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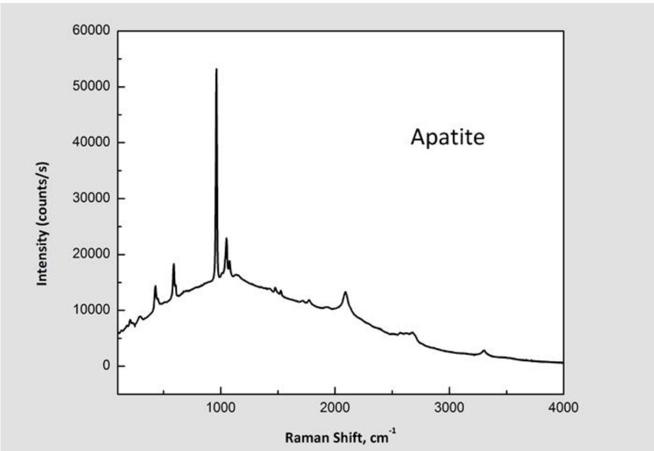
EnSpectr
Enhanced Spectrometry

EnSpectr Raman for Rapid Non Destructive Analysis of Gems & Minerals

Handheld RaPort®, bench top R532® and microscope RamMics® for instant identification of gemstones, analysis of origin and genotype

Raman spectroscopy is a high-power instrument for rapid analysis of gemstones and minerals. Analysis of an object' surface and inclusions reveals a number of facts i.e. whether the gemstone has been treated or not, as well as its origin and genotype. Now this kind of diagnostics can be carried out within just a few seconds by means of a bench top EnSpectr R532, portable Raman microscope RamMics M532 or a handheld Raman analyzer RaPort.

EnSpectr Raman and micro-Raman instruments implement a variety of Raman spectroscopy advantages to scientific and industrial areas of mineralogy, being inalienable diagnostic tools especially when rapid result is needed. The instruments by far reduce the time of analysis, and significantly increase the accuracy of gemstone identification, taking into account that the gemstone under examination may be put still in any set of a jewel. Instead of awkward-to-handle Raman spectrometers EnSpectr supplies highly compact Raman and micro-Raman devices which can even take such analysis in field.



Raman spectrum of apatite

Raman spectrometry helps analyze majority of gemstones and minerals though, of course, the method meets several restrictions. Some gems i.e. cryptocrystalline minerals, like larimar or opal, may incite strong photoluminescence. That can be partly cured with a special CCD shutter (implemented within EnSpectr products). Alternatively laser power may be diminished, measurement time increased, or low-wavenumber analysis applied.

Attention should be paid to thermally unstable gemstones and minerals i.e. ruby silver as they could melt under strong laser emission. In such cases measurement time and laser power should be set carefully.

EnSpectr Product line for Mineralogy

	R532	RamMics	RaPort
Spectral range	100-4000 cm^{-1}		100-4500 cm^{-1}
Spectral resolution	4-6 cm^{-1}		6-8 cm^{-1}
Spatial resolution	20 µm	1 µm	>50 µm
Usability	Tabletop laboratory	Maximum capability	Utmost mobility

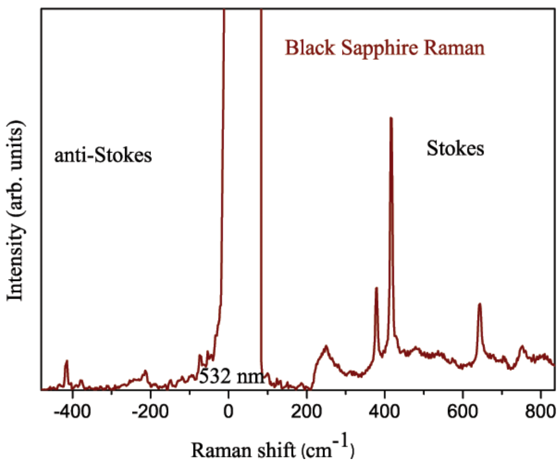
EnSpectr R532®

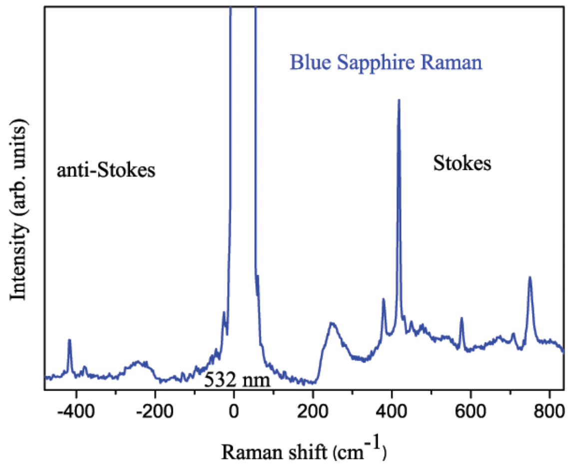
EnSpectr R532 is a benchtop Raman analyzer with superior sensitivity, combining the advantage of a portable probe system with the performance of a highly specified laboratory instrument.

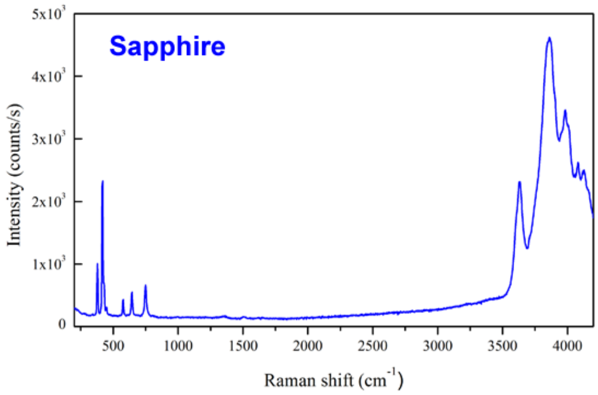
The instrument covers spectral range of 100-4000 cm^{-1} and is also able of measuring Stokes and Anti-Stokes algorithms. EnSpectr R532 can be equipped with a special CCD shutter that cuts luminescence of complicated for analysis gemstones and minerals. Put the device on the Sample Stage or use special attachments for jewels for better sample positioning.

Advantages:

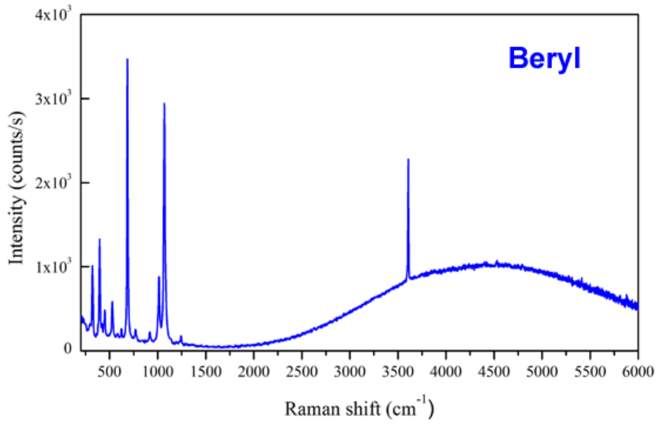
- Non-destructive identification of gems & materials
- Authentication and anti-counterfeiting of gemstones
- Lightweight and portable for in-situ laboratories







Luminescent spectrum of sapphire

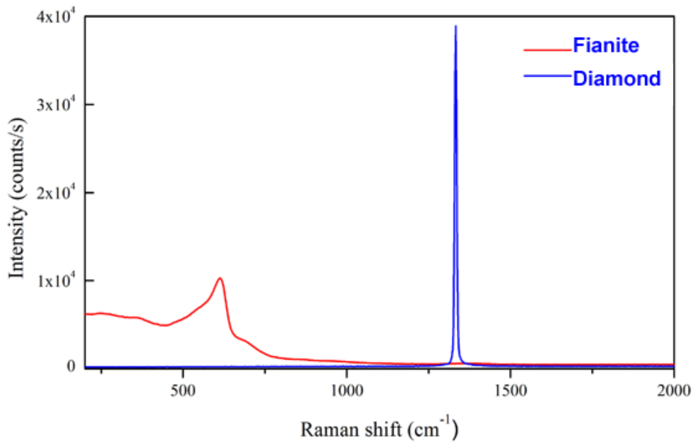


Luminescent spectrum of beryl

EnSpectr RaPort®

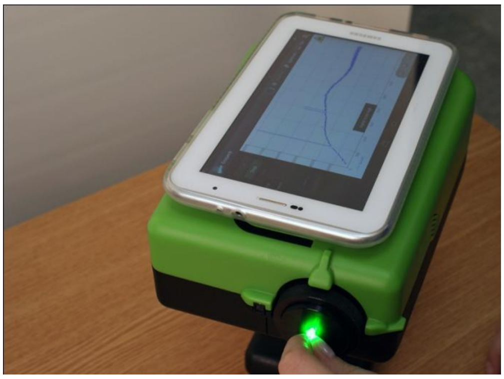
RaPort is a handheld Raman instrument for rapid in-situ identification of gemstones and minerals based on a bench-top model EnSpectr R532. So far the bench top device has equipped the Center of Gemology in Japan (research), the Customs of Russian Federation (authentication and anti-counterfeiting of gemstones), the Gemology Center of Moscow State University (expert laboratory; applies instrument for identification and evaluation of gemstones) and several other labs, and now RaPort provides opportunity for analysis of the same quality outside scientific departments.

Advantages:



- **High-quality results outside the lab**: identification of gemstones, identification and verification of semiprecious gemstones, identification of isomorphs and subspecies.
- **Discovering the essence**: measure directly from jewels never minding the set or

jewelry type. Wide spectral range of 100- 4500 cm^{-1} is complemented with a shutter covering red-yellow photoluminescence.

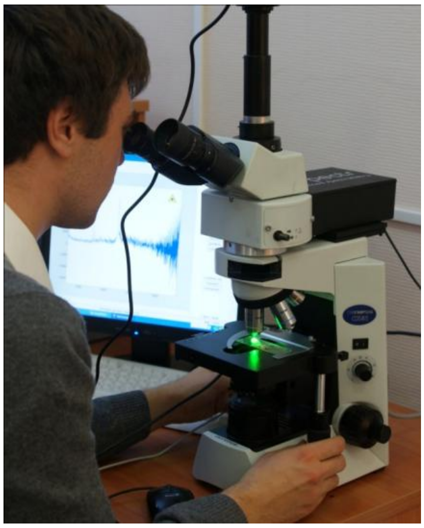


- **Rapid analysis:** time per measurement < 3 seconds.
- **Superb delicacy and sensitivity:** even with laser power of 12 mW and less (which is crucial in case of temperature unstable gems) RaPort perfectly acquires gem or mineral spectrum with high speed and extra quality. RaPort guarantees non-destructive high level protection of gemstones.

- **Instant data at your fingertips:** use the instrument with your smartphone/tablet on Android OS or with a PC. Data transmission via Bluetooth. Long battery life.

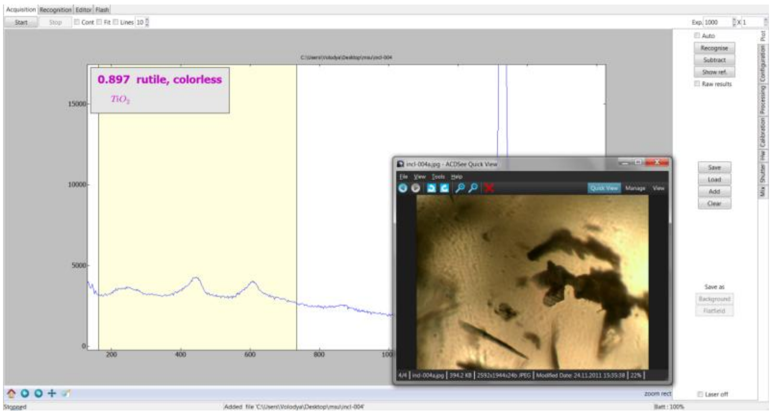
Raman Microscope RamMics®

Raman microscope RamMics M532 integrates opportunities of Raman Analyzer EnSpectr R532 Scientific Edition and Olympus CX-41 microscope adapted both for transmission and reflection measurements. 3 Mp CCD camera allows to focus on each tiny internal gas-liquid inclusion and crack, giving more information for a gemologist to express his opinion about the origin of a stone, its deposit, and type of treatment.



Advantages:

- Analysis of internal gas-liquid inclusions as well as surface inclusions
- Examination of gem feathers and fillers which helps to state whether the stone has been treated or not, and how.
- Analysis of jewel gemstones put in most complicated sets



Rutile in diamond

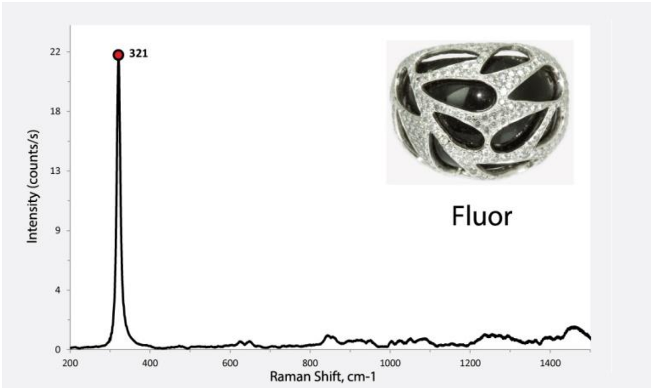
Gems inclusion definition helps identify the origin of a gem

Applications & Measurements

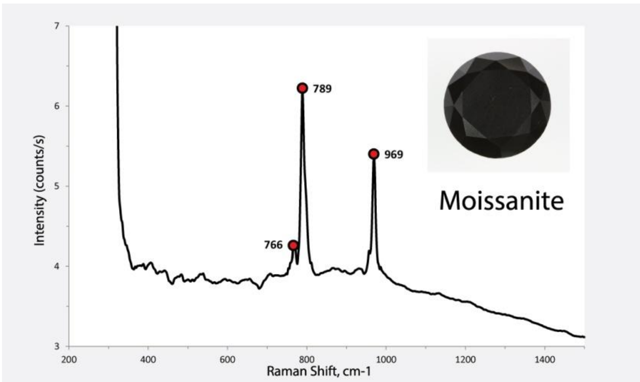
Following measurements were conducted in the Gemological Center of Moscow State University

General cases

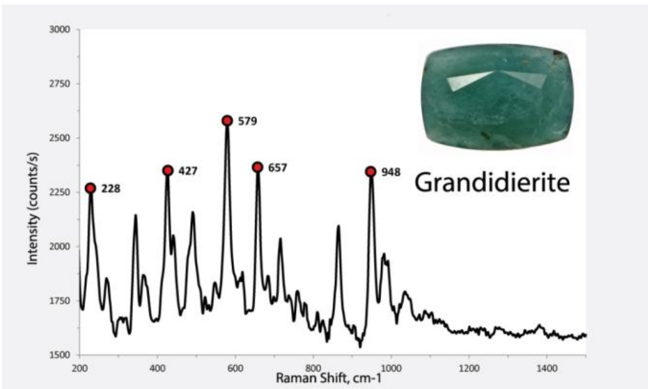
Case study #1.1
Task: Analysis of gemstones in jewels (especially of historic value)
Equipment to use: RaPort, EnSpectr R532, Microscope RamMics
Solution: One of the most important point in analysis of valuable gemstones in jewels is to avoid mechanical contact with the gem which is provided by the nature of EnSpectr instruments. Moreover, EnSpectr needs only a tiny focus spot on the gem surface to examine it, so complicated jewel sets do not pose any challenge to the measurement.



Case study #1.2
Task: Analysis of complicated samples (primary mineral products, non-transparent minerals and objects with high index of refraction)
Equipment to use: RaPort, EnSpectr R532, Microscope RamMics
Solution: This black gemstone that was claimed to be a black diamond is an example of a complicated case due to the index of refraction < 1.8 and its non-transparency. Naturally, it was difficult to examine the object using standard approaches, but EnSpectr quickly detects that the gem is a moissanite.



Case study #1.3
Task: Quick analysis of rare gemstones
Equipment to use: RaPort, EnSpectr R532, Microscope RamMics
Solution: While examination of a rare gemstone may be highly time-consuming, EnSpectr rapidly gathers the spectrum and identifies a very rare mineral grandidierite.



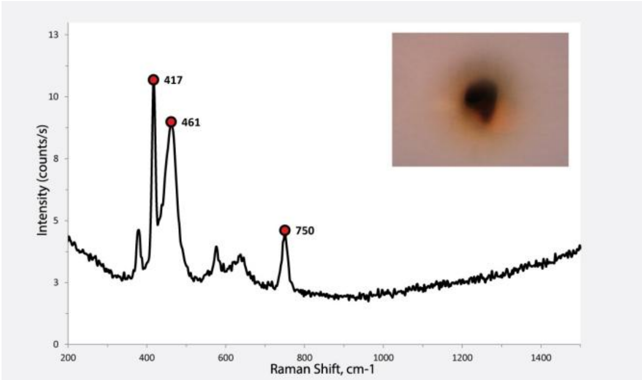
Analysis of mineral, solid and gas-liquid inclusions and determination of origin, deposit and the possible treatment of gems

Case study #2.1

Task: Determination of gemstone's country of origin by analysis of internal inclusions

Equipment to use: Microscope RamMics

Solution: We focus on the inclusion using a CCD camera inbuilt in RamMics. After spectrum is measured, EnSpectr states that inclusion consists of uraninite (UO_2). Inclusions of uraninite are typomorphic for Kashmir sapphire deposits in India. This way analysis of typomorphic inclusions enables laboratories to express an opinion on the country of origin of a stone.

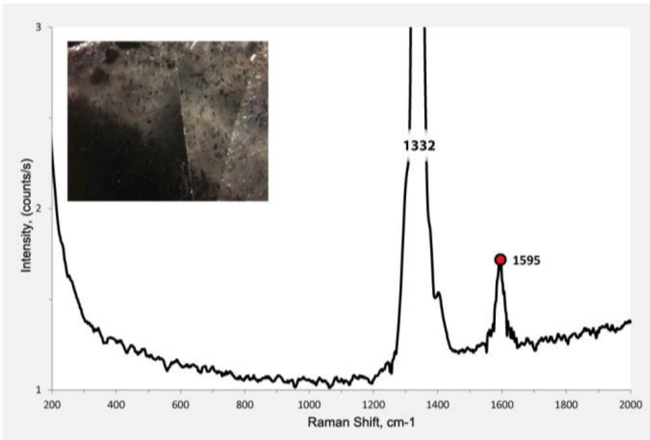


Case study #2.2

Task: Determination of gemstone's treatment by analysis of internal inclusions

Equipment to use: Microscope RamMics

Solution: To tell the nature of a black diamond first it's essential to determine which inclusions give the stone its color: graphite, oxides or sulphides. The picture demonstrates Raman spectrum of a black diamond (the band is at 1332 cm^{-1}), painted with numerous inclusions of graphite (the band of graphite is at 1595 cm^{-1}).

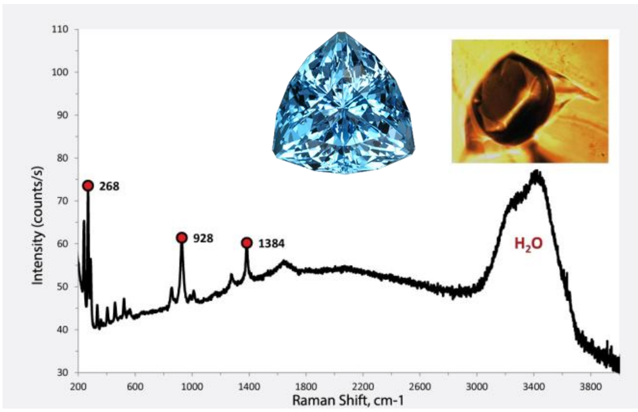


Case study #2.3

Task: Determination of gemstone genesis and deposit by analysis of the composition of its liquid phase.

Equipment to use: Microscope RamMics

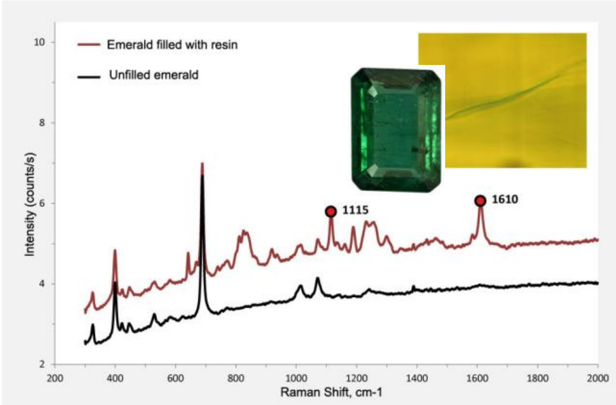
Solution: Many gems contain gas-liquid inclusions, the composition of which is determined by the environment where the mineral was formated. For example, gas-liquid inclusions of rubies from some skarn deposits (like in Pakistan, Afghanistan) consist of CO_2 and impurities of H_2S, while gas-liquid inclusions of rubies from other deposits contain pure CO_2. Of course, this only applies to rubies, which were not treated with high temperature.



Here we use RamMics to measure the Raman spectrum of a gas-liquid inclusion in topaz. All lines in spectrum in the area before 1500 cm^{-1} are associated with the Raman lines of topaz itself, and a broad band in the region of 3000-3500 cm^{-1} is caused by water contained in inclusion.

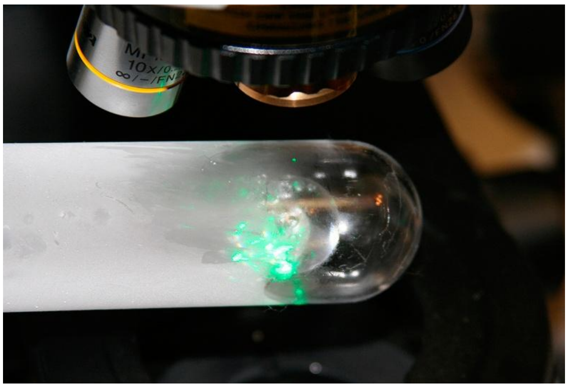
Analysis of fillers in precious stones and of II-a type diamonds' HPHT treatment

Case study #3.1
Task: analysis of fillers in semi- and precious gemstones
Equipment to use: Microscope RamMics

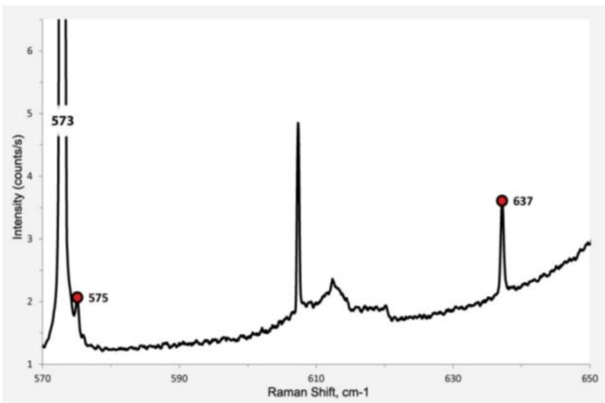


Solution: Generally, if a gemstone has been treated you can find various organic compounds inside. The most commonly used are synthetic resins, which are more resistant and can stay in gems longer than oil fillers. Emeralds are the most prominent example of this type of treatment. Organic substances that are used as fillers, have refractive indexes close to the index of emerald. Thus they significantly reduce the appearance of cracks in a gem. RamMics allows to focus on filler in the crack and acquire its spectrum, which would tell us if it is: resin, oil, Canadian balsam or a mixture. On the picture synthetic resin from the crack of the emerald is presented. For comparison we place a spectrum of unfilled emerald.
Organic fillers are also often used in turquoise, jadeite, nephritis, etc; their presence can be established in a similar way by RamMics.

Case study #3.2
Task: analysis of II-a type diamonds treatment
Equipment to use: Microscope RamMics

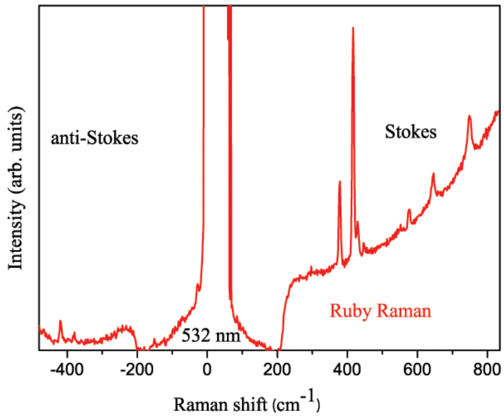
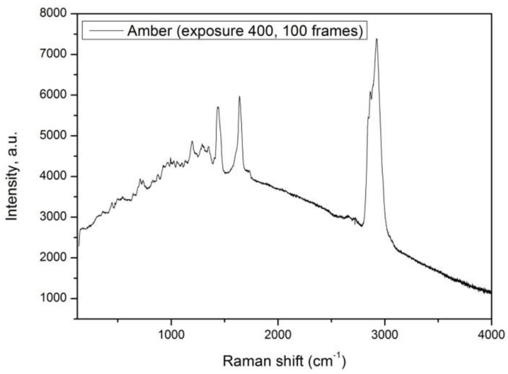


Solution: Brown low nitrogen diamonds of II-a type can be treated with high temperature and pressure (HPHT treatment) in order to remove brown component from the color and get colorless stones, and in rare cases – even pink or blue stones. HPTP treatment can be distinguished with luminescence spectrum measured in liquid nitrogen temperature. At room temperature the majority of lines associated with low concentrations of defects does not appear in the spectrum due to thermal vibrations of atoms in diamond lattice. Therefore, only measurement of spectrum in liquid nitrogen (at a temperature of 70 K = 343 ° C) allows achieving good resolution of lines and diagnosing HPHT treatment.



Luminescence of diamonds is excited with laser and collides with Raman lines. Luminescence spectrum of II-a type diamonds has paired defects: a negatively charged nitrogen-vacancy (637 nm) and neutral nitrogen-vacancy (575 nm). If HPHT treatment was applier, intensity of 637 nm band exceed intensity of 575 nm band. If stone has natural color, the ratio of intensities of the bands will be reversed. In the picture a spectrum of luminescence of HPHT treated II-a type diamond (637 nm> 575 nm) is presented, 573 nm is a Raman line of diamond.

Limitations of Raman Spectroscopy

Problem	Solution
Raman Spectroscopy is ineffective for metals and alloys having a simple chemical composition of high symmetry	Green laser reduces laser power and increases sensitivity at least 10 times (compared to red lasers)
Some minerals produce photoluminescence, which complicates analysis. **Problem materials**: turquoise, opal, pearls, amber **Also produce high luminescence:** ruby, spinel, emerald	 Special shutter reduces red photoluminescence and enables measurements of ruby, sapphire, emeralds which can't be analyzed with other potable Raman systems  Broad spectral range and unique recognition algorithm for analysis of "useful" luminescence and water peaks High spectral and spatial resolution, optimal for material science and analysis of "problem" materials too
Thermally unstable minerals or organic materials could melt under laser	All EnSpectr equipment provides adjustable laser power (5-50mW; default working power - 30 mW). Technique is tested on explosive materials, thermally unstable minerals, objects of art.