# 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.

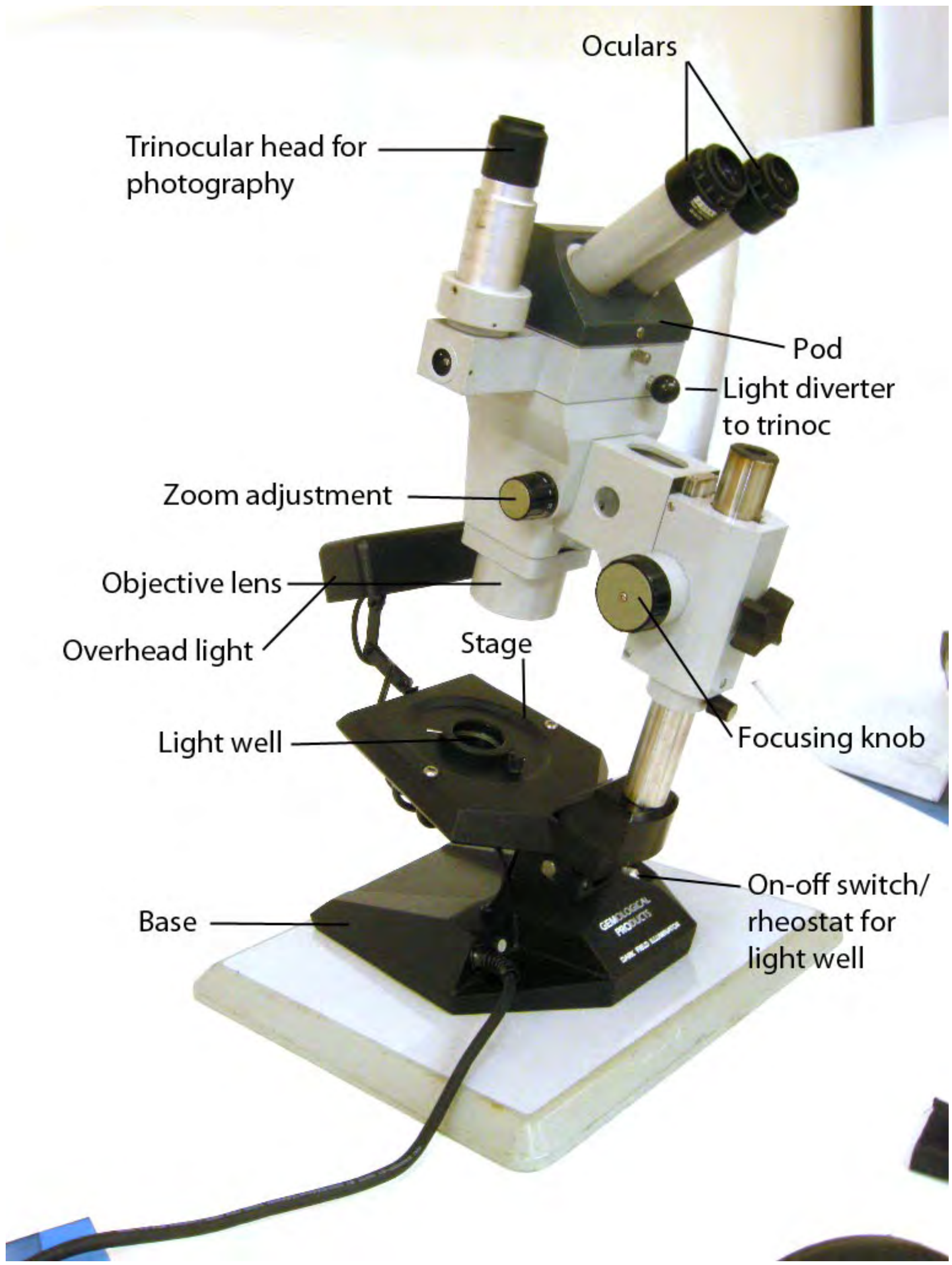
It is interesting to note that in microscopy the size of the object that can be seen is ultimately a function of the source wavelength. The limitation of a well made compound microscope is magnification of 1000x (1400x with oil immersion), yet because the wavelength of electrons is very much shorter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

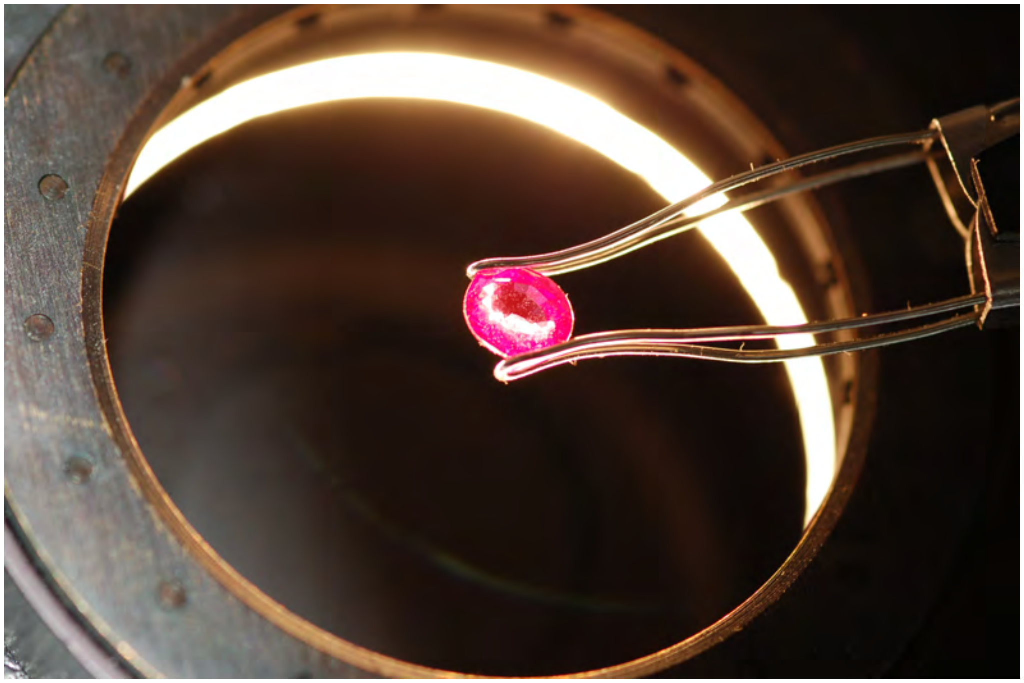
Some people have trouble keeping both eyes open and focusing with one eye. In that case you can remove the alternate ocular that is not in use. Remove the left ocular while focusing the right and vice versa.

## 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

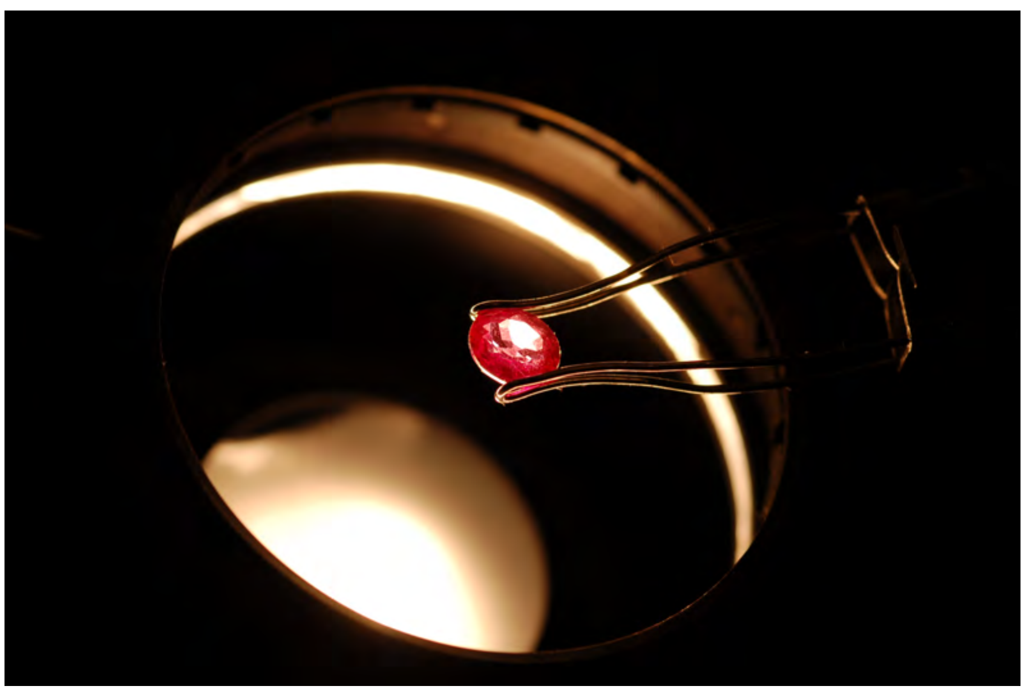
**BRIGHTFIELD ILLUMINATION** or transmitted light illumination happens when the darkfield baffle is removed and light passes directly through the stone



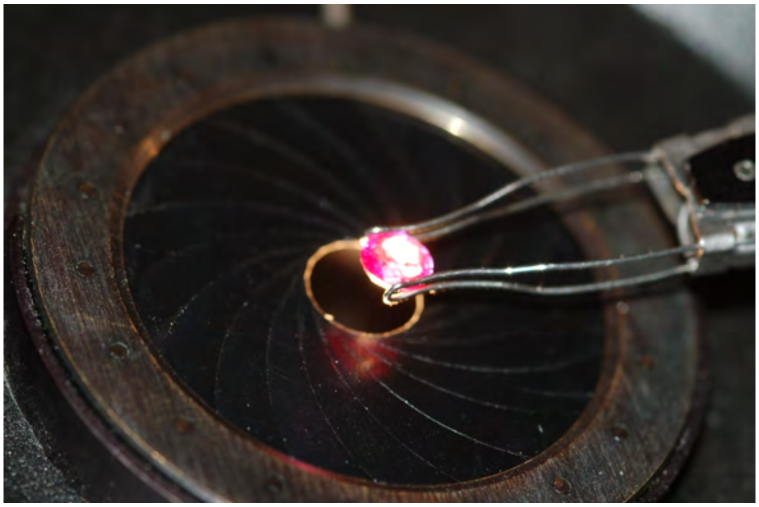
**Darkfield illumination. The black background makes inclusions stand out.**

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.

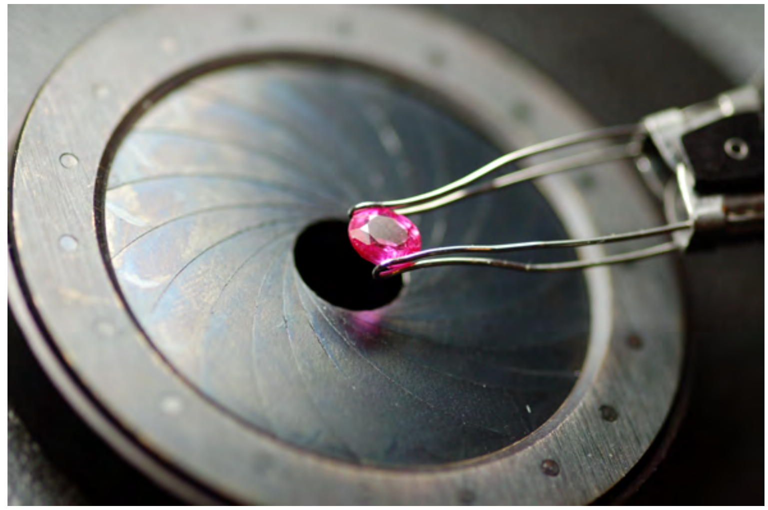
**REFLECTED LIGHTING** is quite valuable to faceters as it is used to reflect light off the surface of the stone and to therefore highlight facet junctions, inclusions that reach the surface, abrasions, polishing marks, ghost facets, cracks, crevices and naturals, etc. Most gem scopes have an overhead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



**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.

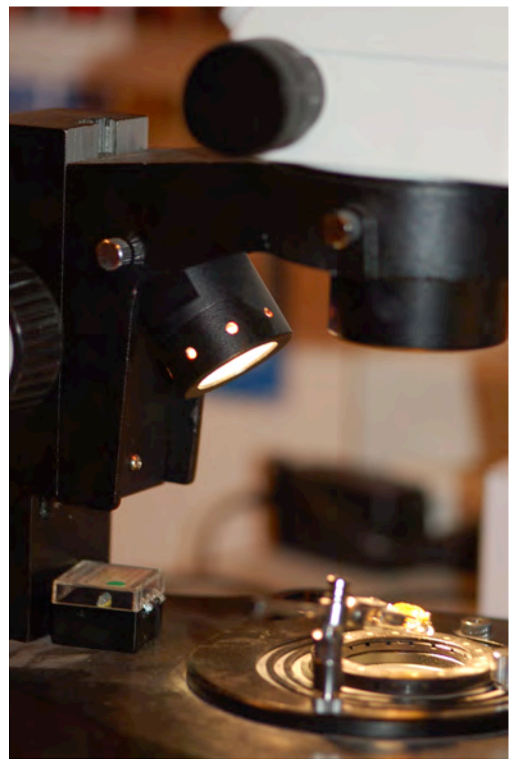
**DIFFUSED LIGHTING** involves placing a white diffuser over the light well. This can be as simple as the cover of the overhead light or a piece of white tissue or it can involve a special filter placed over the light well. Diffused light softens the light and eliminates reflections. It is a good way 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:**

**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**

**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,

**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.**

including those by Zeiss and Wild that require significant modification to fit.

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.

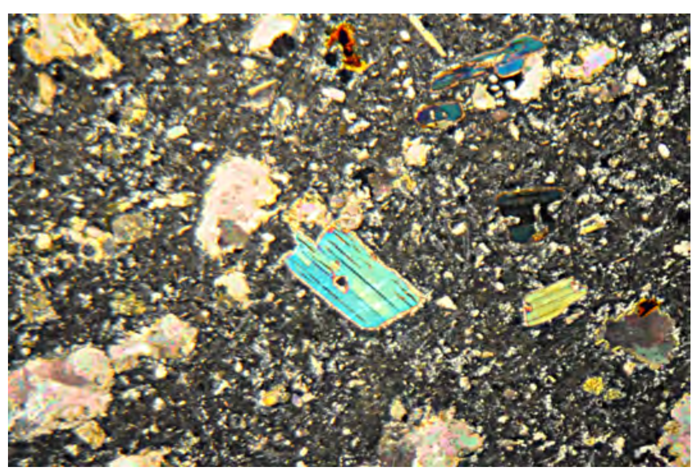
## Conclusion

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.


**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.**


**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.**



**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.**