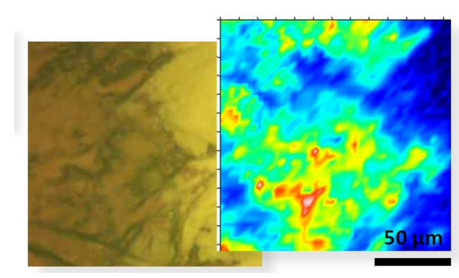




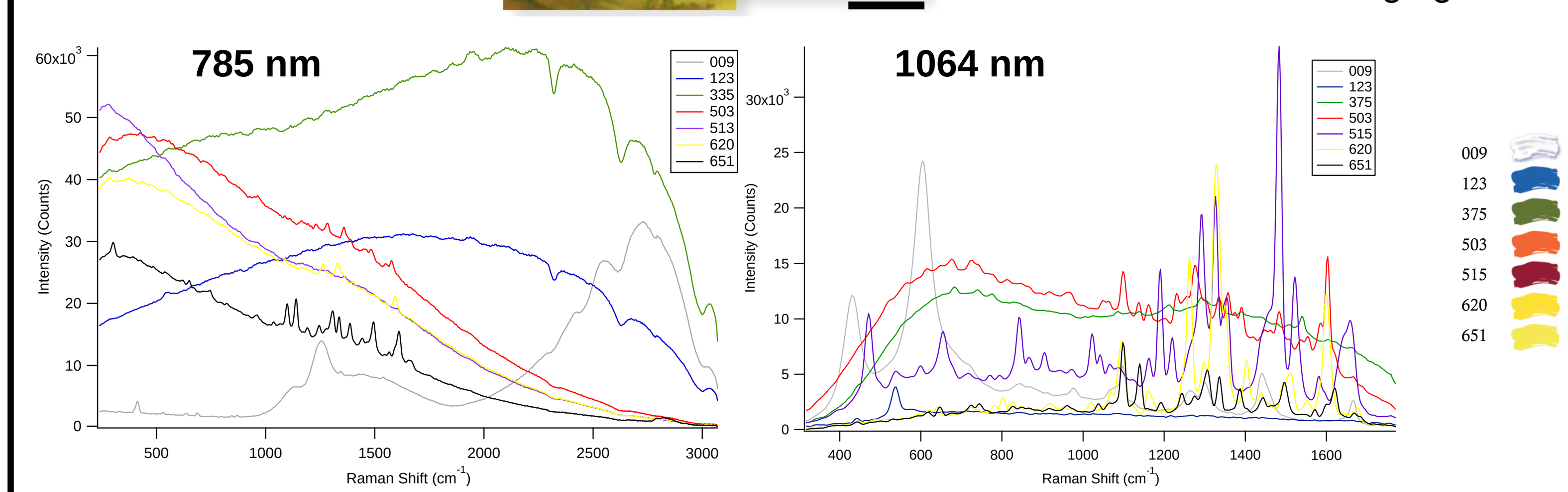




Ink and paint

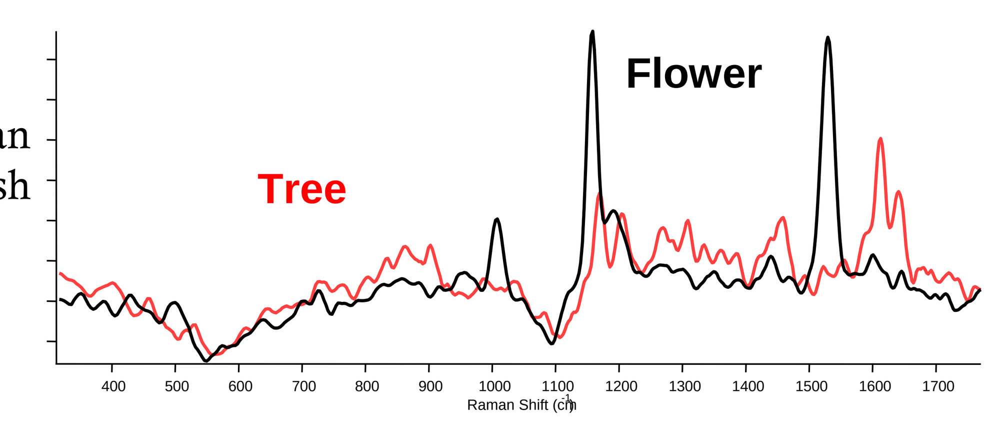


Ink, even just white paper, are highly fluorescent under visible laser illumination. Only 1064-nm excitation produces high-quality Raman spectra and Raman chemical imaging.

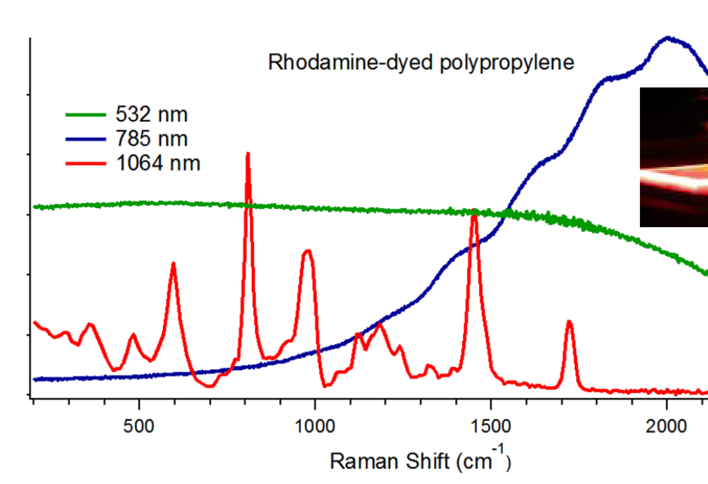


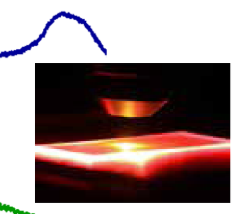
Pollen grains

1064-nm dispersive Raman microscopy can distinguish pollen grains. This application can be useful from plant science to forensics.



Colored materials

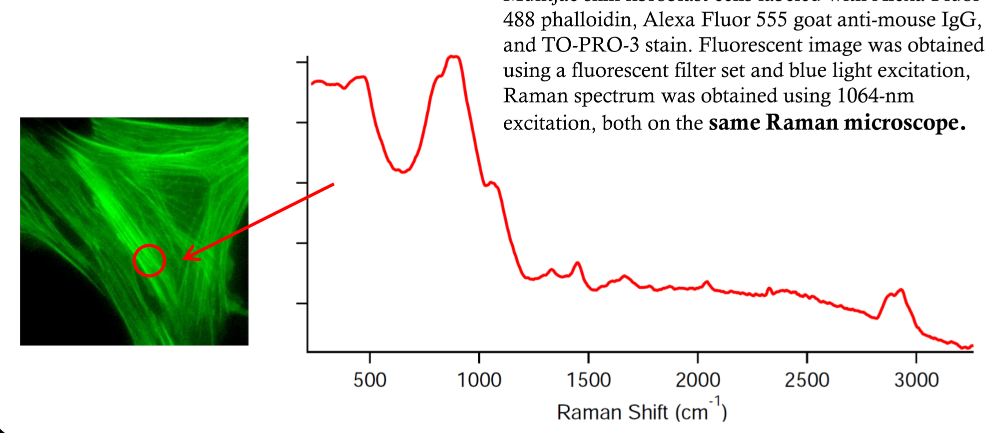




In real-world, most materials are colored (dyed). For these samples, multi-wavelength excitation system is perfect in finding an optimal wavelength (mostly 1064 nm) for Raman spectroscopy of colored materials.

Combined fluorescence and Raman spectroscopy/microscopy

Muntjac skin fibroblast cells labeled with Alexa Fluor 488 phalloidin, Alexa Fluor 555 goat anti-mouse IgG, and TO-PRO-3 stain. Fluorescent image was obtained using a fluorescent filter set and blue light excitation, Raman spectrum was obtained using 1064-nm excitation, both on the **same Raman microscope.**

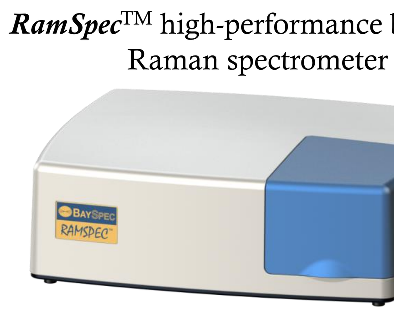


In biology, cell and tissue samples are often fluorescently labeled. 1064-nm dispersive Raman now offer means to do fluorescence and Raman spectroscopy or microscopy together on these samples.

Systems on the Market

Nomadic™ multi-wavelength Raman microscope

Agility™ dual-band transportable Raman spectrometer



RamSpec™ high-performance benchtop Raman spectrometer