Gemology for Faceters #3

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In the June issue we discussed what is arguably the most important instrument for gem identification, the critical angle refractometer. In this, the third installment of a planned series of articles, we introduce the spectroscope as another important instrument in our quest for proper gem identification.

The spectroscope is certainly one of the most valuable gemological instruments and it has an advantage in that it can be utilized on rough and cut stones as well as on mounted jewelry.

The appropriate choice of spectroscope really depends on budget, amount of use, available time to use the equipment, your level of patience and your technical proclivities.

Here is a list of gem materials that have determinative spectra:

Selective Absorption

When white light passes through a substance it is selectively absorbed at different wavelengths and the resultant light provides the color of the object. For instance, emeralds are green because the other colors, other than green, are absorbed as they pass through the crystal. White light can be broken down into its component colors, red, orange, yellow, green, blue, indigo and violet and each color travels at a different velocity and has a different range of wavelengths that define it. Colors other than the spectral seven are cause by the mixture of various wavelengths of light.

Visible light ranges from about 390 nanometers to about 750 nanometers in wavelength, and the wavelengths range immediately below violet is the ultraviolet and those beyond red, infrared. While humans have no visual acuity in the infrared and ultraviolet, spectrophotometers are instruments that can record absorption or transmission in those wavelengths in addition to visible light.

Spectrum of Cr Pyrope. Note the diffuse "fuzzy" bands

List of Gem Materials with Distinctive Spectra

Actinolite	Ekanite	Rhodochrosite
Alexandrite	Elbaite Tourmaline	Rhodonite
Almandine Garnet	Enstatite	Rinkite
Andalusite	Eosphorite	Scapolite
Andesine Feldspar	Epidote	Scheelite
Andradite Garnet	Euclase	Scorodite
Antigorite	Eudialyte	Serpentine
Apatite	Fire Opal	Sillimanite
Axinite	Fluorite	Sinhalite
Bastnasite	Friedelite	Sogdianite
Beryl	Gallium Gadolium Garnet	Spessartine Garnet
Bowenite	Glass	Sphalerite
Bronzite (Orthopyroxene)	Grossular Garnet	Spinel
Cavansite	Hypersthene (Orthopyroxene)	Spodumene
Chalcedony	Jadeite	Staurolite
Chrysobereyl	Kornerupine	Stichtite
Cordierite (Iolite)	Kyanite	Sugilite
Corundum - Ruby	Monazite	Taafeite
Corundum - Blue Sapphire	Nephrite	Tanzanite
Corundum - Fancy Sapphire	Orthoclase Feldspar	Triphylite
Crocite	Painite	Turquoise
Cubic Zirconia	Papagoite	Uvarovite Garnet
Cuprite	Peridot	Variscite
Demantoid Garnet	Pezzottaite	Verdite
Diamond	Pyrope Garnet	Vesuvianite (Idocrase)
Diaspore	Pyrope-Almandine Garnet	Willemite
Diopside, Chrome	Pyrope-Spessartine Garnet	Williamsite
Dioptase	Quartz	Yttrium Aluminium Garnet
Dravite Tourmaline	Realgar	Zircon

Selective absorption in gems is caused by crystal chemistry, the combination of a gem's chemical composition and its crystal structure. **When one looks through a spectroscope one will often find one or more diagnostic absorption bands that characterize the material.**

ABSORPTION LINES are dark, sharp vertical lines that are typically thin and well defined.

ABSORPTION BANDS are also vertical but they cover a range of wavelengths and are broader than absorption lines and generally they are not as well defined and may appear fuzzy.

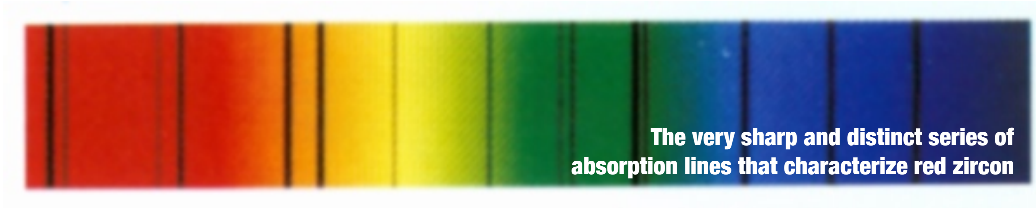
Prism and Diffraction Grating Spectroscopes

Prism spectroscopes use dispersion to break light into its component colors and all early spectroscopes were prism units and these also tend to be the most common types used in gemology. Diffraction grating scopes use the principal of diffraction where light enters through a slit and impacts a thin film of diffraction grating material. There are not many diffraction grating spectroscopes used in gemology but a high resolution diffraction grating provides superior results and is used often in astronomy and also in the two gemological spectrometers made by Imperial Gem Instruments. As a practical matter in a diffraction grating the spectrum is more linear where with a prism scope the spectra appears expanded in the blue and compressed in the red.

In my view, there are several issues to consider when it comes to using a spectroscope. Among them:

Ease of Use

With a fixed slit and fixed focus the <$100 OPL diffraction grating Teaching scope is what I generally recommend for beginning or casual spectroscopists as it is quick and easy to use. The cheaper prism scopes also have fixed slits and focus (e.g. the generic Asian scope sold by I.S.G. with light base). Better scopes have fixed slits but adjustable focus and the most versatile have adjustable slits and adjustable focus.



The very sharp and distinct series of absorption lines that characterize red zircon

Lighting Geometry

A good base is an important consideration and should be capable of both adjustable transmitted light (iris

This is an Eickhorst M9 spectroscope base with a 100W light source set up in reflected light mode. The fiber optic light tube is held at a 45° angle to the stone, set table down, below and the Zeiss spectroscope with integrated scale is located opposite, also at 45°.

diaphragm and rheostat) with the stone directly between the light source and the spectroscope, as well as reflected light where the stone is situated table down and the light source is at roughly 45° and the spectroscope is at an opposite 45° angle. You'll need reflected light for non-transparent stones like jade. You can either buy a spectroscope base, or cobble one together with a fiber optic light source or even a Maglight.

Internal Scale

Basil Anderson, who was the first to formally promulgate the use of spectroscopes in gemology felt that pattern recognition was the best way to use a spectroscope and so no internal scale that read the wavelength of absorption lines was necessary. I come down on the opposite side of the spectrum (pun intended) and absolutely believe that an internal scale is highly useful to beginners and experienced spectroscopists alike. Most internal scales have a separate parallel smaller diameter barrel into which a small light source shines to provide illumination to the scale superimposed on the spectrum. Such scales are not highly accurate but provide valuable information. To use pattern recognition effectively you must have a photo or drawing of a near matching spectral distribution for either a prism or diffraction grating spectroscope. However, with a scale you just need the printed wavelength locations of the absorption spectra. Indeed, everywhere in the gemological literature the description of the lines in a spectrum include the location in nanometers or Ångstrom units.

Acclimation

Basil Anderson postulated that as one gets older the vitreous humor of the eye starts to yellow and causes a decrease in visual acuity when viewing the blue and violet portions of the spectrum. Irrespective of your age or visual acuity the lines in the deep blue are the most difficult to discern. The proper way to use the spectroscope is to use it in a darkened room with your eyes fully acclimated to the dark and to erect a light shield so that your eyes will not inadvertently encounter your light source. This, unfortunately is quite time consuming but if you want accurate observations, it's necessary.

A Beck prism spectroscope. The unit is focusable and has an adjustable slit.

Sources

EBAY. EBay is a good source for older prism spectroscopes. Offerings by Beck, Zeiss, Krüss and Lafayette can be found at reasonable cost. With spectroscopes, you get what you pay for and generic Asian knock-offs abound. Caveat emptor.

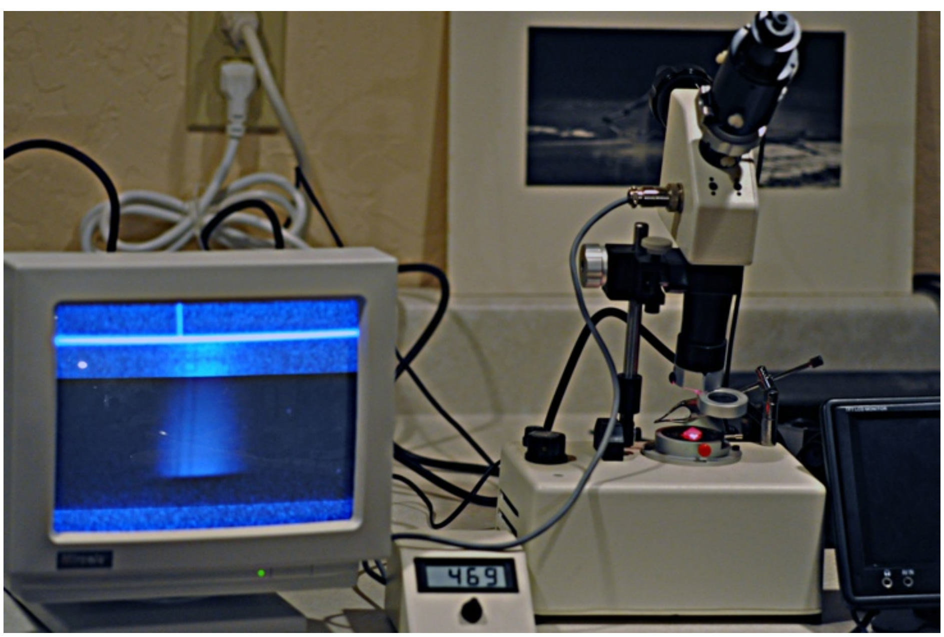
OPL. Don't forget, with the $100 OPL Teaching Spectroscope a Maglight and a little ingenuity you can do a lot of quality determinative gem work (http://www.oplspectra.com)

Gemological Spectrometers

Imperial Gem Instruments builds the Challenger Gemological Spectrometer and the new MDM Direct Reading Digital Gem Spectroscope. These units use diffraction gratings and B&W video cameras and monitors (B&W being much better at discerning the dark absorption bands than color equipment) with a separate digital LCD readout accurate to 1 nm. You can measure the wavelength of each absorption band with excellent precision and accuracy and you can do it very quickly without light acclimation. In the case of the Challenger

In transmitted light mode the light passes directly up through the stone stand, through the stone and into the vertical spectroscope.

you can get readings in the near infrared as well. With these units you can routinely see absorption lines you would have no hope of detecting with a conventional spectroscope and you can make identifications/separations that you could not make otherwise. The price of the new MDM is $1200 and the Challenger, $3200. (http://iginstruments.com)



The Challenger Gemological Spectrometer. The light source and variable geometry diffraction grating assembly with integrated video camera is on the right, the wavelength scale in the center and the B&W monitor on the left. Two absorption lines and the cursor can be seen. The unit is fast, accurate and very sensitive.

The ISG sells a small light base with rheostat and iris diaphragm with a generic prism spectroscope for about $450.

What Can You Do?

The spectroscope is useful in a number of different areas even though only about 90 gem species have diagnostic spectra.

When a stone is mounted and one cannot get an R.I. the spectroscope is a powerful tool for identification.

For faceters, when you're looking at rough in the field or at a show and it's not practical to polish a flat and use a refractometer, the spectroscope can often provide information that leads to identification.

Some common separations that can be made with a spectroscope include:

- Natural vs. synthetic sapphire
- Peridot vs sinhalite
- Garnet species I.D.
- Ruby vs. red spinel
- Syn blue. vs. nat. spinel vs. glass
- Separate emerald from green stones
- Separate turquoise from imitations
- Detect dye in jadeite & chalcedony
- Detect diamond treatment (sometimes)
- Identify gems listed on first page of this article

Transition Metal Cations

Transition metal cations are the elements that typically cause the absorption lines and bands responsible for the distinctive color of gems. The most common transition element to cause color is iron. Other transition elements include chromium, vanadium, cobalt, titanium, nickel, manganese and copper. Those gems that have the transition elements as part of their critical and distinctive general chemical composition are said to be IDIOCHROMATIC. Gems that have trace amounts of transition elements as impurities in the crystal structure are said to be ALLOCHROMATIC.

As you gain experience with the spectroscope you'll note that many absorption bands or lines related to the transition elements often occur in the same area of the spectrum. Iron lines, for instance are often located in the blue while lines due to chromium are found in the red.

Technique

The most useful and common spectroscope set-up consists of a prism spectroscope with a light source/stand combination with an adjustable rheostat to control light intensity and an adjustable iris diaphragm. Transmitted light is the technique most often used for transparent gems unless they are small or very light in color, in which case reflected light might provide better results as the light path through the material is roughly twice as long. For semi-translucent to opaque materials the reflected light technique is the only choice.

Turn on the light source and place the stone over the iris diaphragm adjusting it so that it is just less than the stone's diameter. Adjust the spectroscope so that it is directly over the stone. Generally, the best results have the base of the spectroscope from between 0.5" to 2.5" over the stone with the only light entering the spectroscope slit passing through the gem.

Open the adjustable slit if you have one, on the spectroscope, and then close it until you see the spectrum and the lines look sharp. In most cases the slit will be barely open.

Push or pull the draw tube focus until the spectrum appears sharp. You may have to go back and forth between the slit width, focus and rheostat adjustment to get the optimum set-up.

As discussed early, turning the room lights out and allowing your eyes to acclimate, plus erecting a shield to keep from being dazzled by the light source, will help significantly with observations.

Spectrophotometers

Gemological laboratories with advanced instrumentation will often have an

A Fourier Transform Infrared Spectrophotometer in use at the SSEF in Basel, Switzerland.

analytical instrument known as a spectrophotometer. A visible light spectrophotometer is very similar to a spectroscope, but provides a recording and is more sensitive. The best units tend to be dual beam units where the a reference beam is used in comparison to the beam that passes through the sample. The record is in the form of an x-y diagram where the x-axis represents the wavelength scale in nanometers and the y-axis represents the absorption or transmission intensity. Such a graph can be seen on page 13 of this newsletter.

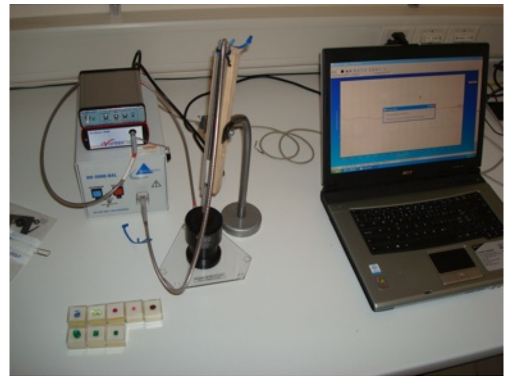
Spectrophotometers come in several forms and are tuned to specific wavelengths the most common being UV-VIS-NIR (ultraviolet-visible-near infrared) of from 200-1000 nm and FTIR (Fourier Transform infrared spectrometers). Collectively, these instruments are used for such things as to characterize diamond types and detect HPHT and CVD diamonds, detect the type of filling in emeralds and determine the origin of some gemstones, particularly sapphires. Many other specific separations can be made and new research with this type of instrumentation is being accomplished daily.

Recently low cost (e.g. $2500 without a light source) spectrophotometers are being produced by such firms as Ocean Optics and some gemologists are purchasing these units. The problem is that with a spectroscope or gemological spectrometer you have 100 years of recorded data to rely upon when making separations. There is no direct correlation between what you see with the human eye through a spectroscope and what is recorded by a spectrophotometer and there is no published database for spectrophotometric results of gem spectra. In addition, significant experience is required to be able to get the most out of a spectrophotometer. Sample set-up is critical and to be useful the data for anisotropic stones must be recorded with reference to orientation.

Conclusion

The spectroscope is a powerful tool for identifying gemstones and making various separations of interest to the faceter and the gemologist. Perhaps more than any other typical gemological instrument, developing the proper technique is important to obtaining good results. Until one has practiced, the use of a spectroscope can be somewhat frustrating but the results are interesting and quite often definitive. It's certainly worth the time and effort.

Colin Winter of OPL in the U.K. has written a good introductory text on the subject and is also the source of the OPL Teaching spectroscope we so highly recommend. The best source of information that shows full color spectra for gemstones is the book *Tables of Gemstone Identification* by Dedeyne &

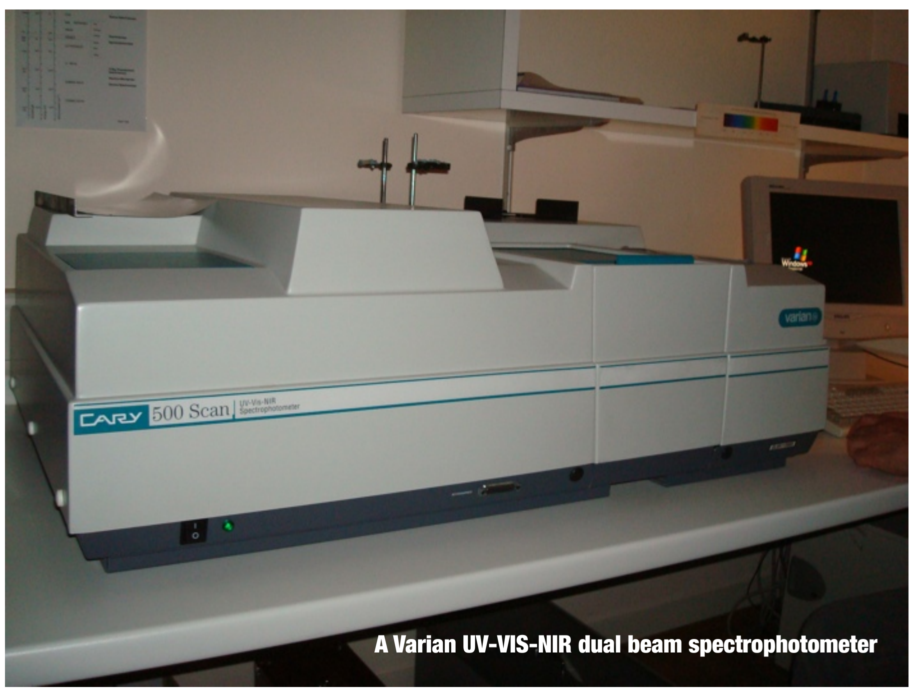


A new small USB-based UV-VIS spectrophotometer with a combination deuterium-halogen light source. The deuterium lamp provides a rich UV spectra. The SSEF sells this setup for about $20,000.

Quintens available at http://www.gemmologie.be

The Challenger & MDM units from Imperial Gem Instruments represent the fastest, easiest and most sensitive instruments available.

In the next installment we'll be discussing the gemological microscope.



A Varian UV-VIS-NIR dual beam spectrophotometer

Editor's Note:

I'm happy to try to answer any technical gemological or gem instrument related questions for any USFG Member. I'm also quite willing to identify any gem material free of charge for USFG members. I can be reached at 208-712-0172 or by e-mail at bruce@gemscientist.com