Gemmology for Faceters #1

by L. Bruce Jones, G.G., F.G.A., D.Gem.G.

We all share a fascination with gemstones and the efficient practicing of our craft of faceting requires that we learn something about the gems that we cut. In my case I was a faceter first, then a geologist specializing in mineralogy and then a gemmologist and gem lab operator and finally, a part time researcher trying to coerce the secrets from gem materials. But if it wasn't for learning to facet all those years ago I would have no knowledge today of the science that has made my life immeasurably richer.

As faceters, the study of the gems that we cut can teach us a lot and it can make our cutting better as well. There are a wide variety of books and videos and formal courses that we can seek out in our investigation of gem materials, but not many of them relate directly to the gemmology pertinent to the gem cutter.

I thought that a series of articles on gemmology for faceters would be useful. But where to start? Clearly, understanding the physical and optical properties of gem materials as it relates to our faceting the raw crystals into gems would be pertinent, but is there anything more pressing?

We all have to buy rough. Fortunately, most dealers, particularly those that we establish long term relationships with, are scrupulously honest about representing the nature of the gem materials they sell. But, do they always know? Do they take the word of their suppliers and do their suppliers always know for sure? All of us have no doubt seen material that was suspect and perhaps the deal was so good that we even purchased it, not being sure of what it was. And even though the majority of sellers might be honest, the further you travel from home in the pursuit of gem materials, the more you need to know to protect yourself. I can remember years ago consulting for a buyer at a gem mine in Thailand where the miners were salting their claims with synthetic Knischka ruby crystals!

Now, more than ever before, sophisticated synthetics, and all manner of treated and manipulated stones exist that are often not what they are represented to be.

As faceters, then, perhaps one of the most valuable skills to have and to learn is the capability of identifying gem species. Particularly if we are selling the stones we cut. Then we have an absolute obligation to be accurate in our representations. "I didn't know," is no excuse.

Now, given that we want to improve our identification skills, where do we start?

Most courses in gemmology start with basic mineralogy. Defining a mineral, attempting to understand basic crystallography, crystal systems and classes, crystal chemistry etc. That then gets translated into the complexities of optical mineralogy. It's all important to an in-depth understanding of the subject but its pretty dry stuff. For those interested, the best basic introduction can be found in the book *Gemology*, by Hurlbut and Kammerling, now out of print. By far the best book on mineralogy is quite recent. Entitled, *Mineralogy and Optical Mineralogy* by Dyer & Gunter, it is published by the Mineralogical Society of America and is the finest book on the subject ever published.

Let's take a more instrument oriented, practical approach to learning about gem I.D. And let's start with, "Just what instruments are available and how relevant are they?"

Gem Instruments

I admit to being an instrument junky. I'm currently writing a book on gemmological instruments and it gives me a great excuse to indulge myself in a wide variety of gemmological and mineralogical periphernalia that runs the gamut from the mundane to the horribly exotic. The horribly exotic has taken over my sunporch in the form of 7500 lbs of electron microprobe. Want to see how good your marriage really is? Try installing one of those and explaining the "budget modifications" to your wife. But I digress. If you are interested you can see the story at gemscientist.com.

The Number 1 Gem I.D. Instrument Is?

Many might vote for the hand lens but in most cases it is an instrument to evaluate quality save in some circumstances. Then there is the microscope. Great to see meets, double refraction and inclusions, but not quite the first stop when it comes to I.D.

#1: The Critical Angle Refractometer

One thing we faceters can do easily is polish a flat spot on a piece of rough and so the prerequisite for using a refractometer is met. If you have a finished gem it's even easier. A drop of contact fluid on the hemicylinder and away we go.

A refractometer will provide you with information on the refractive index, birefringence, optic sign and optic character and even dispersion. Combined, they will provide a highly definitive result in most cases. We'll explain all those terms in the next installment which will concentrate on the refractometer and its use.

The bad news about a gem refractometer is that a good instrument is expensive ($550-$950). The four best instruments are made by Gemmological Products (Gem Pro refractometer), Rayner Instruments (Dialdex), GIAs Gem Instruments (Duplex II) and System Eickhorst (SR 0.01). The good news is that with proper care they will last a lifetime and a good refractometer, given an appropriate light source, is the most important instrument you can own. Avoid the cheap Chinese eBay instruments that cost in the $100 range.

A lightsource with monochromatic filter and refractomers, a Dialdex, Duplex II and Gem Pro

#2 Specific Gravity Kit & Scale

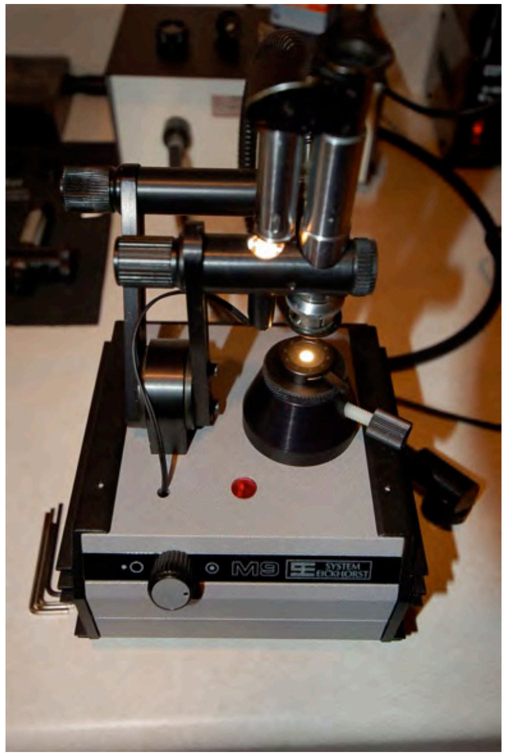
Most faceters have an electronic scale that is accurate to 0.01 carats. With a specific gravity attachment, such as the one sold by Mineralab for $79, you can determine the specific gravity (e.g. relative density) of the stone in question. With a scale of .01 ct precision and accuracy (available for about $100), you can expect an accurate S.G. reading down to about .41 carats. If you have an analytical scale that reads to a thousandth of a carat (0.001) you can expect accurate readings down to about 0.04 cts. We'll discuss techniques in a future installment but the weight in air divided by the weight loss in water (e.g. weight loss in water = weight in air minus weight in water) gives you a relatively determinative number that you can then look up in a table of gemstone physical values. The best published source of determinative tables for gemstones is *Tables of Gemstone Identification* by Dedeyne & Quintens available at http://www.gemmologie.be

A Sartorius gem balance with specific gravity attachment

#3 The Diffraction Grating Spectroscope

A spectroscope breaks the light that passes through a gem into its component colors where one can see, in many cases, characteristic absorption lines valuable in identifying the stone. A very good inexpensive spectroscope is the OPL Teaching model from Orwin Products in the U.K. The cost is about $100, although a light source/stand can add to that price. Colin Winter, the owner of the company, has written a very nice book on gem spectroscopy called *A Students' Guide to Spectroscopy*. Next up in price are several prism spectroscopes with scales that more easily assist the viewer in determining the location of the absorption lines and oftentimes these units include a light source stand combination.

A series of spectroscopes, top to bottom: A Lafayette, an OPL, a generic prism, a Hartridge Reversion, a Beck and a Zeiss with wavelength scale



An Eickhorst M9 Spectroscope base fitted with a Zeiss prism spectroscope with scale

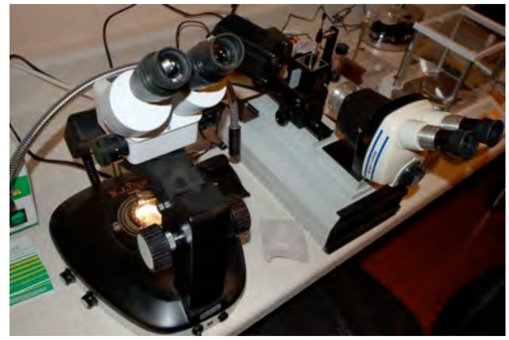
The ultimate tool in this category is the Challenger Gemological Spectrometer which uses a monitor/camera and accurate wavelength scale to make viewing very simple and also is capable of readings in the near infrared. The price is $3200 and the Challenger is made by Imperial Gem Instruments. The company also builds the Alpha-Taurus faceting machine.

The Challenger Gemological Spectrometer

#4 The Gem Microscope

A good microscope is useful to most faceters as an unyielding arbiter of mistakes. Beyond that a good binocular gem microscope introduces one to the internal world of gemstones and the study of inclusions, a science in and of itself. Inclusion identification can tell us a great deal about many gems and oftentimes it is a suite of inclusions that bears mute testimony to a gem's geographic source and conditions of formation. The ultimate guide to gem inclusions is a series of three volumes entitled *Photoatlas of Inclusions in Gemstones* by Gübelin & Koivula.

The microscope is a great tool for separating natural from synthetic, imitation and assembled stones and for quality grading of both diamonds and colored stones. Properly equipped, a microscope can measure distances, evaluate proportions and even estimate refractive index.



A GemOro scope on the left with an Eickhorst immersion scope on the right

To be useful for gemmology, a microscope must have a gemmological base that includes both darkfield and brightfield illumination. Without a fully effective gem base the microscope's usefulness is dramatically diminished. It is very difficult for anyone but an expert to tell the difference in the quality of the optics of a microscope, but poor lighting is immediately obvious. A good new 'scope to start with is the Gem Oro Elite 1067ZX for about $875. From there, Meiji or GIA gem scopes are very good as are the scopes by Eickhorst or Krüss. In addition, GIA Gemolites with AO or Bausch and Lomb optics often come up on eBay at reasonable prices.

The ultimate gem base is made by Jeff Wildman's Gemological Products and he'll fit the $2000 base with a new or reconditioned scope from Leica or Nikon for a reasonable price. If you can find a Wild M8, M400 or M420 with a photoport or, even better, a Zeiss Stemi V8 or V10 with photoport then you have the ultimate microscope set-up for gemmology.

#5 Other Equipment

Other pieces of equipment are quite useful in a well set up gem lab but if you buy just one instrument, it should be a good refractometer. We'll discuss its use next time. Here are just some of the additional equipment possibilities.

Polariscope
Dichroscope
Fiber optic lightsource
Assorted color filters
U.V. lights and viewing cabinet
Measuring devices
Specific gravity liquids
R.I. immersion liquids
Immersion microscope
Hardness points
Geiger counter
Reference books and software

Gemology for Faceters #2

by L. Bruce Jones, G.G., F.G.A., D.Gem.G.

In the March issue we discussed the importance of gem identification for faceters and provided information on the most significant common gemological instruments. In this, the second installment of a planned series of articles, we introduce the refractometer as arguably the most important single instrument in our quest for proper gem identification.

Mineral Definition by Chemistry and Structure

Every mineral is uniquely defined by two characteristics; chemistry and structure. The chemical composition of a mineral is provided by its chemical formula which typically omits minor and trace elements and those may be important in determining physical properties, including color. A full chemical analysis goes beyond a simple formula and lists all major, minor and sometimes trace elements. It used to be that chemical analysis was undertaken by complex wet chemistry methods that were time consuming and subject to error. Today, most chemical analysis of minerals is done by electron microprobe although a number of other analytical instruments and techniques are also used. The most extensive set of mineral formulae are published in the 9 volume set of *Rock Forming Minerals* by Deer, Howie & Zussman.

Minerals may have identical chemical compositions but completely different structures. The simplest and most elegant example is the difference between graphite and diamond. Exact same chemical composition - simply carbon, but different structures that provide for widely divergent physical properties.

While the chemical composition of a mineral is important to its definition, the second requirement for absolutely defining a mineral is the arrangement of the atoms in its crystal structure. The determination of crystal structure is done by x-ray diffraction, the main instruments used being the single crystal diffractometer and the powder diffractometer.

As an example of why structure is important let's take an aluminium silicate with the formula Al_2SiO_5. The formula defines three different minerals, kyanite, andalusite and sillimanite, and to know which one you have there has to be an understanding of the structure as well as the chemistry.

The combination of chemical composition and crystal structure is referred to as crystal chemistry and it is crystal chemistry that causes the complex physical, chemical and optical properties that characterize each mineral.

Fortunately we don't need electron microprobes and powder diffractometers to identify gemstones, but if you had this equipment and knew how to operate it you could unambiguously identify any of the known 4300 minerals. The fact that there are 14,000 historical mineral names is quite another issue.

As you start off, or continue, the quest to identify gem species it is important to understand that an absolutely definitive identification is not made by measuring physical and optical parameters. It always comes back to the basic two issues – chemistry and structure, or if you like, crystal chemistry.

Optical Mineralogy

Optical mineralogy, comprised of the disciplines of optical crystallography and optical crystal chemistry, is an enormously complex subject that is typically introduced to the geology major when they learn to use the polarizing petrographic microscope as a means of rock and mineral identification. Fortunately, we can skip most of the complexity and focus on the use of the critical angle refractometer.

Crystal chemistry causes light to behave in certain ways when it impacts a crystal and then passes through it. Practically speaking, the ratio of the speed of light in air to the speed of light in the crystal is known as the refractive index (R.I. for short) and for most minerals this is **the most important** of several measurable properties used in a gem's identification.

Optic Character

Several things can happen when a ray of light impinges upon a crystal. We know that the ray slows down, due to the optical density of the material, but beyond that we categorize the material as:

1. Isotropic
2. Uniaxial
3. Biaxial

Isotropic materials are those that form in the cubic crystal system (e.g. like diamond or garnet) or are amorphous, like glass, plastic and amber. Light travels in all directions at the same speed and as a result only one reading will be seen on the refractometer.

Uniaxial crystals have one optic axis which corresponds to the c-axis and where the light behaves as if isotropic. The light ray splits into two rays that travel at different speeds and vibrate in different directions, one in the horizontal plane, which is called the ordinary ray, and one in the vertical plane corresponding to the c-axis and this is called the extraordinary ray. In the refractometer you will see one fixed reading and one variable reading as the stone is rotated. Uniaxial materials crystallize in the tetragonal, trigonal and hexagonal crystal systems and include such gems as corundum, quartz and beryl.

Biaxial crystals have two optic axes that are singly refractive and three refractive indices that vibrate in different directions designated alpha, beta and gamma. In the refractometer you will see two variable readings when the stone is rotated. Biaxial materials belong to the triclinic, monoclinic and orthorhombic crystal systems and include such stones as topaz, peridot and tanzanite.

Birefringence and Optic Sign

Looking at things in their simplest form, when you have a stone on the refractometer and you rotate it, three things can happen:

1. You get one reading that remains constant as the stone is rotated on the hemicylinder. In this case you have an isotropic (singly refractive) material.
2. You get one reading that remains constant and one reading that is variable and thus you have a uniaxial material.
3. You get two readings that are variable in which case you have a biaxial material.

Fortunately, the minimum and maximum readings are available to us on any single facet of the gemstone when it is rotated. The difference between the minimum and maximum readings is called the **birefringence**. Birefringence is an important quantity that is oftentimes more consistent than refractive indices which can be somewhat variable within gem species based on variations in crystal chemistry.

Uniaxial and biaxial materials have what is called an optic sign and can be either positive or negative (or rarely, in the case of biaxial materials, indeterminable). When the index of refraction of the extraordinary ray of a uniaxial material is greater than the ordinary ray the sign is positive, when the converse is true then the material is negative.

For biaxial crystals the sign is positive if beta is closer to alpha than gamma and negative if beta is closer to gamma than alpha.

In most cases you will not need to determine optic character and sign to make an identification. Typically, just determining the maximum and minimum

Two U.S. made GemPro refractometers. On the right you can see the relative size of the hemicylinder and the magnifying eyepiece and polariod filter.

Part of a refractometer scale with a monochromatic light source.

R.I. and the birefringence will suffice. Note that it is not possible to determine optic character and sign on any facet of a doubly refractive stone.

The Refractometer

So how good is your stop watch? It's clearly not practical to flip the light-switch on and off and record how much slower light is that passes through a crystal. Fortunately a refractometer can measure the critical angle of a gem allowing light to form a shadow line on the calibrated scale of the refractometer and so you can directly read the R.I. from the scale. More detail on how a refractometer works is available in many books on gemology and gem identification.

As indicated in the last article, a good refractometer is not inexpensive with new models ranging from $550-$950, yet with proper care they will last a lifetime. The best instruments are made by Gemological Products (Gem Pro refractometer), Rayner Instruments (Dialdex), GIA's Gem Instruments (Duplex II), System Eickhorst (SR 0.01) and Krüss (ER601 & ER604). Again, avoid the cheap Chinese eBay instruments that cost in the $100 range new, but by all means purchase a used high quality refractometer on eBay.

In addition you will need contact fluid with an R.I. of 1.80 +/- .1, usually included with the instrument, and a light source.

Dispersion & the Light Source

When light passes through an optically dense medium like a crystal its speed varies with its wavelength. Violet light with its shorter wavelength has the least velocity and is refracted most, while red light with its longer wavelength and greater velocity is refracted least. As a result, the refractive index of a gem will be slightly less for red light than it will be for violet light. The difference is known as dispersion and is commonly seen when a prism breaks light into its component colors or when a diamond flashes different colors of the spectrum as it is moved in relationship to the observer's eye. Different gem materials have different coefficients of dispersion, a measurable property.

The practical matter is that when you view a gem's refractive index on the refractometer scale the line that you see will not be as sharp in white light as it will be with monochromatic light (light of one-wavelength). By convention, sodium light is the standard, with a wavelength of 589 nm. As a result, many refractometers have built in yellow light sources that attempt to duplicate this wavelength by using bandpass filters or LEDs, thus providing a sharper shadow line on the refractometer scale and a more accurate reading.

Some refractometers come with built-in light sources (e.g. Krüss) but most use separate light sources that may have both white and yellow monochromatic light. GIA's older grey Utility Lamp is often seen on eBay for $100 or less and functions quite well. Fiber optic light sources and even a Maglite can also be used. The GemPro refractometer, at about $545, comes with a yellow monochromatic filter and represents the lowest-cost, high-quality instrument and is made in the U.S.. (http://www.gemproducts.com/products.html)

GIA makes the Utility Lamp. This is an older model with three ports. The yellow port is monochromatic and the top is useful for a dichroscope. Often found on eBay for $100.

Care and Feeding

Before we talk about the techniques of using the refractometer, there are a few things you should know.

1. Naturally occurring gem materials have refractive indexes that range from a low of about 1.37 in the case of opal to 2.87, in the case of hematite.
2. Most critical angle refractometers can measure from 1.30 to 1.80. The limitation is caused by the R.I. of the contact fluid between the gem and the hemicylinder (usually composed of leaded glass with an R.I. of 1.90 or so), with fluids over 1.81 being highly toxic and increasing in viscosity as R.I. gets higher. Fortunately, the R.I. of the most popular gemstones typically fall within the refractometer's range, the most common exception being diamond and many of its simulants along with some garnets and zircon.
3. Refractive index fluid is generally a mixture of diiodomethane (methylene iodide) and sulfur with added tetraiodoethlene, which is mildly toxic and corrosive. Don't let it get on your skin and wipe it off the hemicylinder surface with a tissue when you are finished. The liquid turns dark upon exposure to light so keep it in a dark place.
4. The glass of the hemicylinder is typically quite soft and can be scratched easily by a gem. Take care not to apply pressure to the gem when placing it on the hemicylinder, and don't use tweezers!

Using the Refractometer

On a faceted stone select the largest facet with the best polish, generally the table, and clean it quickly by rubbing it briskly back and forth on a piece of paper. Place a **very small** droplet of R.I. fluid on the center of the hemicylinder and place the stone, table facet down, on the drop. You've now made an optical connection between the hemicylinder and the stone.

Look through the eyepiece, moving your head up and down slightly until you see a shadow-line and note its position. It should be possible to interpolate to .001 if you are using a monochromatic yellow light source. If the only reading you are seeing is 1.80 or 1.81, then the material is over the limit of the refractometer.

Place the polarizing filter on the ocular and rotate it 90° back and forth (N-S to E-W). Does the shadow-line move? If it does not, rotate the stone 45° and rotate the polarizer back and forth again. Any movement? Repeat with the stone rotated to 90° and 135°. If the shadow-line stays the same then the stone is very likely singly refractive (isotropic).

If the shadow-line appears to move then record two readings, one with the polarizer at its initial position and one turned at 90°, and do that with the stone at the 45°, the 90° and the 135° position.

You will have eight readings in all. Note the high and low readings. These are the minimum and maximum R.I. values, subtract the lowest from the highest and you have the birefringence. Let's say your lowest reading is 1.624 and your highest is 1.644 with birefringence of .020. You have a tourmaline!

Plotting Optic Sign

For most cases the technique above will give you the numbers necessary to look up your unknown in a table of refractive indices and you'll be able to identify what you have, or more than likely, confirm your suspicions. If you can't manage a definitive answer with just R.I. you can revert to other gemological instruments to measure specific gravity, check the spectra or inspect internal characteristics and we'll discuss those techniques and more as the series of articles continues.

In very rare cases you might need to plot the indices of refraction and their variation to determine optic character and sign. Typical examples usually given are separating quartz from scapolite or peridot from sinhalite.

While with the standard procedure you might check a gem in four positions, when you are plotting I like to expand to eight sets of readings at 0°, 30°, 60°, 90°, 120°, 150° and 180°.

In the more complex case of a biaxial stone you will have two shadow lines that move. The higher R.I. is designated gamma, the lower, alpha. If gamma moves less than half way to the lowest alpha reading, the stone's sign is optically negative, if it moves more than half way, the stone is optically positive. If it moves exactly half way the stone is without sign as the 2V=90° (a 90° angle separates the two optic axes. The lowest R.I. reading of gamma is typically called beta. If the alpha and gamma actually meet, then that index is beta; if they don't, then it's a close approximation and you may want to try another facet. There is a technique to find true beta using the transmission angle of the polaroid filter of the refractometer but it is beyond the scope of this necessarily brief discussion.

You can easily graphically plot the eight upper readings as a line and the eight lower readings as a line to graphically see how things sort out.

A Few Caveats

Of course there are some exceptions that make this all a little more interesting.

- In some cases where birefringence is high one reading could be off the scale of the refractometer.
- If you have an R.I. reading on an isotropic stone between 1.50 and 1.70 the stone is most likely glass.
- The optic axis is the direction of single refraction in a doubly refractive gem and so along the optic axis there is only one constant R.I. reading. So, if the optic axis is perfectly aligned perpendicular with the facet upon which you are taking the reading it is possible for a uniaxial stone to act as if it were isotropic. This is, fortunately, unusual, and if you expect this is the case taking a reading on another facet, or using the polariscope, will solve the problem. This is why many formal gemological examination procedures start with the polariscope to determine single or double refraction and that test takes literally less than 10 seconds to accomplish. Some gemologists use the refractometer first and then quickly confirm whether or not the stone is isotropic with the polariscope. Some always take readings on two facets of every stone they test on the refractometer.
- If the facet on the refractometer is cut perfectly perpendicular to the optic axis of a uniaxial stone then the extraordinary ray, the one that usually moves, will remain stationary. Fortunately this is at it's full spacing from the ordinary ray so both R.I. indices and birefringence can be determined.
- Finally, in a biaxial crystal you may have a condition where the optic axis is perpendicular to the facet being tested and one shadow edge will remain stationary, so the stone appears uniaxial.
- In summary, you can find the minimum and maximum R.I.s, and thus the birefringence, on any facet, but you may not be able to determine optic character and sign on any facet of a doubly refractive stone.

Again, if more than two or three stones of every 100 you test require the determination of optic character and sign, I would be surprised. The high and low R.I.s and birefringence will almost always tell the tale.

The Distant Vision or Spot Technique

Occasionally you may want to determine a rough approximation of R.I. on a cabochon or a stone with no flat surfaces. In this case you can use the "distant vision" (U.K.) also called the "spot" (U.S.) technique.

Critical to the effort is a very tiny droplet of R.I. fluid, equivalent to no more than the distance between two of the closest divisions on your refractometer. Place the droplet on the hemicylinder and the apex of the cab on the drop thus making your optical connection.

Looking through the eyepiece of the refractometer from a distance of between 10" and 16" nod your head up and down a bit like you were nodding in agreement and look for the tiny dot that should turn from dark to light. If you can move your head with precision you may actually see, under ideal conditions, a shadow line that bisects the spot and this is your R.I. approximation. If not, note where on the scale the spot turns from light to dark and read the scale. Spot readings are usually only given to .01 units and birefringence measurements are typically not possible.

Using a larger spot of fluid and rotating the polariod filter can induce "carbonate blink" if birefringence is very large and a very rough estimate of birefringence is sometimes possible. You might use this on a cab of rhodochrosite, for instance.

Some people have trouble getting the spot and the scale of the refractometer in simultaneous focus. This is where the Dialdex refractometer is superior because of its external scale.

In Closing

While optical mineralogy is a complex subject, the techniques necessary to effectively use a refractometer are easily learned and just require a precision instrument and a bit of practice. As a faceter, you are probably generally familiar with gem materials and the use of the refractometer is the quickest way to confirm your stone's identification. It will assist greatly in your confidence that what you are cutting and selling is what's been represented to you. And, who knows, you may discover that the 10 carat spinel you just cut is really a taaffeite!

Three contemporary refractometers. The one in back is the GemPro model available from Gemological Products in Oregon for $545 with a monochromatic filter that installs in the light port in the back. You could use a Maglite as a light source.

The center unit is made by GIA's Gem Instruments and is familiar to thousands of GIA trained gemologists. It comes with R.I. fluid but requires an external monochromatic light source. Cost is about $850.

The unit in the foreground is the Rayner Dialdex, made in the U.K. but hard to find. The Dialdex is unusual in that you match a black tape with the position of the shadow line and then read your R.I. directly from the dial mounted on the right; there is no internal scale. This is an excellent instrument and is available from Rubin & Son in Antwerp for about $760 and requires an external light source.

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

Gemology for Faceters #3

by L. Bruce Jones, G.G., F.G.A., D.Gem.G.

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
Chrysoberyl	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.

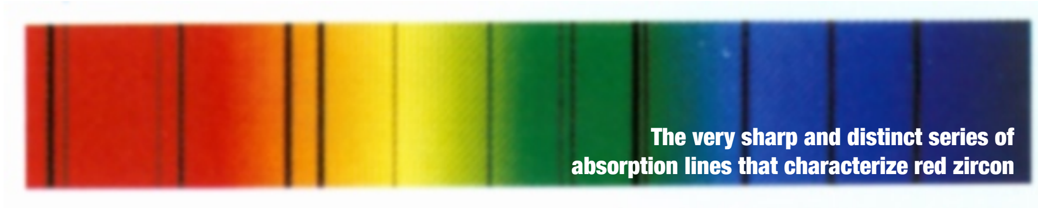
Prism and Diffraction Grating Spectroscopes

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 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.

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°.

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.

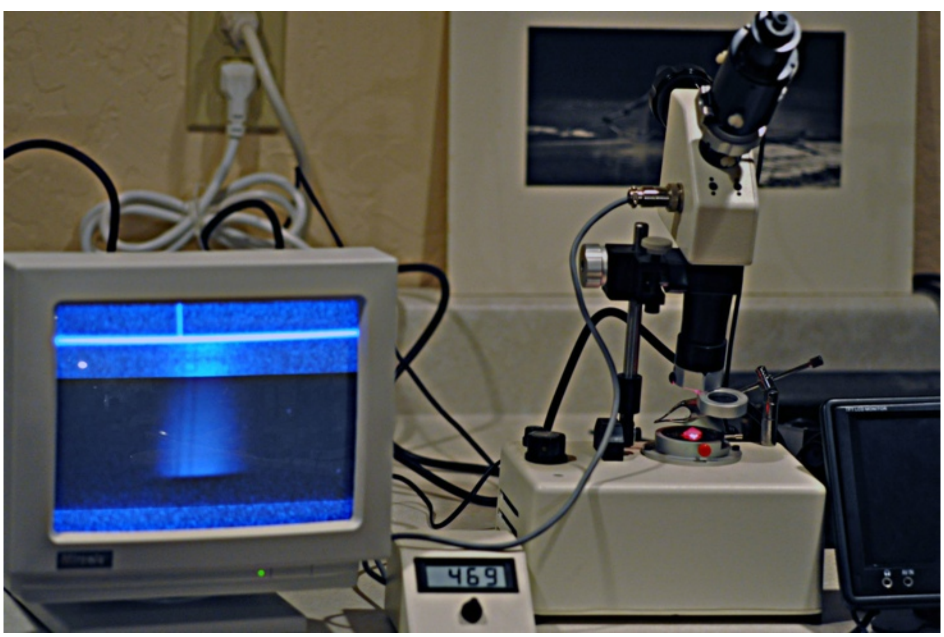
OPL. Don't forget, with the $100 OPL Teaching Spectroscope a Maglight and a little ingenuity you can do a lot of quality determinative gem work (http://www.oplspectra.com)

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

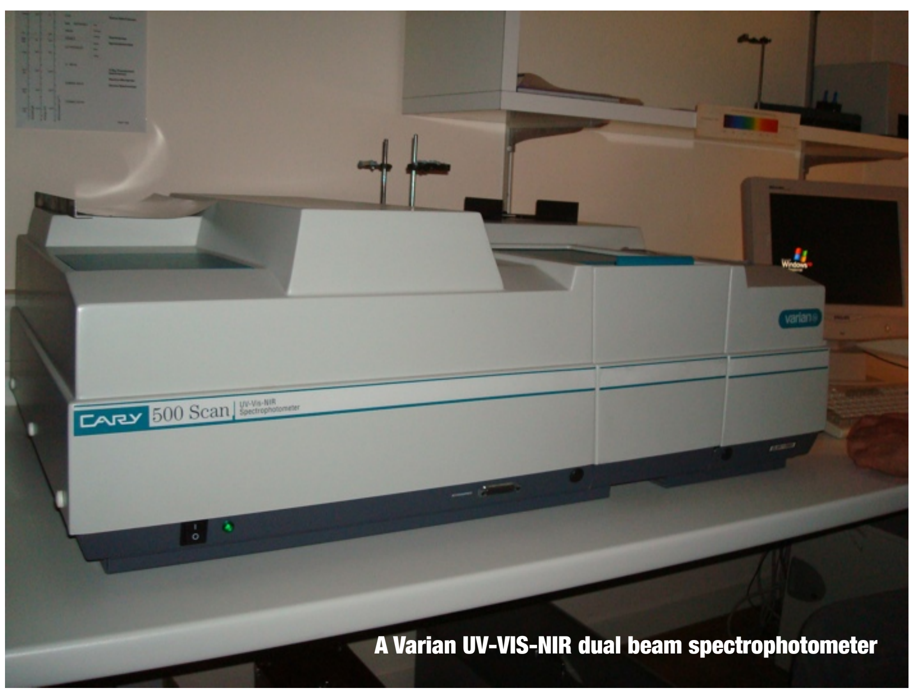
Gemological laboratories with advanced instrumentation will often have an

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.

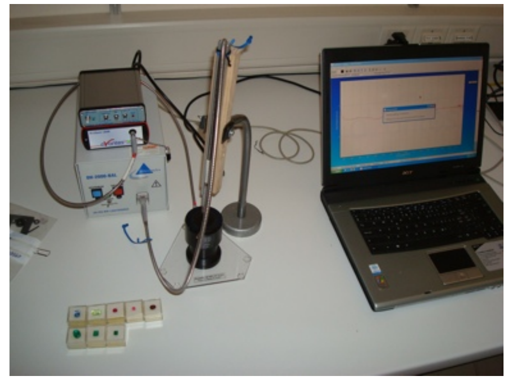


A Varian UV-VIS-NIR dual beam spectrophotometer

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



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.

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.

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

Gemology for Faceters #4

by L. Bruce Jones, G.G., F.G.A., D.Gem.G.

In the September issue we discussed an important instrument for gem identification, the spectroscope. In this, the fourth installment of a planned series of articles, we introduce magnification and discuss the loupe and the gem microscope as very significant instruments in our quest for proper gem identification.

The Loupe

The jewelers loupe or hand lens is the instrument in the gem trade that gets the most use. The loupe is portable, convenient and easy to use, although there are a few tricks that can increase its usefulness substantially.

Loupes typically come in magnification ranges from 2x to 30x with the 10x loupe being the most popular and the most useful under most circumstances. With a 2x lens the object image appears twice as large in diameter as its actual size. With a 10x loupe the object image appears 10x larger in diameter. As magnification increases, the **focal length**, which is the distance from the surface of the lens to the point of focus, decreases. The focal length of a 10x lens is one inch, but for a 20x lens it is 0.50 inch. The **depth of field**, the distance or depth of area that remains in focus also decreases with magnification. The combination of a short focal length or working distance and a limited depth of field make high magnification lenses significantly more difficult to manage.

The type of loupe most useful for the gemologist is the triplet, which refers to a loupe composed of three lenses. Single lenses suffer from two issues:

CHROMATIC ABERRATION is a distortion that causes color fringes around the image due to optical dispersion of the glass. It is corrected by combining two lenses of different dispersion, one bi-convex and one bi-concave. An **achromatic** doublet is made to focus both red and blue light at the same location and is typically composed of a high dispersion concave flint glass element cemented to a low dispersion convex crown glass element. The higher quality **apochromatic** lens is made to focus red, green and blue light at the same location.

SPHERICAL ABERRATION is found in curved lenses and refers to the lens' inability to focus light across the lens at a uniform distance. The edges of the image appear distorted. This can be corrected by using two or more lenses of differing radii or by using an aspheric bi-convex lens.

A **Hastings Triplet** is the most common form of quality fully corrected loupe that is widely available and comprised of three lens elements, generally cemented together. It is typically superior to both the doublet and Coddington lens systems.

The diameter of the lens is related to both the field of view and the light gathering capacity of the lens. A small pocket loupe will generally be about 15mm in diameter. A larger loupe will be approximately 20mm in diameter. Interestingly, a number of manufacturers note the full diameter of the lens as opposed to the actual viewing area. For instance, the Gem Oro loupes said to be 21mm only have a viewing diameter of 18mm. Likewise I have an inexpensive Chinese loupe with built-in LED illuminators that claims 20x-18mm that is actually only about 12x-16mm.

The loupe in the top left is a Bausch & Lomb that has served for 30 years. You can buy one today for less than $35. Center left is a Gem Oro 10x loupe followed by a Gem Oro 20x loupe that while advertised as a triplet suffers from substantive spherical aberration. Upper right is generic Chinese loupe with built in LED light. Bottom right is a GemologyPro Harald Schneider unit that is the highest quality 10x Achromatic-Aplanatic Triplet and costs $300.

Construction Quality

In addition to the quality of the optics the quality of overall construction is important. Some loupes have cheap die-cast bodies with friction rings to secure the lenses and under hard use the bodies will break and the friction rings will fail and the lens elements will fall out. Pivot construction is also important. If the pivot wears out prematurely the lens friction will be lost and the lens will dangle from the case. If the pivot fails completely the lens assembly will separate from the case.

Recommendations

Bausch & Lomb makes a high quality Hasting's Triplet in 10x that can be purchased from many suppliers for less than $35. With proper care it will provide years of service.

For those for whom only the best will do a Gemology Pro Harald Schneider 10x-20mm corrected triplet can be purchased for $300.

Lighting Hints

In many cases the loupe is used where there are not many lighting options. In such cases it is best to let light enter the side of the gem which will highlight internal features and still provide a good view of the surface of the stone. At times you can use reflected light where you position the stone with respect to the light source such that light reflects off the gem's surface. The reflected light technique allows you to see the facet junctions, the condition of the polish, any surface reaching fractures or imperfections as well as any cavities, naturals or abrasions. I can only surmise that faceting contest judges are highly adept at this technique and can see point deducting artifacts the rest of us cannot!

A more arcane technique is to use darkfield illumination with a loupe. You can do this by purchasing a darkfield loupe, or, more simply, by taping a piece of black paper to the back reflector of a desk lamp. Line the girdle of the stone up with the front edge of the lamp reflector so that the lamp light is entering the stone but the loupe is kept out of the light. You will find that the inclusions in the stone stand out strongly against the dark background. If possible, turn off the room lights when you use this technique.

And finally, you will find that diffused lighting can be effective in finding curved color banding in synthetic flame fusion material or diffusion treated stones with surface coloration. In this case a translucent piece of paper between the light source and the stone will often be effective.

One effective technique for utilizing a loupe has the index finger inserted through the casing with the hand steadied by thumb contact with the cheek and the lens an inch from the eye. The opposite hand holds the tweezers with them locked under the little finger of the loupe holding hand. The stone then rests approximately an inch from the lens. The printing on the loupe case should always face the eye.

The Gem Microscope

If I am in out in the field with my geologist's hat on, or at a gem show, then a loupe is always around my neck on a lanyard. However, if I am anywhere close to a gem microscope I abandon the loupe immediately and without remorse.

Microscope Types

The gem microscope differs fairly significantly from compound microscopes used by scientists. Most gem microscopes are binocular, in that they have two eyepieces the observer uses simultaneously with both eyes open. As a result, viewing is generally comfortable for long periods of time. Most gem microscopes are stereo units in that there is an angular difference between the view between each eye so objects are seen in 3D. Other advantages are that the view is spatially correspondent where with a compound microscope the view is upside down and backwards. Stereo microscopes are also designed with lower magnification to have a larger field of view and good working distances with excellent depth of field. In gemology, it would be unusual to use more than 100x with most work being done in the 10x-30x area. Besides gemologists, surgeons, engravers, and electronic circuit board technicians are examples of people that use binocular stereo microscopes.

Background

Microscopy is a complex subject which we can simplify somewhat by virtue of the fact that we are dealing with gem microscopes and not the more complicated compound microscopes.

MAGNIFICATION causes the object viewed to appear larger to show detail that we cannot see with the human eye alone. In microscopy, the magnification is the product of the power of the eyepieces, also called oculars, times the power of the objective lens, which is the lens closest to the object being viewed. A typical 10x ocular and a 4x objective would give a magnification of 40x. The units are "diameters," where an object with a diameter of 1mm would be viewed as if it were 40mm in diameter. If the microscope had a screw-on 2x doubler, the magnification would be 80x.

RESOLUTION is the ability of the microscope and the viewer to separate two close objects as individual and distinct. The higher the resolution, the smaller the two objects can be and the closer together while still remaining distinctly separate. Without resolution you have **empty magnification** where further detail is not resolved and the objects combine in a blurred single form.

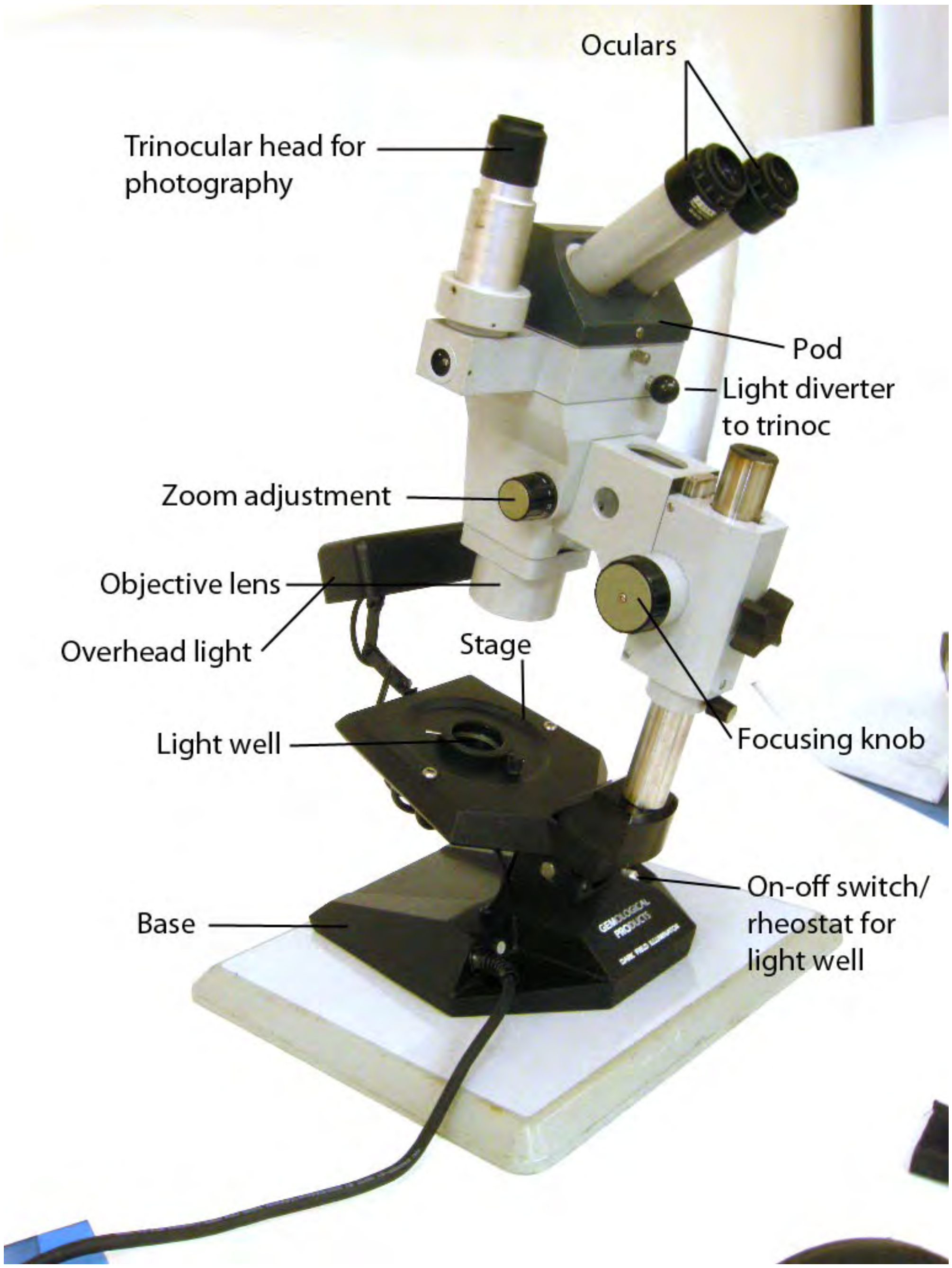
It is interesting to note that in microscopy the size of the object that can be seen is ultimately a function of the source wavelength. The limitation of a well made compound microscope is magnification of 1000x (1400x with oil immersion), yet because the wavelength of electrons is very much shorter than that of photons an **electron microscope** can magnify over 100,000x.

Gem Microscope Components

Today, the majority of quality gem microscopes have zoom capability such that the magnification is continuously variable over a certain range. For example 0.7x to 6.4x engraved on the zoom knob represents the objective magnification and would give you an effective range, with 10x eyepieces, of 7x to 64x. if the eyepieces were 15x the range would be 10.5x to 96x.

The components shown in the image below are fairly self explanatory and are common to most gem microscopes.

The first step in using the gem microscope is to properly focus the unit.



The author's trinocular Zeiss Stemi SV-8 mounted on a Gemological Products base.

Focusing

To focus the microscope turn on the unit and adjust the rheostat so ample light is emitted from the light well. Place a gem or other object in the center of the field of view and set-up for 10x magnification. Look through the right ocular (e.g. eyepiece) with your right eye, keeping both eyes open and focus on the object by turning the focusing knob on the microscope until the object is clear and sharp. Now, leave the focusing knob alone and look through the left ocular, turning the focusing ring at the base of the ocular until the object is in focus. Now look through both eyepieces and adjust the distance between them if necessary. The object should be in clear and coherent three dimensional focus.

Some people have trouble keeping both eyes open and focusing with one eye. In that case you can remove the alternate ocular that is not in use. Remove the left ocular while focusing the right and vice versa.

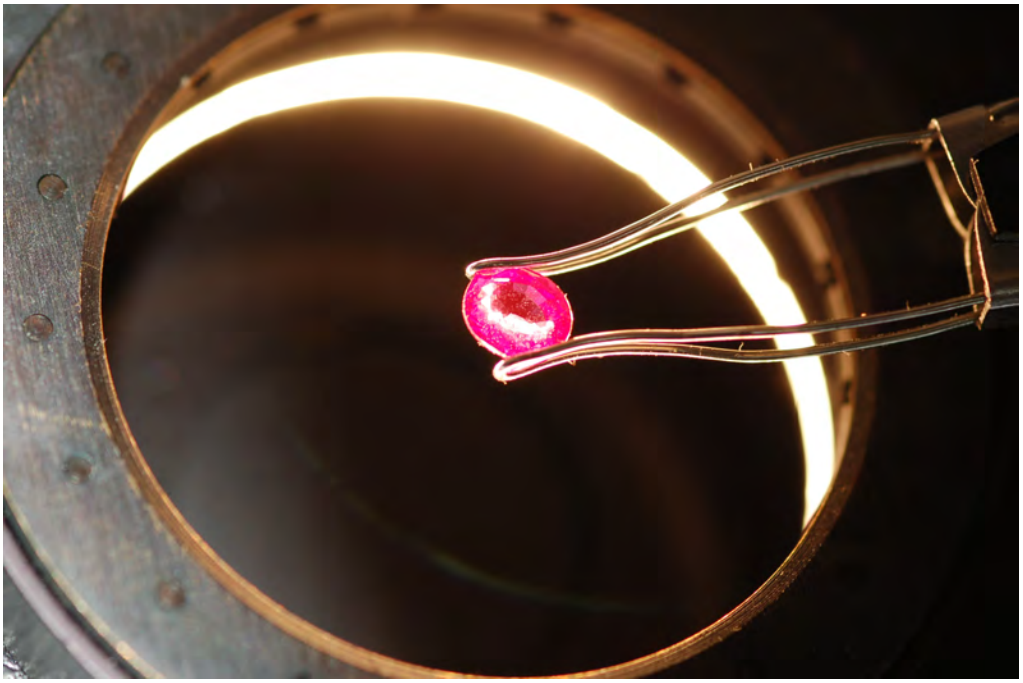
Types of Lighting

DARKFIELD ILLUMINATION is the most useful type of lighting for gem observation. When the microscope is set-up for darkfield illumination, light enters the gem from the sides and back and the background is black, allowing most internal features to be highlighted.

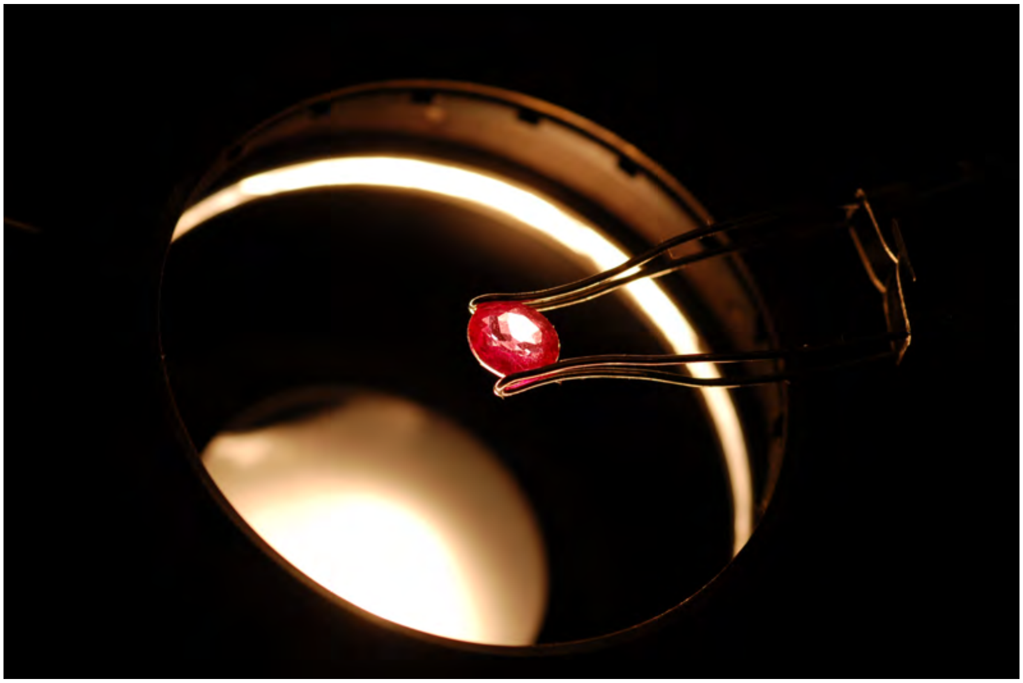
Gemological microscopes are set-up with dark field illumination specific to maximizing the observational capabilities with three dimensional objects. More darkfield illumination systems are found on biological microscopes where they are optimized for flat lab slides. These systems are not at all suitable for gemology and should be avoided. For more information see: http://gemscientist.com/Gemscientist/Blog/Entries/2010/6/15_Darkfield_illumination.html

BRIGHTFIELD ILLUMINATION or transmitted light illumination happens when the darkfield baffle is removed and light passes directly through the stone creating a light background. Brightfield illumination is often most useful when the iris diaphragm is closed to just under the diameter of the stone creating pinpoint illumination that is more collimated. Low relief inclusions and curved striae in flame fusion synthetics are best discovered in this configuration.

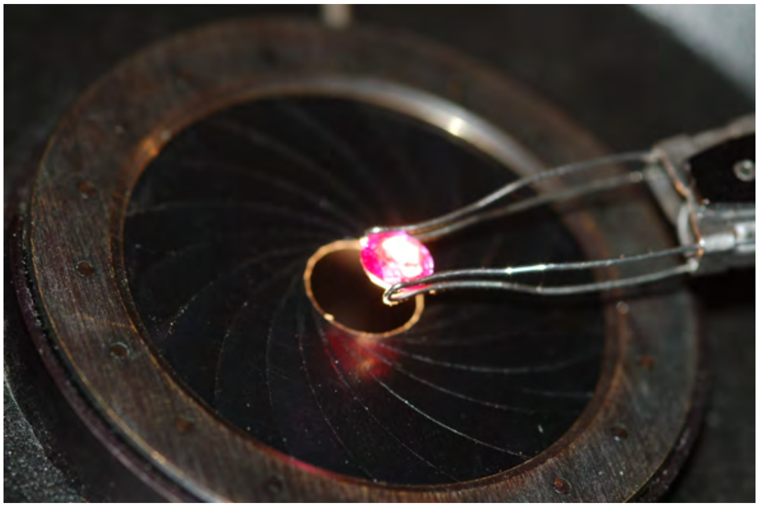
REFLECTED LIGHTING is quite valuable to faceters as it is used to reflect light off the surface of the stone and to therefore highlight facet junctions, inclusions that reach the surface, abrasions, polishing marks, ghost facets, cracks, crevices and naturals, etc. Most gem scopes have an overhead daylight fluorescent light and some have a separate incandescent spotlight built under the pod. A separate fiber optic light



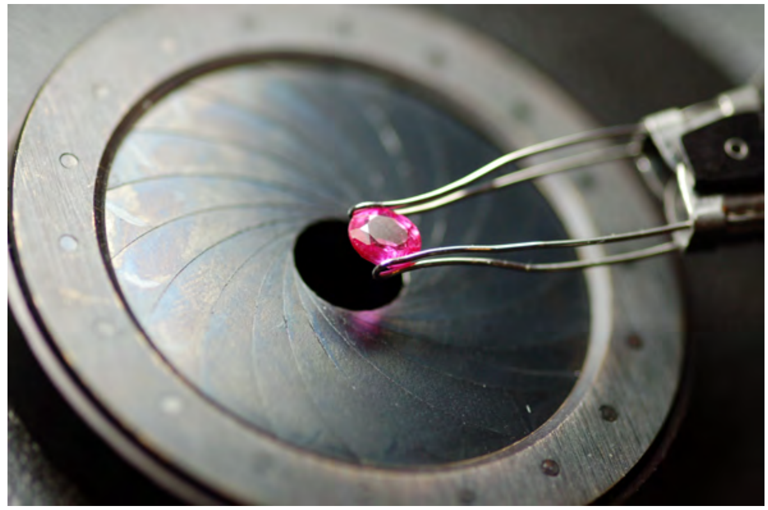
Darkfield illumination. The black background makes inclusions stand out.



With brightfield illumination the black baffle has been swung out of the way allowing a bright background. The effect is most obvious when viewed through the microscope.



Here the iris diaphragm is closed down beneath the stone allowing the brighfield rays to be more collimated. This condition is good for observing curved striae.



In this case of reflected light no light is coming from the light well. All the light is coming from the fluorescent daylight light-source above the stage.

source can be used for reflected light observation as well.

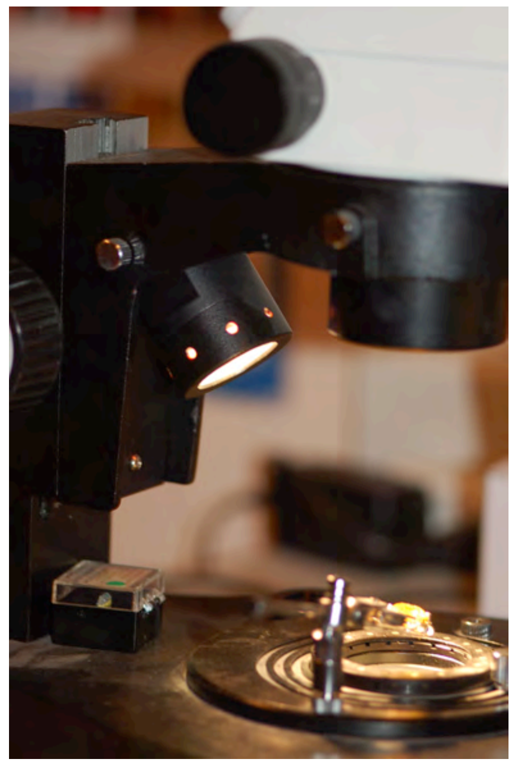
DIFFUSED LIGHTING involves placing a white diffuser over the light well. This can be as simple as the cover of the overhead light or a piece of white tissue or it can involve a special filter placed over the light well. Diffused light softens the light and eliminates reflections. It is a good way to observe the actual color of inclusions or, with a polaroid filter placed between the stone and the objective, to observe pleochroism in an inclusion.

POLARIZED LIGHTING is very helpful in observing strained crystal inclusions, twinning, optic figures and birefringence. A pair of polaroid filters, one placed between the gem and light source, designated the polarizer, and one between the gem and the objective, called the analyzer, is all that is required.

FIBER OPTIC ILLUMINATION takes advantage of fiber optic illuminators to add an amazing amount of versatility to the microscope lighting issue. Light can be added from virtually any angle with either fixed-flexible light pipes that stay where you place them or by small totally flexible smaller diameter light pipes to which tips of specific shapes and diameters can be added for **pinpoint illumination** and **light painting**.

IMMERSION is a microscope technique where a gem is placed in a container of liquid that approximates its refractive index (i.e. methylene iodide for corundum), thus eliminating surface reflections of all types. Immersion can be carried out in plain or polarized light and with a vertical microscope set-up equipped with an immersion cell, or more conveniently, with a horizontal immersion microscope. Immersion is effective for observing curved color banding, surface diffusion, plato lines,

Polarizing filters, horizontal immersion cell and camera adapter for ocular port.



An incident illuminator provides bright reflected light and is controlled by a rheostat separate from that of the light well.

Editor's Note:

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An Eickhorst horizontal microscope base designed for immersion and polarization work. The base is fitted with a B&L Stereozoom 5 head.

gem treatment evidence, country of origin inclusion studies, etc.

Photomicrography

Once you've invested in a microscope one of the most interesting things you can do is equip your gem scope with a camera system that allows you to take quality photographs of internal and surface features of gemstones. The subject of gem photomicrography is complex and the space available here does not allow for much discussion. Interested readers are directed to the many articles written by GIA's John Koivula, the world's foremost living gem photomicrographer and inclusion expert.

There are two types of gem microscopes suitable for taking photos. Most commonly, a binocular microscope can be used with an attachment that allows a camera and adapter to be inserted into the space once one of the oculars is removed. Virtually all binocular microscopes have ocular diameters of either 23mm or 30mm and so to order an adapter you need to know the appropriate size for your microscope. Since most adapters screw on to the filter threads on the front of the camera lens, you'll need to know that diameter as well.

Some microscopes are trinocular in that they have a third viewing port and ocular specifically for photomicrography. The advantage is that the camera can remain mounted while the user is viewing the gem through the eyepieces.

Many older microscopes with trinocular arrangements came with dedicated elaborate film camera systems with automatic exposure controls. In their day, they were expensive and effective but with the advent of new DSLRs they are generally superfluous.

Obtaining a Microscope

There are a number of gemological microscopes on the market and essentially the buyer has three choices, 1) purchase a new gemological microscope from a reputable source, 2) purchase a used complete gemological microscope with darkfield/brightfield and reflected light capability, 3) buy new or used components and assemble a gem scope to meet your needs.

New Microscopes

In my opinion the least expensive new gem microscope that is of adequate quality and has the necessary features is the GemOro Elite 1067zx which can be purchased for approximately $800.

Next on my personal list would be any of the gem scopes made by Meiji, ranging in

DSLR camera mounted in photoport.

GemOro Elite 1067zx is a passible gem microscope for the price.

price from about $2300 to $3400. These gem microscopes are the price-value leaders with excellent optics and durability.

If you don't mind shopping in Europe the gem microscopes by Eickhorst and also by Krüss are excellent pieces of equipment.

I absolutely would not buy a new gemological microscope from anyone else. No eBay Amscope models nor anything offered by GIA which, in my opinion, is overpriced for the quality currently offered.

Used Gem Microscopes

Older GIA Gemolites with Bausch & Lomb or American Optical heads can be found on eBay at reasonable prices and make excellent scopes. It is absolutely preferable to buy quality used equipment as opposed to buying cheap new equipment that will not provide adequate service, reliability and longevity.

If you can find used Meiji, Eickhorst or Krüss scopes, by all means consider them. All others not mentioned here should be viewed as suspect.

Assembling Components

Assembling a gemological microscope from used and new components is an excellent idea that has one significant drawback. There have been very few dedicated quality dark-field illumination systems made for gemological microscopes. The quality of the darkfield illumination in a gem scope is at least as important as the quality of the optics.

There is only one producer of high quality gem microscope bases where you can pick your optics and have them mounted, and that is Jeff Wildman's Gemological Products in Sunriver Oregon. (http://gemproducts.com). Jeff sells quality refurbished microscope heads (Nikon, Leica, Leitz) that can be mounted on his incomparable base resulting in a system of the highest quality. Jeff will also mount virtually any microscope head you can find to his base, including those by Zeiss and Wild that require significant modification to fit.

A B&L Stereozoom microscope with fiber optic ring-light is mounted on a boom and stand that allows direct observation of a stone on the dop of a a GMII.

It's important to note that there are a lot of quality used microscope heads available with excellent optics. Years ago the best microscopes were made in Germany and Switzerland by companies like Wild, Zeiss, Leica, Leitz and Aus Jena, in the U.S. by Bausch & Lomb and American Optical and in Asia by Nikon, Olympus and Meiji. Some of these companies are no longer in business and others have outsourced manufacturing to Asia where in some cases quality has suffered making an older microscope a much better buy. A list of microscopes to buy and avoid can be found here: http://www.absolute clarity.com/buy&avoid.htm

A Faceting Set-up

In some cases a faceter might not be interested in the gemological separations and determinations a microscope can help make. In this case a simple stereo microscope equipped with a ring-light and mounted to a base and boom configuration can assist with detailed microscopic viewing while the stone is on the dop. Older Bausch & Lomb Stereozoom 5 heads were made by the thousands and can be found on eBay occasionally at prices below $300 and these seem to be particularly well suited to this application.

Applications in Gem Microscopy

We've discussed some of what you can accomplish with a gem microscope. Besides evaluating gem quality in terms of color, cut and clarity and detecting all manner of assembled and imitation stones, the study of inclusions, although complex, is incredibly valuable and can tell us much about a stone. Synthetic stones have certain characteristic inclusions and internal features based on the manufacturing technique and inclusions in natural stones occur in a remarkable and complex variety of forms that can tell us about the geologic conditions of formation, the geographic source of the stone, the stone's age, etc.

If you are interested in gem inclusion analysis there is one body of work that easily stands out as being the definitive and authoritative source for information on the subject, and that is the three volume set of the Photoatlas of Inclusions in Gemstones by Eduard J. Gübelin and John I. Koivula.

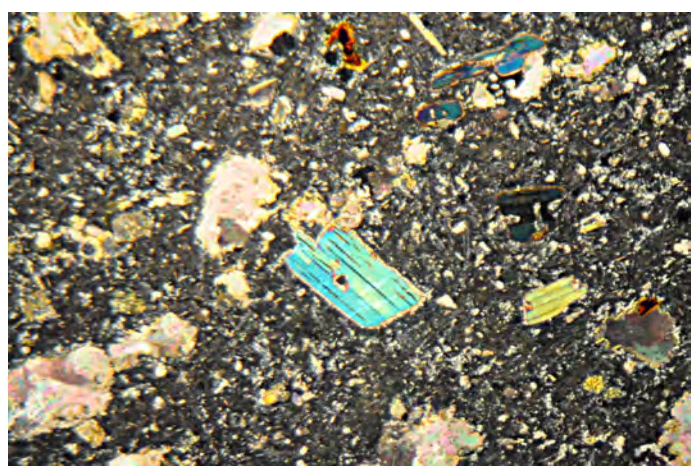
Conclusion

It has often been said that the basis for gem identification is the triad comprised of the refractometer, the spectroscope and the gem microscope. Along with the introduction in Gemology for Faceters #1 we've now discussed the main three gemological instruments and the four articles combined will be placed in the USFG newsletter archive as a bonus set.

In the next issue we'll discuss gem scales and balances as well as techniques for determining specific gravity.

An Olympus BH-2 series set up for Raman microanalysis where laser light travels through the optic train and the objective lenses directly impinging on the sample at a 90° angle. The Renishaw Raman system is confocal and can identify virtually any organic or inorganic substance.

A Meiji polarizing petrographic compound microscope is a tool used by mineralogists and petrologists to identify crushed grains with complex optics techniques and to analyze thin sections of rocks in transmitted and polarized light. Magnification to 1000x is possible.



This is a thin section of a lamprophyre, an ultrabasic rock from the French Bar area of Montana. The rock type is the original host material for the Missouri river sapphire deposits around the Eldorado Bar and it tells a fascinating story.