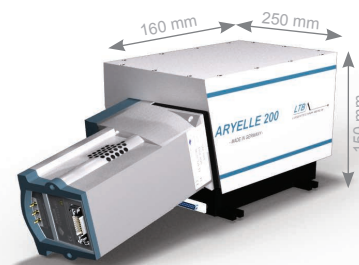


ARYELLE²⁰⁰ Spectrometers

Interaction of light and matter –
induced and analyzed with lasers
and measuring systems of LTB

ARYELLE 200* ARraY EchELLE Spectrograph



- Compact and very stable
- High resolution (7,000-15,000)
- Large simultaneous wavelength range
- Can be combined with different detectors (CCD, EMCCD, ICCD, CMOS)
- Up to 30 spectra per second
- Easily configurable dispersion unit

ARYELLE 200 is a compact and inexpensive high-resolution echelle spectrometer for the material/elemental analysis with LIBS and Raman spectroscopy in industrial applications.

ARYELLE 200 is a cost-efficient echelle spectrometer with fibre coupling for different CCD-, EMCCD, ICCD and CMOS image detectors. It is characterized by high sensitivity and high imaging quality. The dispersion unit with grating and prism can be easily configured for different applications.

Application fields of the ARYELLE 200 are the material and elemental analysis by means of laser-induced breakdown (LIBS) or Raman spectroscopy. Due to its compact design it is well suited for the industrial process control, e.g. in the steel, glass and ceramics industry or in pharmaceuticals, chemistry and environmental analytics.

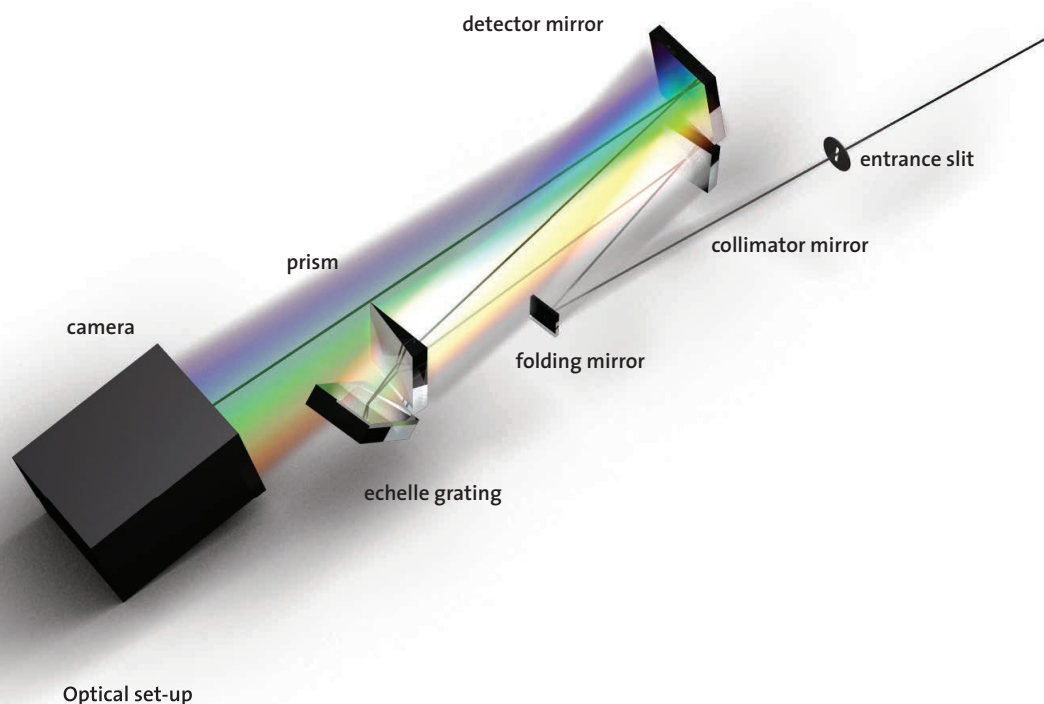
In combination with the MA 300 you get a complete LIBS system. Other customized system setups can be realized according to your requirements.

Spectrometer concept

ARYELLE 200 has a focal length of 200 mm and an aperture of f/10. Depending on the required simultaneously detectable wavelength range, it is possible to measure spectra from the UV up to the NIR with a spectral resolving power of 7,000 to 15,000 (at a slit width of 40 μm).

The maximum sensitive area that can be used for detection is 20 x 20 mm^2 . Thus most CCD, EMCCD, ICCD and CMOS cameras of different suppliers can be used.

As standard detectors 1k x 1k CCD or ICCD cameras with an image area of 13 x 13 mm^2 are used for the spectra recording. Their combination with our standard dispersion unit result in large gap-free inspection ranges with a resolving power of greater than 9,000.



Spectrometers

The internal shutter and the integrated mercury lamp for the automatic recalibration of the spectrometer as well as the intuitive software allow a comfortable operation of the spectrometer.

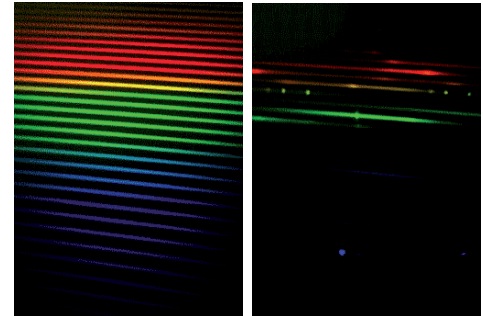
Software

The controlling and evaluation software Sophi controls all spectrometer and detector functions. A two-dimensional spectrum is extracted from the detector raw data which is automatically analyzed with an integrated data base. The spectral lines are assigned to the corresponding elements and specified.

Quantitative analysis algorithms are integrated as well. For a quantitative evaluation, a calibration with comparable samples is necessary. Quantification curves can be generated with only few mouse clicks.

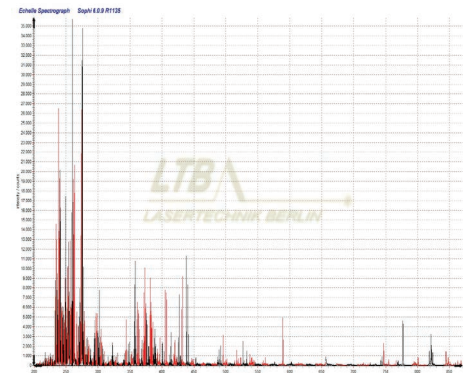
The integrated script language enables the automation of sophisticated or repeated measuring tasks. For spatially resolved measurements, an optional XYZ-table can be integrated in the script.

The optional SDK/LabView allows the complete access to all spectrometer functions and the incorporation into in-house software applications.

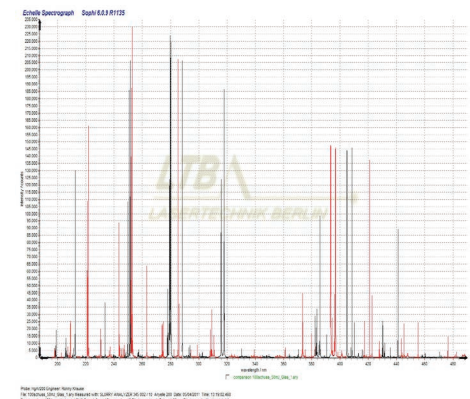


Spectrum of a tungsten lamp

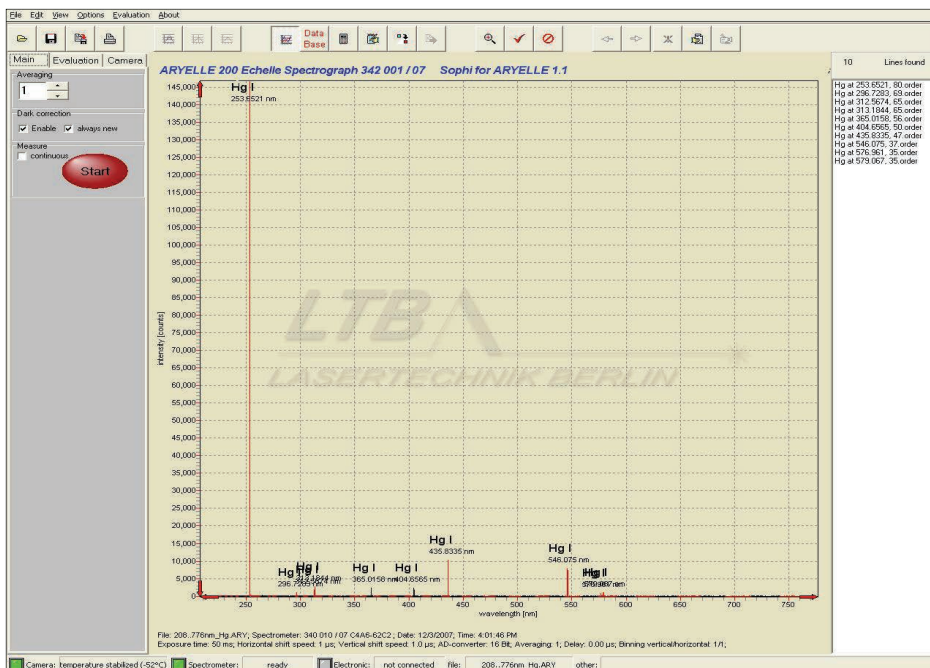
Visible spectrum of a fluorescent lamp (400 - 800 nm)



Highly resolved spectrum of a steel sample
Resolving power 9,000



Part of a spectrum of a glass sample
Resolving power 9,000



Software

Spectrometers

Specifications ARYELLE 200, typ.

Aperture	f/10
Focal length	200 mm
Slit width	40 μ m
Wavelength range	220 - 800 nm / 200 - 750 nm
Spectral resolving power	9,000
Spectral resolution	24 - 90 pm / 22 - 83 pm
Crosstalk	5×10^{-3} (ICCD) / 2×10^{-3} (CCD) measured @ 253.652 nm and full slit height
Straylight	1×10^{-4}
Detector	CCD/ICCD 1,024 x 1,024 pixels, 13 x 13 mm ² image area
Dynamic range	15 bit, AD conversion 16 bit
Light coupling	SMA-fibre coupling
Wavelength calibration	With Hg lamp
Absolute accuracy	Spectral resolution/4
Computer	PC or laptop with Windows
Software	Sophi
Dimensions without detector (L x W x H)	(260 x 160 x 185) mm, (10.24 x 6.3 x 7.28) in
Weight without detector	7.3 kg (16.0 lbs)

other spectral resolutions and wavelength ranges are possible

APPLICATIONS

- [LIBS – laser-induced breakdown spectroscopy](#)
- [Raman spectroscopy](#)
- Industrial process control
- Absorption spectroscopy
- Gas chromatography

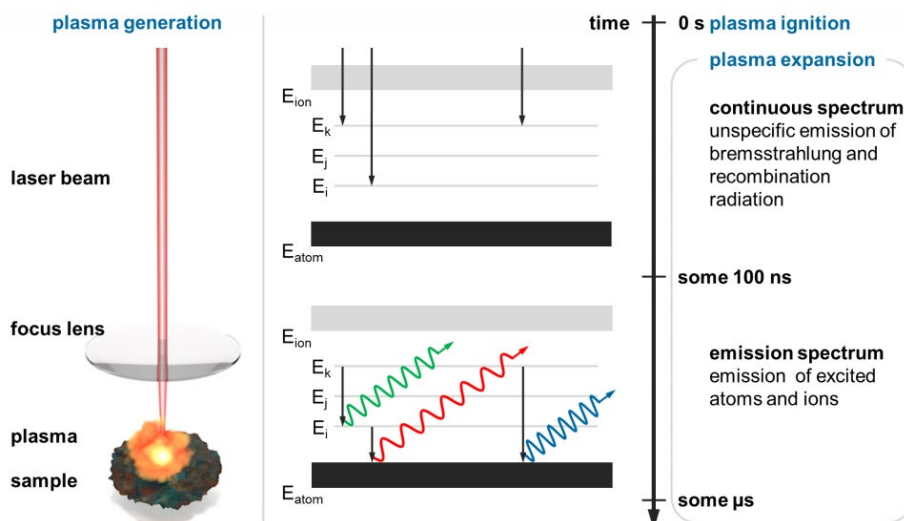
(APP) LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS)

Laser-Induced Breakdown Spectroscopy (LIBS) is a type of atomic emission spectroscopy for the qualitative and quantitative chemical multi-elemental analysis in real time for a wide range of applications.

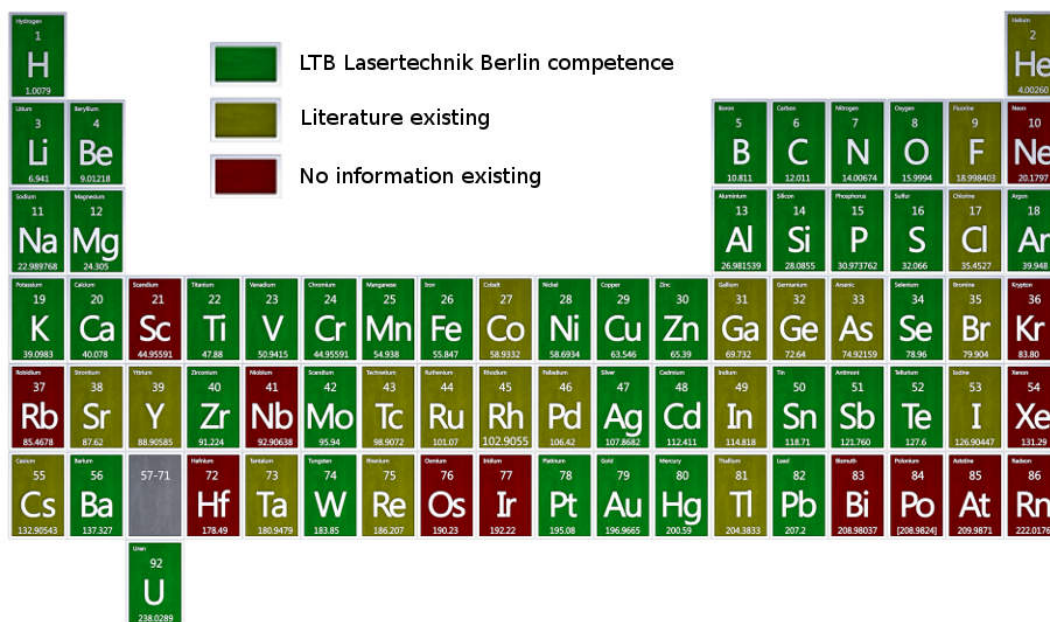
- For solid, liquid, gaseous sample and slurries
- Contact-free and almost non-destructive
- No or little sample preparation necessary
- Spatially- and depth-resolved analysis possible
- Remote sensing up to several meters

HOW DOES LIBS WORK?

The measuring principle of **LIBS** is based on the spectral analysis of characteristic emission lines of atoms and ions. Short pulse laser radiation that is focused on the surface of a sample causes a local heating of some 10,000 °C and leads to the generation of a light emitting plasma – consisting of atoms and ions of the ablated material. Shortly after its ignition, the expanding plasma emits unspecific bremsstrahlung and recombination radiation (continuous spectrum). After some 100 ns atoms and ions recombine while emitting a characteristic emission spectrum – like a fingerprint. The spectral analysis by means of a high-resolution spectrometer allows the determination of the atomic composition of the sample.



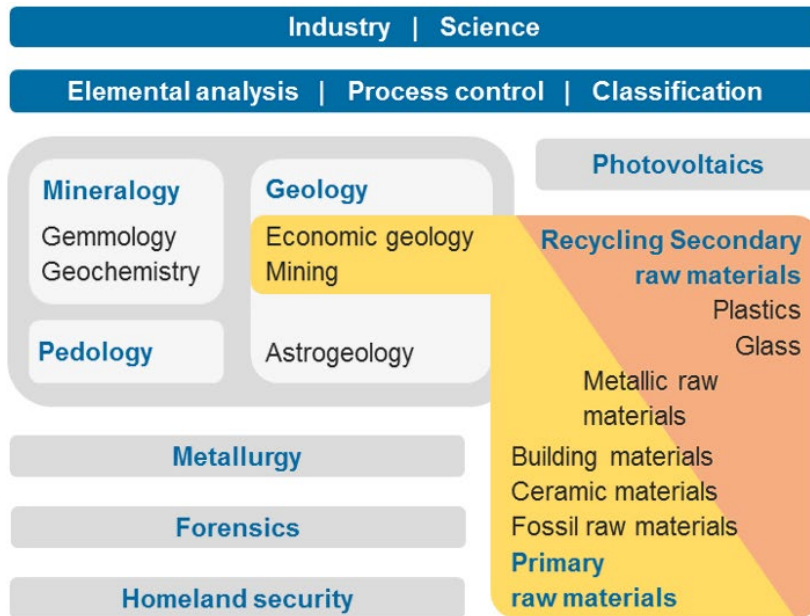
LIBS CAN?



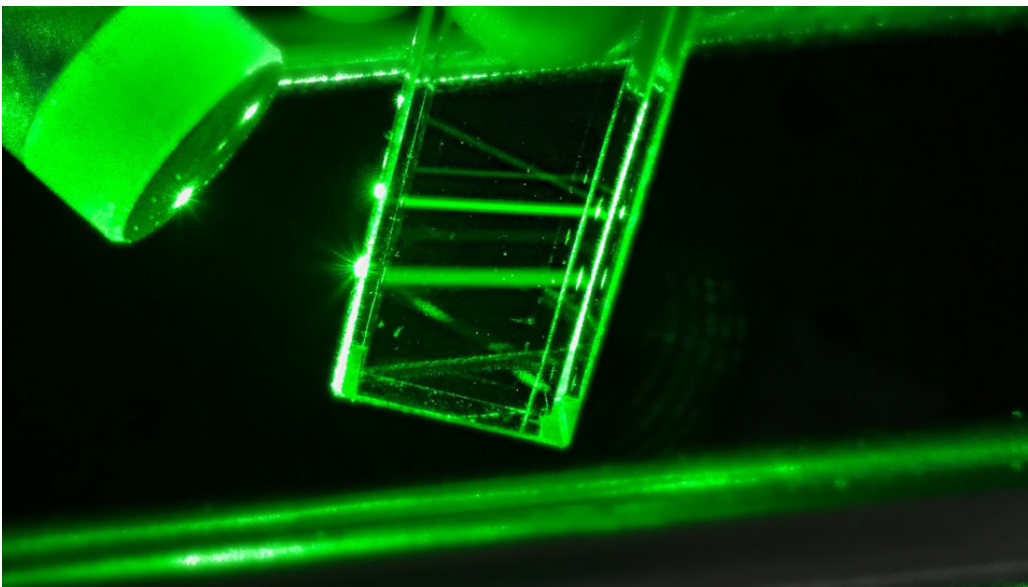
LIBS is one of the few analytical techniques which is capable of measuring a large number of chemical elements simultaneously. Unlike X-ray fluorescence (XRF) and other methods, light chemical elements can be characterized. LIBS provides multi-elemental analysis with the advantage to quickly determine the atomic composition of an unknown sample with only a single measurement. The detected LIBS spectrum is characterized with the help of atomic data bases and qualitatively assigned to the corresponding elements. Quantitative analysis is based on calibration with reference materials containing different analyte concentrations. Depending on the analyte-matrix, element concentrations in the low ppm-range can be measured.

LIBS - WHICH APPLICATIONS?

The application possibilities of LIBS are virtually endless. The spectrum ranges from chemical analysis of elements in vacuum environment, contact-free remote sensing in hazardous – e.g. radioactive – environments, classification of geological resources and scrap materials to online quality control of industrial goods. LTB Lasertechnik Berlin offers a variety of LIBS analyzers.



(APP) RAMAN SPECTROSCOPY

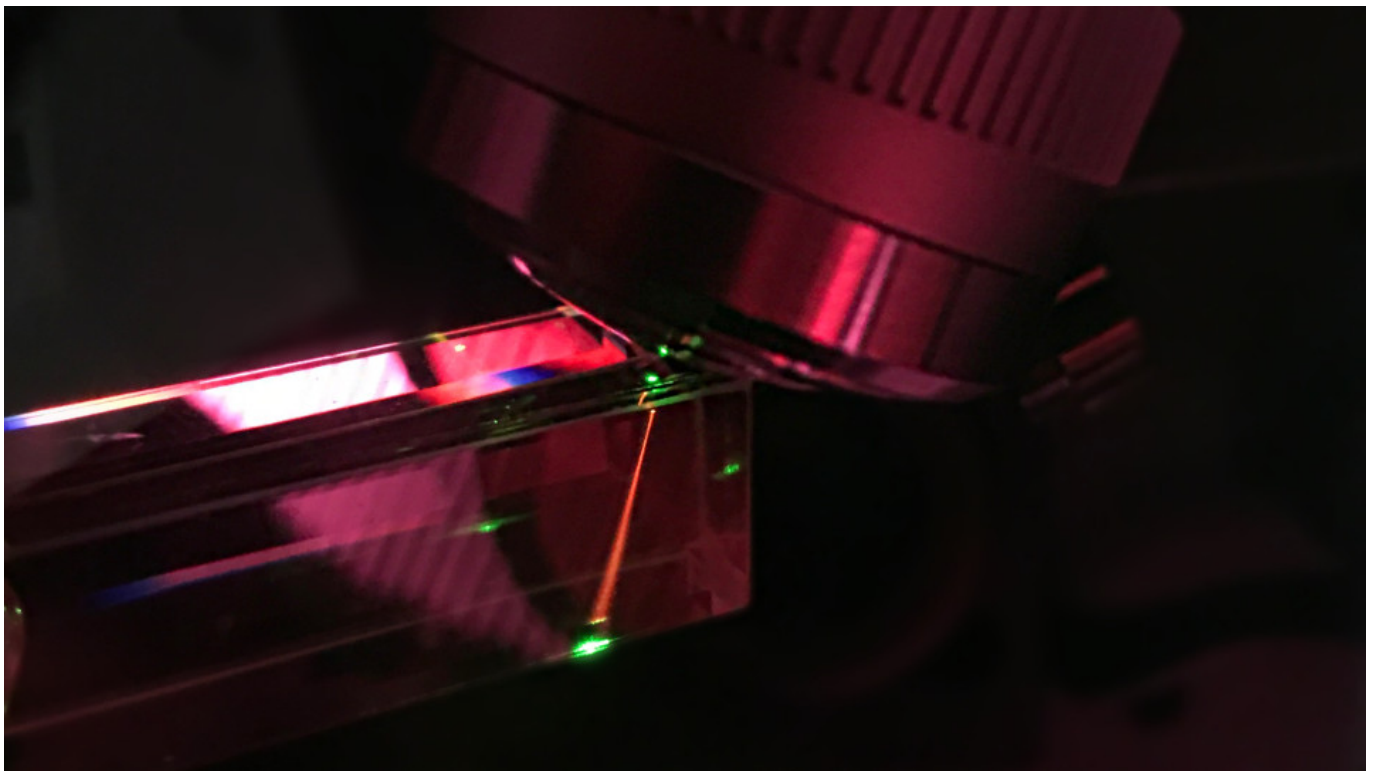


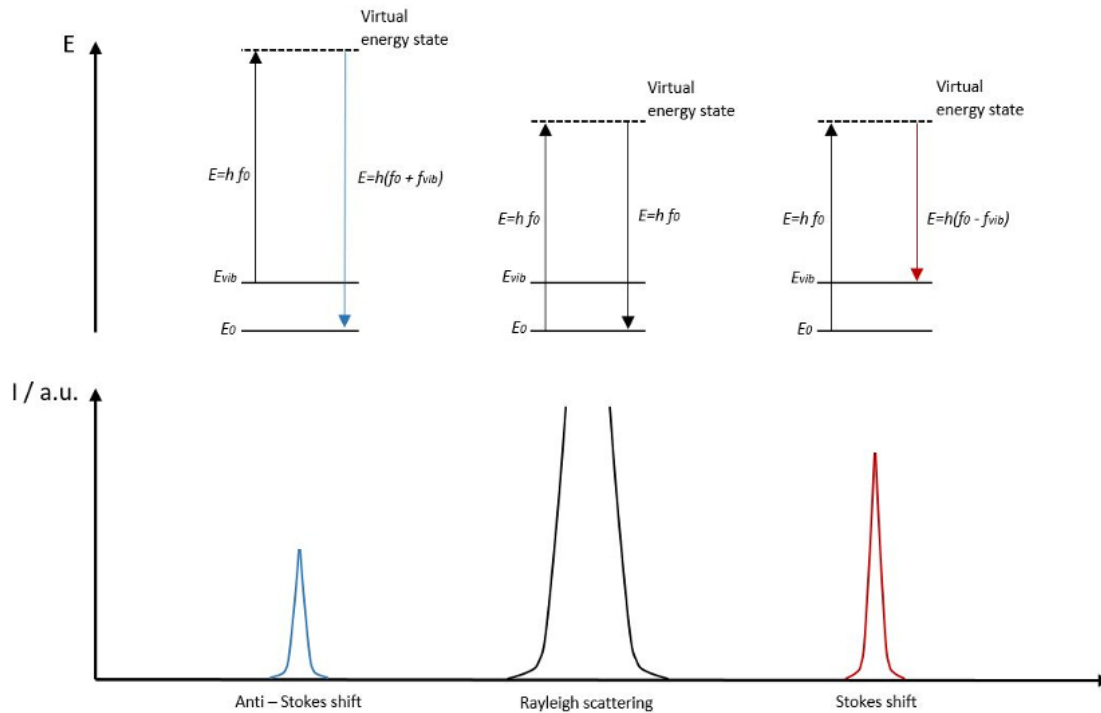
Raman spectroscopy, named after Sir C. V. Raman, is a physical measuring technique used to detect and interpret scattered light. In chemical analytics, the technique is applied to acquire information about molecular structure, and is well established in a vast variety of material-specific applications in science and industry all over the world. **Raman** enables:

- Analytics in geology, chemistry, biology and materials science
- Measurements independent of the state of matter of the sample
- Combined measuring techniques: **Raman** and **laser-induced breakdown spectroscopy (LIBS)**
- Acquisition of information regarding chemical composition, crystal orientation and structure, presence of internal stresses, detection of chemical doping and material temperature

FUNCTIONALITY

The material of interest is illuminated with a monochromatic light source (typically a laser) and the returning light is measured. Due to scattering caused by the interaction between light and matter, the formerly monochromatic light that has interacted with the sample material experiences changes in wavelength. Detected spectra include, therefore, not only the excitation wavelength (via both reflection and Rayleigh scattering), but also a red and blue shift known as the Stokes and anti-Stokes effects respectively. This is due to the reactions of molecules in the material to the incident light: namely, vibration and rotation at characteristic frequencies as determined by molecular bonds. Therefore, by observing the scattered light, **Raman spectroscopy** enables the determination of molecular bonding type, organic composition and a variety of other chemical properties.





Stokes and anti-Stokes scattering are symmetrical phenomena on a wave-number axis centered on the excitation/Rayleigh wavelength. They occur only in the case of characteristic vibration and rotation and cause an energy shift of the scattered light, whereas Rayleigh scattering does not affect energy or wavelength. In the case of the Stokes effect, wherein light is red-shifted, the energy of the scattered light is lower than that of the excitation source by a factor exactly equal to the vibrational energy of the excited molecules. The anti-Stokes effect – a blue shift from the excitation wavelength – is characterized by an energy increase as compared to the light source caused by vibrational energy already present in the radiated molecules which is transferred to the scattered light. According to the Boltzmann equation, Stokes shifts occur with higher probability than anti-Stokes and are therefore typically detected with much higher intensity. For this reason, many measurement systems rely more on detection of Stokes than anti-Stokes.

APPLICATIONS

As a state-of-the-art technique, spectroscopy offers many experimental possibilities to acquire compositional information of materials. Raman spectroscopy is particularly suited to the collection of information about chemical and molecular structure, and therefore highly applicable in not only research, but also industry. One such development already undertaken by LTB Lasertechnik Berlin is a single Echelle spectroscopy system capable of both Raman and LIBS measurements. This combined apparatus therefore enables the measurement of not only the composition of a material, but also its molecular structure. The potential applications of such a flexible system are innumerable – examples might include the measurement of geological samples, organic and inorganic materials, metallic alloys and even pharmaceutical compounds.

