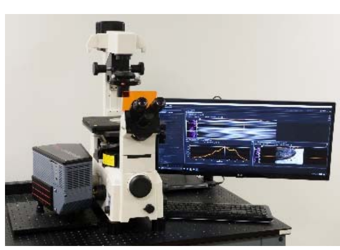
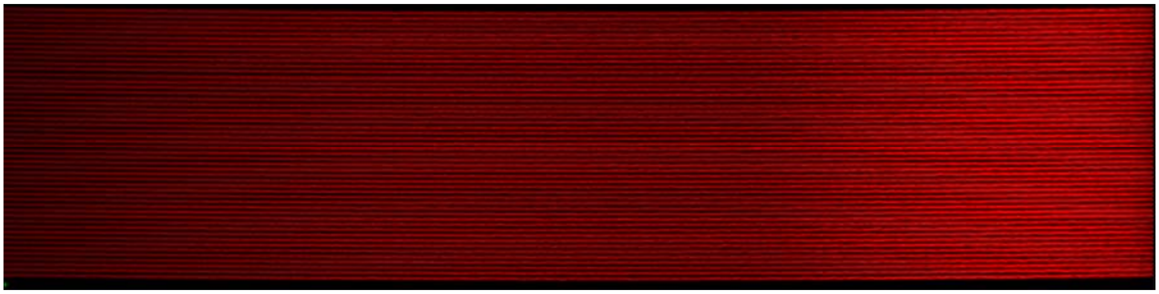
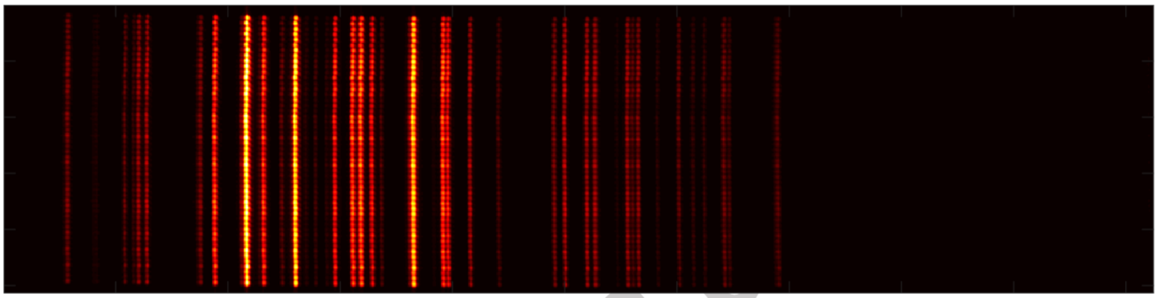
Advanced Spectroscopy Laboratory

- Raman Spectroscopy
- Emission Spectroscopy
- Absorption Spectroscopy
- Raman Microscopy
- Hyperspectral Imaging Spectroscopy

FERGIELAB™

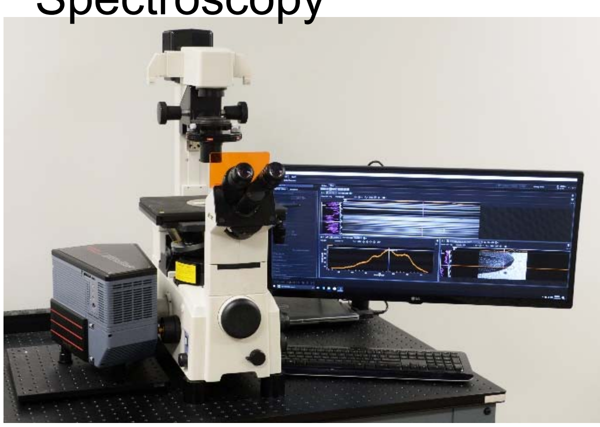




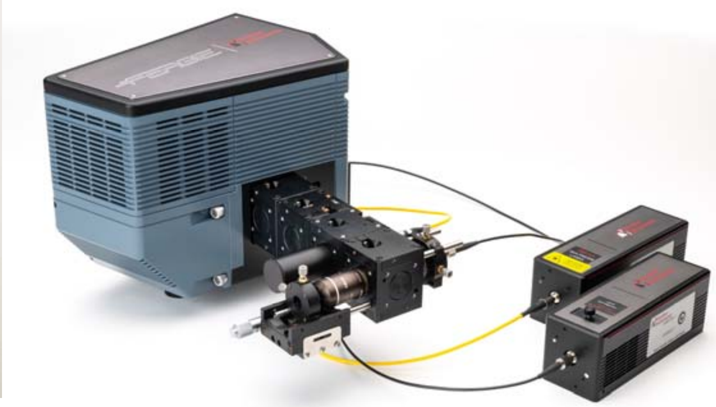
Raman Spectroscopy

Absorption Spectroscopy

Hyperspectral Imaging Spectroscopy

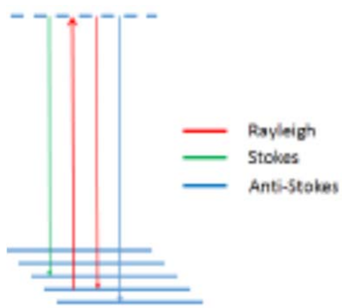


Raman Microscopy



Raman Spectroscopy

Raman scattering was discovered by Indian scientist C.V. Raman in 1928, which won Nobel Prize in physics for his work two year later. Since then, Raman spectroscopy has become one of the most important analytical technologies in scientific research and industrial material characterization.

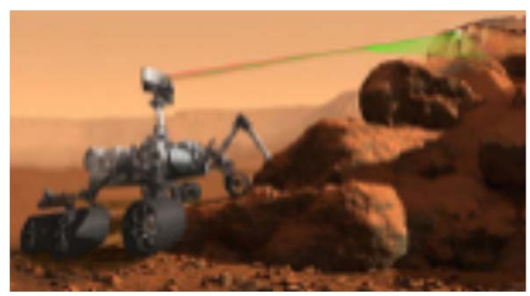


Raman scattering is inelastic where the scattered light has a wavelength shift due to the interaction of incident light with molecules dipole moment. The wavelength shift in Raman scattering is determined by the vibration modes of the molecules under investigation. The intensity of the scattering is also determined by molecular structure (induced dipole moment). Therefore, Raman spectroscopy is widely used for chemical identification and quantification in many different research fields. Since Raman scattering is considered a 'weak' effect with a cross section orders of magnitude lower than fluorescence or absorption, laser is used as light source for its brightness and monochromatic properties.

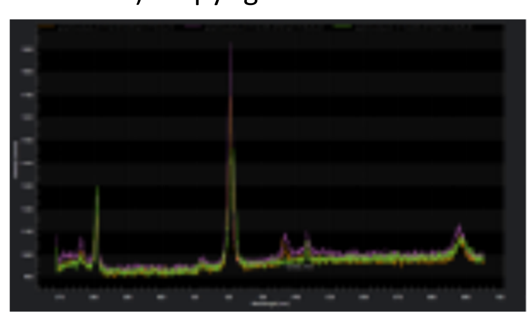
Advantages:
- Non-invasive/non-contact/non-destructive
- No sample preparation
- Work for gas/liquid/solid samples
- Standoff detection
- Fingerprint spectral information
- Good for IR inactive species

Disadvantages:
- Not for metal and some inorganics
- Fluorescence interference
- Sample burning
- Laser safety

Applications:
- Pharmaceutical/food/cosmetics
- Geology and mineralogy
- Carbon material (graphene)
- Life science



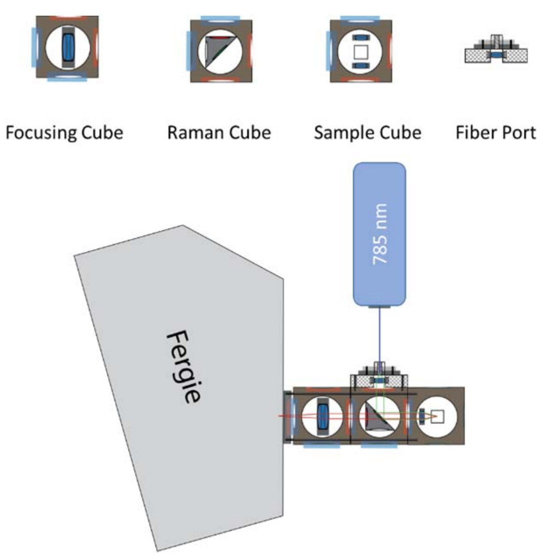
Artistic rendering of SHERLOC on Mars 2020 Rover (Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals). Copyright NASA 2018.



Raman spectra of graphene at 10 K, 100K and 200 K

Raman Spectroscopy

Instrument Setup:



Experiment:

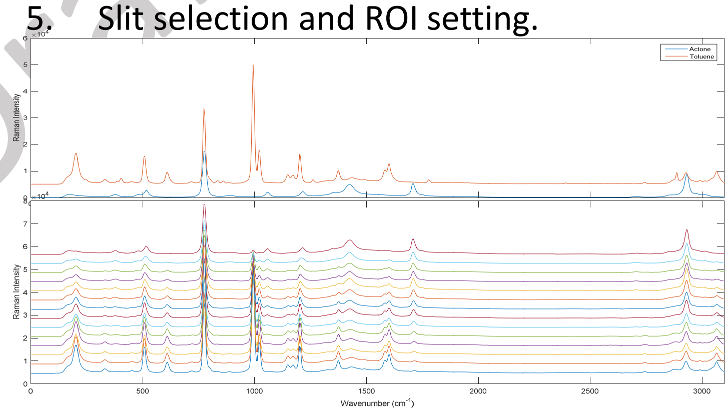
1. Setup the Raman spectroscopic measurement;
2. Use LightField™ software to control the spectrometer and laser;
3. Collect Raman spectra from chemical samples

Notice:

1. Alignment of the focusing cube;
2. Avoid saturation by using proper exposure time;
3. Correct wavenumber coverage;
4. Background and ambient light interference;
5. Slit selection and ROI setting.

Raman Spectra:

1. Chemical information;
2. Raman peaks assignment;
3. Mixture analysis;



Discussion:

- Why use laser as illumination source for Raman spectral measurement?
- The function of the filters in the Raman cube;
- Comparison of Raman spectroscopy with other spectroscopic technologies: FTIR, Fluorescence spectroscopy, UV-VIS spectroscopy;
- Can Raman spectroscopy be used for gases (O2, N2 et al)?
- What's the benefit of using a laser source at different wavelengths (248 nm, 532 nm and 1064 nm?
- Spectral resolution and signal-to-noise ratio.

Topics for consideration:

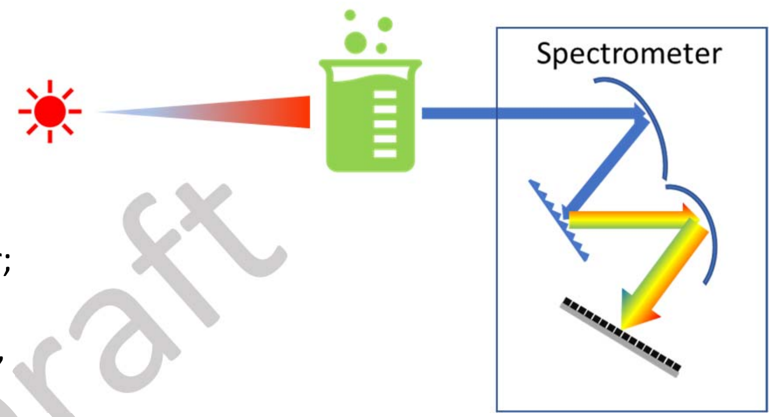
- Raman probe to measure house hold materials, druges, food, et al.;
- Raman probe to monitor dynamic process: reaction for example;
- Advanced data analysis with chemometric tools;
- Other Raman related tests: Surface Enhanced Raman Spectroscopy (SERS), Raman Microscopy, 532 nm/1064 nm Raman, and anti-Stokes Raman.

Absorption Spectroscopy

Absorption spectroscopy measures the radiation absorbed by materials as a function of wavelength. The first observation of optical absorption phenomenon may be traced back to early 19th century when scientists discovered 'dark' lines in solar spectrum, Fraunhofer lines named after a German physicist. It was until late 19th century that these lines was correctly attributed to absorption of various gaseous species in the solar atmosphere.

The light dispersion mechanisms in modern optical spectrometers are primarily:

- Grating based spectrometer (shown in the picture);
- Fourier transform interferometer;
- Others (AOTF, optical thin film filter, Fabry-Perot interferometer, tunable laser et al.)

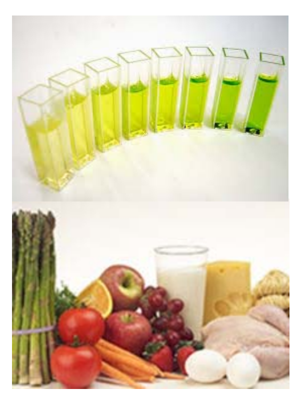


Absorption of radiation as described by quantum mechanics is due to the excitation of molecular / atom from one energy state to an excited state after absorbing photon/s:

- Microwave (THz): rotational
- Infra-red: vibrational
- NIR: vibrational overtone and combination
- UV-Vis: electronic/atomic
- X-ray: inner shell electron excitation

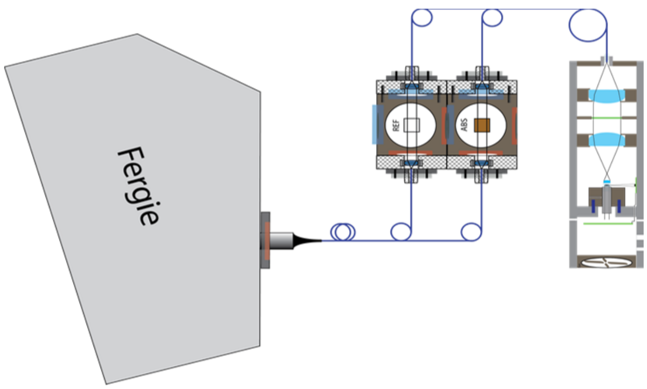
Applications:
Absorption spectroscopy technologies are widely used in many researches and industries

- Material analysis
- Remote sensing
- Astronomy
- Food/Pharma/Agriculture
- Petroleum/chemical
- ……



Absorption Spectroscopy

Instrument Setup:



Experiment:

1. Setup the absorption spectroscopic measurement with a reference cell;
2. Use LightField™ software to control the spectrometer and the broad band light source;
3. Collect absorption spectra from chemical samples;
4. Develop a concentration calibration curve and use it to measure concentration of a mixture

Notice:

1. Alignment of bifurcating fiber bundle;
2. Avoid saturation by using proper exposure time;
3. Correct wavenumber coverage;
4. ROI and formula setting

Discussion:

- Beer's law and its limitation
- Advantages of using a reference cell
- What spectral information can be obtained at 200-1100 nm range?
- Unit conversion transmission-absorption
- Color and color-blind

Topics for consideration:

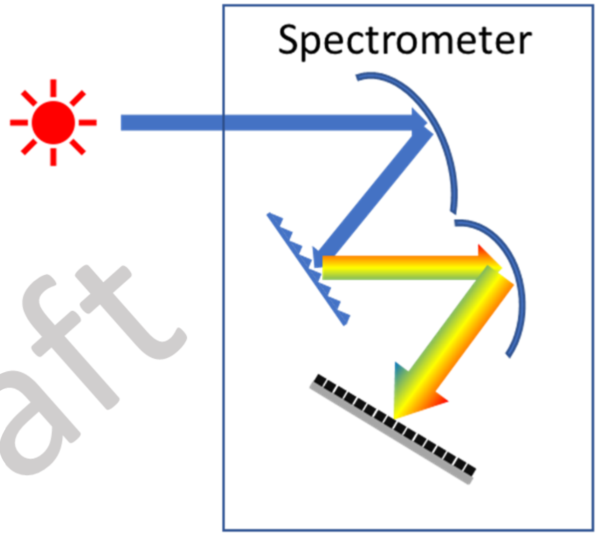
- Reflectance measurement
- Time-resolved spectroscopy for dynamic processes
- Advanced qualitative and quantitative data analysis with chemometric software

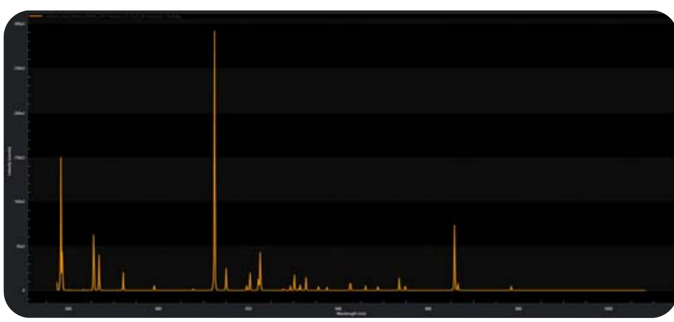
Emission Spectroscopy

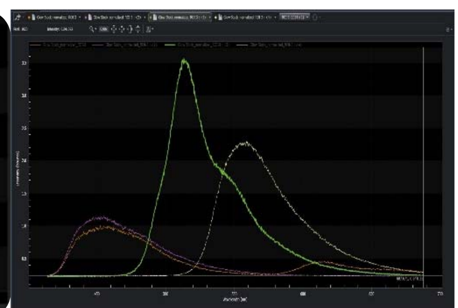
Emission spectroscopy measures the radiation emitted by materials as a function of wavelength. Newton was perhaps among the most famous scientists who studied solar spectrum, the discovery of dispersing sun light into rainbow colored spectrum using a prism can be traced back to ancient Rome and Greece.

The light dispersion mechanisms in modern optical spectrometers are primarily:

- Grating based spectrometer (shown in the picture);
- Fourier transform interferometer;
- Others (AOTF, optical thin film filter, Fabry-Perot interferometer, tunable laser et al.)





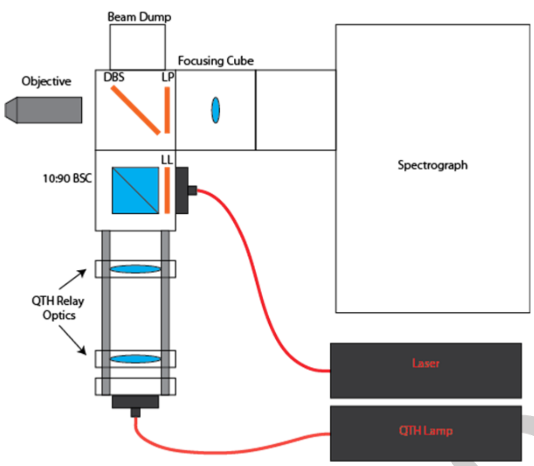


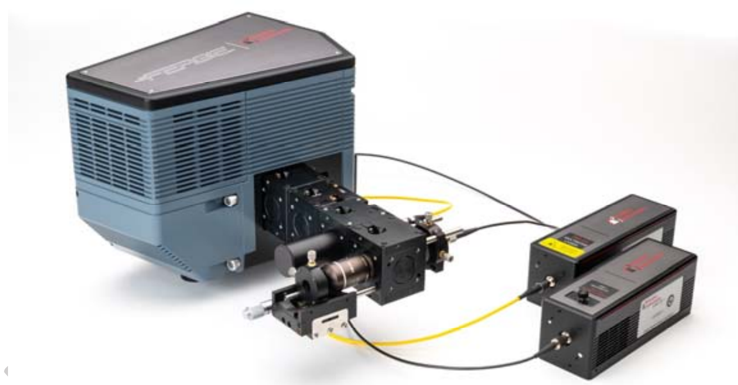
Applications:

- Chemiluminescence
- Remote sensing
- Astronomy
- Element analysis

Raman Microscopy

Raman microscopy combines the power of two commonly used analytical technologies. It provides both the imaging and spectral information which is particularly useful for heterogeneous material analysis. Confocal Raman microscopy can provide not only spectral information on sample surface but also in depth.

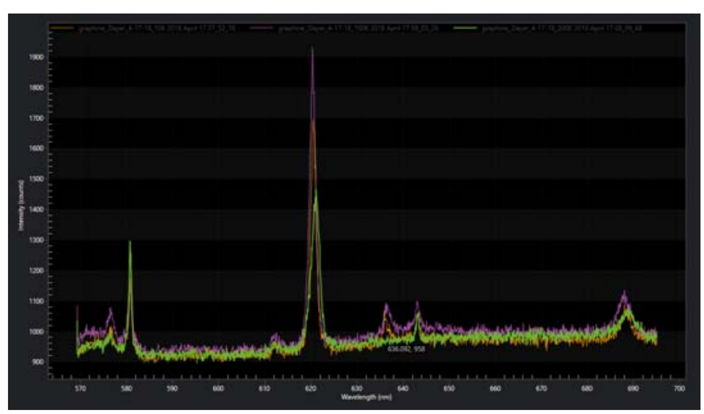




Schematic of Raman microscopy setup. QTH lamp provide illumination of white field image of the sample

Applications:

- Graphene
- Bioscience
- Semiconductor
- Pharmaceutical
- Solar cell
- 2D material



Raman spectra of graphene at 10K, 100K and 200K