application note

HÜBNER Photonics

Have I selected the right laser for my Raman experiments?

Thanks to rapid technology advancements in recent years, Raman spectroscopy has become a routine, cost-efficient, and much appreciated analytical tool with applications in material science and in-line process control for pharmaceutical, food & beverage, chemical and agricultural industries. Improvements in laser technology, detectors (CCDs and InGaAs arrays), and spectral filters (VBG-based notch filters), along with developments of new schemes for signal generation and detection, have aided Raman instrument manufacturers in overcoming the challenge of weak signals which has accelerated instrument development and market growth. In this white paper, we discuss important performance parameters to consider when selecting a laser for Raman spectroscopy experiments.

Why is the choice of laser wavelength important for Raman spectroscopy?

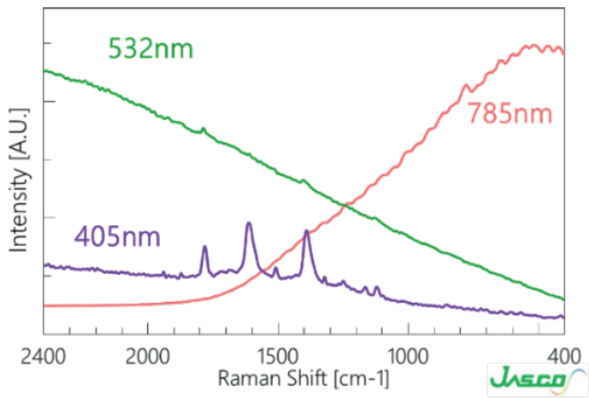
A number of different wavelengths are commonly used in Raman spectroscopy, ranging from the UV, over the visible, and into the near IR. Choosing the best illumination wavelength for a given application is not always obvious. Many variables must be considered in order to optimize a Raman spectroscopy experiment, many of which are connected to the wavelength selection.

To start with, the Raman signal is inherently very weak. It relies on the photon-phonon interaction in the sample material, which is typically a one-in-a-million event. In addition, the Raman scattering intensity is inversely proportional to the 4th order of the illumination wavelength, which means that illumination at longer wavelengths results in a decreased Raman signal.

The detector sensitivity is also dependent on the wavelength range. CCD's are commonly used for detection of the Raman signal. The quantum efficiency of these CCD devices rolls off fairly quickly beyond 800 nm. For illumination beyond 800 nm, it is possible to use InGaAs array devices, but those are associated with higher noise levels, lower sensitivity and higher cost.

The wavelength dependence of the Raman signal strength and the detection sensitivity all seem to point towards the use of shorter wavelength illumination (UV and visible) as opposed to longer wavelengths (in the near-IR). However, there is still a challenge to overcome with shorter wavelength illumination: Fluorescence emission. Many materials emit fluorescence when excited with UV-visible light, which can swamp the weak Raman signal.

Even so, the most commonly used wavelength in Raman spectroscopy is 785 nm. It offers the best balance between scattering efficiency, influence of fluorescence, detector efficiency and availability of cost-efficient and compact, high-quality laser sources. However, the use of visible lasers in the blue and green (in particular at 532 nm) is increasing.



Raman spectrum of polyimide using 3 different wavelengths. For the green and NIR the Raman signal is buried in fluorescence for 532 nm and 785 nm laser excitation. However it is easily resolved when using 405 nm.

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What types of lasers are commonly used for Raman spectroscopy and how do you decide which one is best for your application?

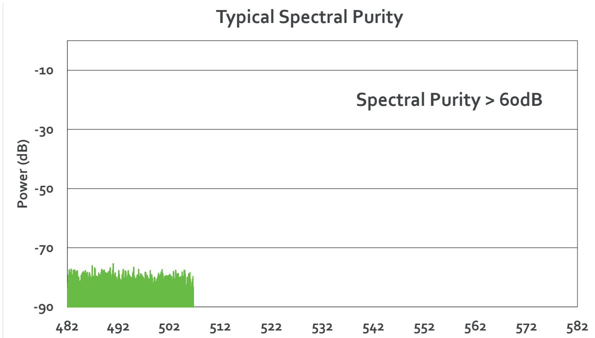
Solid-state based CW laser sources that are commonly used for Raman spectroscopy can be grouped into three categories:

i) Diode-pumped lasers: SLM (single-longitudinal mode)

ii) Single-mode diode lasers: DFB (distributed feedback) or DBR (distributed Bragg reflection)

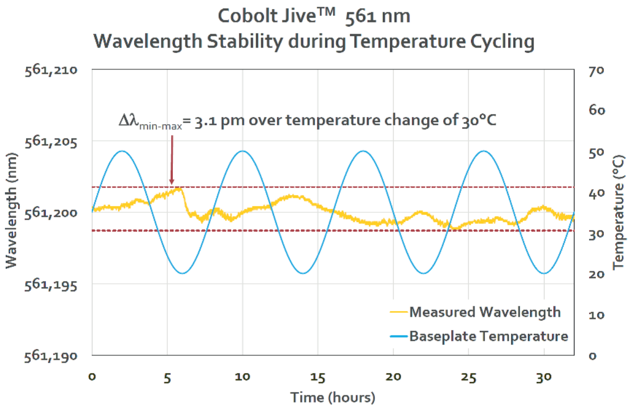
iii) VBG frequency stabilized diode lasers

These laser technologies cover different wavelength regions and have significant differences in optical performance, explained below.

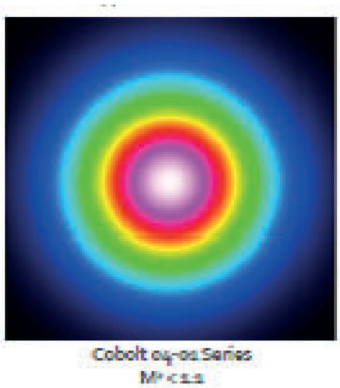


Wavelength spectrum of a Cobolt DPL (diode pumped SLM laser), the latter showing a very clean spectrum (no side-modes) below 60 dB.

i) Diode-pumped SLM lasers (DPL lasers) combined with built-in nonlinear optical frequency conversion are readily available in compact formats from the UV to the near-IR. Up to Watt power levels are achievable at 1064nm in the near IR. In the visible range, a large number of lines in the blue-green-red region (660, 640, 561, 532, 515, 491, 473, 457 nm) are available and with output powers on the scale of several hundred mW. Lower power levels are achievable in the UV, such as 10 to 50 mW at 355nm. These lasers provide excellent TEM00 beams, very precise wavelengths with low drift and a single-frequency linewidth of typically far less than 1 MHz. These lasers also offer a very high level of spectral purity with typically much greater than 60 dB SMSR up to within pm of the main peak. There may be occurrence of low level emissions at neighbouring laser lines, but they are several nanometers shifted from the main peak and therefore easily eliminated by integrating a dielectric band-pass filter. The wavelength stability is inherently excellent (see figure).



Wavelength stability of a Cobolt DPL (diode pumped laser) showing a shift < 3.1 pm over 30 °C base plate temperature change.



Typical TEM00 beam profile

ii) Single-mode diode lasers provide very compact and cost efficient illumination sources with single-frequency linewidth (<1 MHz) and single-transversal mode beam quality. A number of wavelengths are available in the red to near IR, with output powers up to a few 100 mW and MHz linewidth. The most commonly used wavelengths are 785, 830, 980 and 1064 nm. Side-band emission limits the SMSR of these lasers to around 50 dB, which is normally achieved at a few 100 pm away from the main peak.

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