

When to use a 1064 nm Laser with an InGaAs Detector for Raman Microscopy?

TN_011; Nikesh Patel

Introduction

In Raman spectroscopy, NIR lasers such as 785 nm, 830 nm, and 1064 nm, are often used to overcome fluorescence interference in Raman measurements. In most cases, 785 nm or 830 nm lasers are sufficient to reduce fluorescence backgrounds and observe Raman bands with a high signal-to-noise ratio. Highly fluorescent samples can still mask Raman signatures at these wavelengths, and a 1064 nm laser is necessary (Figure 1).

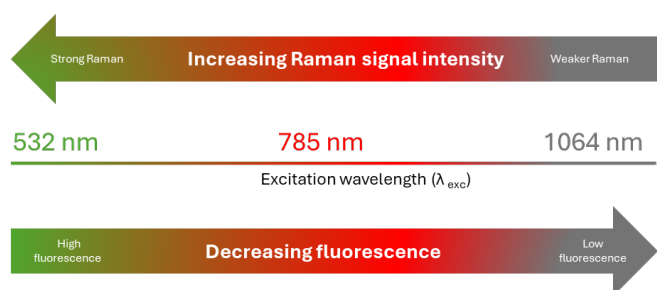


Figure 1. Raman signal intensity strength and the impact of fluorescence emission with respect to laser excitation wavelengths.

Most Raman lasers are used with silicon CCD detectors; however, their quantum efficiency (QE) drops around 1000 nm (Figure 2) and is therefore unsuitable for 1064 nm excitation. When using a 1064 nm laser, an InGaAs detector must therefore be used, which is an NIR-sensitive detector with photosensitivity out to 1650 nm.

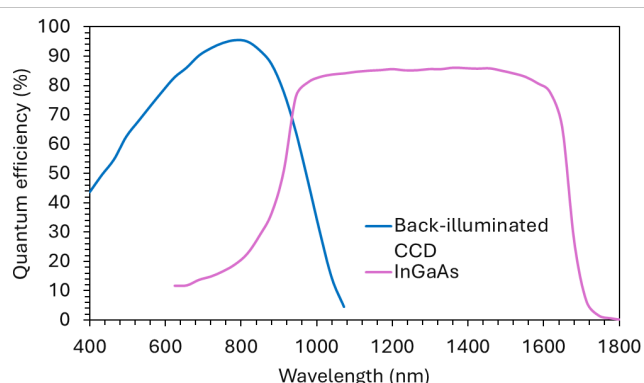


Figure 2. Quantum efficiency plot for back-illuminated CCDs (blue trace) and InGaAs detectors (pink trace).

This Technical Note compares the performance of a 1064 nm laser with an InGaAs detector against 532 nm and 785 nm lasers with the CCD detector, specifically with respect to fluorescence suppression and detection sensitivity.

Extreme Fluorescence - When 1064 is needed

A 1064 nm laser with InGaAs detector is recommended when measuring samples that exhibit extreme fluorescence backgrounds when excited with all other lower wavelength lasers. Common samples where this can occur are dyes, pigments and oils.

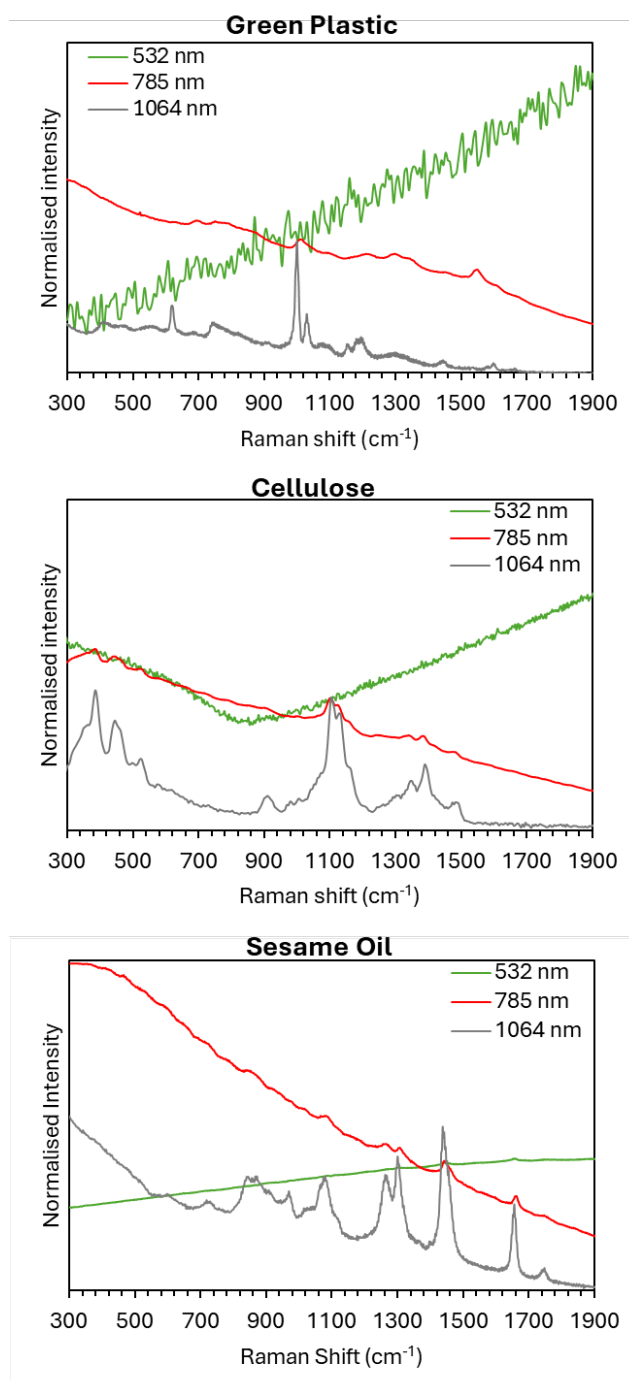


Figure 3. Normalised Raman spectra of plastic, cellulose and sesame oil samples acquired using 532 nm (green traces), 785 nm (red traces), and 1064 nm (grey traces) laser excitations.

In Figure 3, three examples of intense fluorescence interference are demonstrated. In all samples, excitation at 532 nm failed to show Raman signatures because the spectra were dominated by strong fluorescence. Raman information was observed at 785 nm, but the bands occurred on top of high baselines caused by the tail of fluorescence bands. Only when using 1064 nm laser excitation did clear Raman signatures appear without interference from background fluorescence.

Intermediate Fluorescence - When 1064 is Not Needed

Raman scattering intensity is proportional to λ^4 , therefore increasing the laser wavelength reduces the Raman scattering intensity. This, combined with the lower sensitivity of the InGaAs detector, means that 1064 nm Raman spectra require significantly longer acquisition times to achieve the same signal to noise. This is particularly important for Raman mapping, where the acquisition time per point should be kept as low as possible to acquire detailed chemical images quickly.

For many samples, the fluorescence suppression provided by the 1064 nm laser does not justify the lower sensitivity and longer acquisition times. To demonstrate this, an aspirin tablet was analysed at 532 nm, 785 nm, and 1064 nm (Figure 4).

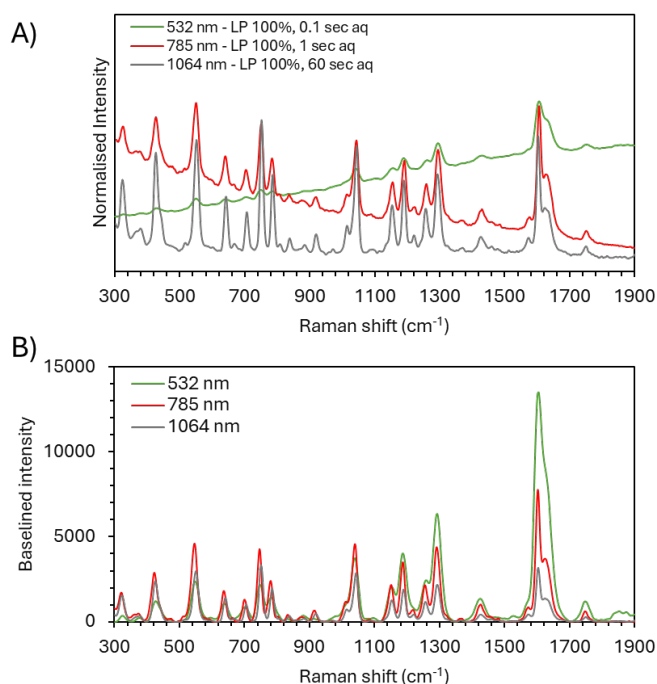


Figure 4. A) Normalised Raman spectra of Aspirin acquired using 532 nm (green trace), 785 nm (red trace), and 1064 nm (grey trace) laser excitation. B) Background-subtracted spectra demonstrating sensitivity differences.

Although the 532 nm and 785 nm spectra display a fluorescence background, the observed spectra still clearly show the Raman signatures of aspirin. Post-processing background subtraction can be performed in Ramacle® to remove the underlying fluorescence backgrounds and obtain high signal-to-noise Raman spectra.

Figure 4B displays the post-processed, background subtracted spectra for aspirin. Spectra for 532 nm and 785 nm show no background fluorescence and exhibit the same Raman bands as seen in the 1064 nm spectrum, which took considerably longer to acquire. This aspirin sample is indicative of many intermediately fluorescent samples where utilising background subtraction or using 785 or 830 nm lasers is recommended over 1064 nm.

Wavelength Sensitivity Comparison

To quantify the difference in sensitivity between the 532 nm, 785 nm and 1064 nm lasers a non-fluorescent cyclohexane sample was measured. Figure 5A demonstrates the effect of laser wavelength on Raman scatter intensity. The intensity difference between the three wavelengths, using the same 5-second acquisition time, is significant. Focusing on the 802 cm⁻¹ ring breathing mode, 532 nm gave 51 times stronger signal intensities compared to 1064 nm, and 25 times more for 785 nm (Figure 5B).

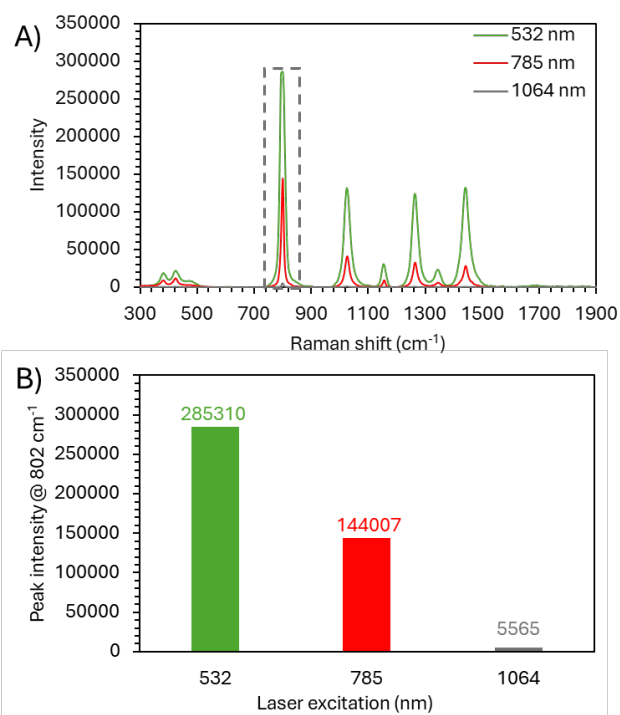


Figure 5. A) Raman spectra of cyclohexane acquired using 532 nm (green trace), 785 nm (red trace), and 1064 nm (grey trace) laser excitation with a 5-second acquisition time. B) Bar chart showing a comparison of each laser excitation for peak intensity at 802 cm⁻¹.

Conclusion

The use of a 1064 nm laser coupled with an InGaAs detector is beneficial when analysing samples with extreme fluorescence backgrounds. However, it is significantly less sensitive than other Raman lasers due to the negative 4th power wavelength dependency on Raman spectra and the use of an InGaAs detector to the InGaAs detector and is therefore only recommended when 785 nm and 830 nm lasers do not sufficiently suppress sample fluorescence. Table 1 provides a guide for the different laser excitations and their impact on factors that would influence Raman qualities and the recommended sample types.

	532 nm	785/830 nm	1064 nm
Detector type:	Silicon CCD	Silicon CCD	InGaAs
Fluorescence:	High	Medium	Low
Raman sensitivity:	High	Medium	Low
Burning risk:	Low	Medium	High
Typical mapping speed:	Fast	Normal	Slow
Optimum sample types:	Non-fluorescent organic and inorganic samples (Carbon nanomaterials, semi-conductors, etc.)	Common wavelength choice for most sample types	Dyes, pigments, coloured plastics and oils

Table 1. Guide for choosing laser excitation wavelengths for a Raman spectrometer.



For more information, please contact:

+44 (0) 1506 425 300
sales@edinst.com
www.edinst.com