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Basic Considerations When Mounting a Camera on a Trinocular Tube

If you do not have the luxury of simply adding a microscope manufacturers dedicated components to accommodate a camera, you will need to put together a "custom" solution. For photomicrography a good camera-to-microscope connection, both optically and mechanically, is essential. This document is rather basic, and suggestions for some more detailed information are provided near the end. But the principles presented in the next few pages should be helpful start for individuals undertaking this task.

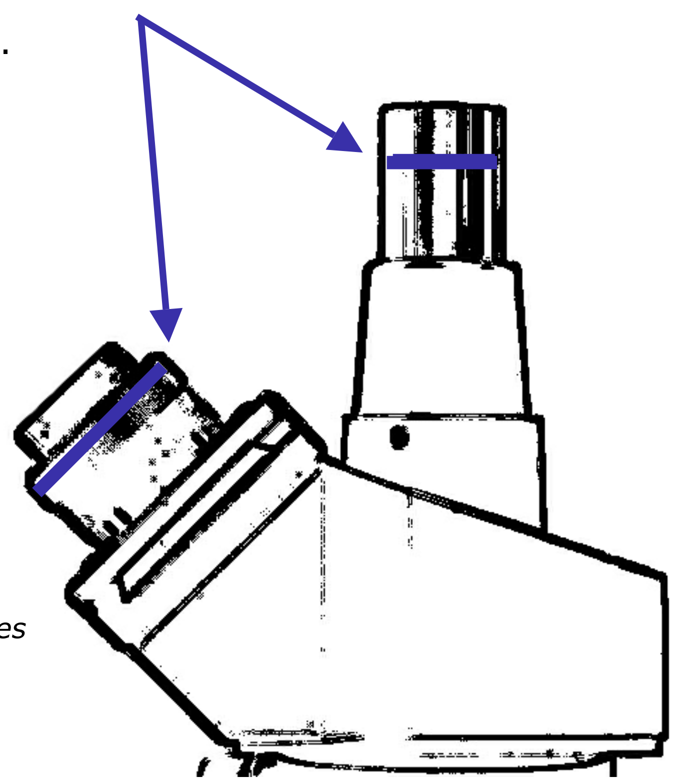
The image formed by the microscope objective is located in the eyepiece tubes, and also in the trinocular tube. Trinocular heads generally have a "slider" that will determine where the image will be directed... to the eyepiece tubes, to the trinocular tube, or in some cases to both the eyepiece and trinocular tubes simultaneously. This image is referred to as the "intermediate image".

Location of the intermediate image:

This is a "real" image (if a small screen were at this location the image would be seen on the screen). In a "finite" optical system it is formed solely by the objective. In an "infinity" optical system it is formed by the objective together with the (fixed, internal) tube lens. Via beamsplitters and prisms, the same image appears in both eyepiece tubes and the trinocular tube. This real image created by the objective is (usually) located 10mm down from the top edge of the (empty) eyepiece tube. (And also 10mm down from the edge of many trinocular tubes).

In the eyepiece tubes, an eyepiece is inserted and the diaphragm of the eyepiece coincides with the location of the intermediate image. It is then magnified and forms a "virtual" image that is observed by eye.

The intermediate image that is located in the trinocular tube is the one that will be used for photography.



A basic trinocular head with no eyepieces inserted. The blue lines indicate the location of the intermediate image.

The image in the trinocular tube must somehow be placed on the camera sensor. There are several ways of accomplishing this. But first there are some important factors that must be considered for best results.

Microscope objectives are designed to very specific parameters including lens-to-subject distance and (for finite systems) a specific tube length. When your microscope head is set up properly and focus is achieved through the eyepieces these parameters are met, and optical quality can be maximized. With the possible exception of a very slight "fine-tuning", the focus should not be changed from proper eyepiece focus in order to provide accurate focus in a camera. While a poorly set-up camera can often be brought into focus by significantly changing the microscope focus (and thus losing proper focus in the eyepieces), this would upset the optical design parameters and can result in serious image degradation. And photomicrography is certainly more productive and enjoyable when the eyepiece focus and camera focus are the same (“parfocal”). So the intermediate image that will be utilized for photography should be considered to be at a fixed location in the trinocular tube once the microscope viewing eyepieces are focused. ***Focus is achieved with the viewing eyepieces, and only a slight (if any) fine adjustment should be allowed to bring the camera into focus.***

Another key consideration is the "completeness" of the intermediate image. The majority of "finite" microscopes produced over the years did not correct for all optical aberrations in the objective alone. It was expected that the objectives would be used with eyepieces (for both viewing and photography), and so these eyepieces were designed to provide the final color correction. Such eyepieces are called "corrective" or "compensating" and are generally marked with a "K" or "C". For this reason it is important that objectives be used with the eyepieces designated by their manufacturer. (While most manufacturers had corrective eyepieces there was no standardization as to type or degree of correction). If an objective designed to be used with compensating eyepieces is used an eyepiece that does not offer the proper correction, there will be some amount of uncorrected chromatic aberration found in the final image. It may be small enough that it is not very troublesome, but it can also be very significant at times.

There are some exceptions. In 1976, Nikon introduced 160mm tube length (i.e.”finite) "CF" objectives that did not require chromatically corrective eyepieces. Current microscopes that use "infinity" optical systems do not require corrective eyepieces. (In some "infinity" systems, all corrections are done in the objective, while in others the internal tube lens makes some final color correction). Before contemplating a camera arrangement, it is important to ascertain if the microscopes intermediate image can be used "directly" (as with Nikon finite "CF" objectives and the newer "infinity" optical systems), or whether the image needs to pass through the proper corrective eyepiece before it can be used.

There are several ways the intermediate image in the trinocular tube can be placed on a camera sensor.

1) Projection Eyepiece in the trinocular tube (no lens on camera).

Some manufacturers made/make "projection" type photoeyepieces. These are inserted into the trinocular tube. They "pick up" the real intermediate image that is located in the trinocular tube and project it to form another real image some distance above. Generally they will also magnify (or reduce) the intermediate image to some degree in order to provide a better “fit” onto the sensor used. With proper adapters a camera body can then be positioned above this projection eyepiece so that the newly created "real" image coincides with the camera sensor.

If there are no projective type eyepieces or manufacturer designed camera connection optics available, a “regular” viewing eyepiece can be pressed into service to allow this technique. If it is elevated in the trinocular tube a little higher than the normal position (about 5-10mm often works out OK), it can project an image onto a camera sensor placed above it. (Image quality may be variable, and I would suspect it is generally a little lower than when using a manufacturers designed projection eyepiece, should one be available.

2) Afocal Method

A "regular" eyepiece is inserted into the trinocular tube. In this case it is not “raised”, and it should be in focus at the same time as the binocular viewing eyepieces. Then, a camera with an attached lens (focused at "infinity") is located very close and directly over the trinocular eyepiece. This can provide excellent images, but it can be tricky to get a camera lens that can be positioned close enough to the eyepiece to get a full image with no vignetting. Most lenses are too large, and the entrance pupil is set back too far into the lens to "couple" well with virtual image created by the eyepiece. Eyepieces with a "high eyepoint" design can help.

Although not immediately obvious, both Zeiss and Leica used essentially this method for some of their camera arrangements. However, instead of having a lens attached directly to the camera it was built into the adapter. This approach permitted optimizing this lens, especially when used together with eyepieces (such as the Zeiss S-Kpl) that were made for this use.

3) "Direct projection"

The camera body (no attached lens) is mounted so that the sensor is located at the exact position of the trinocular tube intermediate image. (Very often this is not possible because of physical constraints). With this approach it is important to be certain that corrective eyepieces are not needed. It is also important to think about the relationship between the sensor size and the intermediate image size (this is discussed in a following section).

A physical constraint is frequently encountered with SLR cameras. Often there is simply no way to get the camera sensor to the location of the focused intermediate image unless the trinocular tube is removable or you cut it off. Even then, a DSLR has a body depth of about 45mm, so it still may not be possible to achieve camera focus simultaneously with the eyepiece focus.

The cameras that are in the “micro 4/3” class might be of special interest for a direct projection arrangement since the flange-to-sensor distance is only 20mm. In addition, the sensor size itself, 18mm x 13.5mm, is a good fit with the image produced directly by a microscope objective.

With all these methods the positioning and spacing of the components is important.

The goal should be to have the camera and eyepieces "parfocal" ... or at least very close, and with a quality "optical" connection to the camera. This is both from a simple operational consideration as well as an image quality one. If the manufacturer of your microscope makes the requisite components and they are used as intended this will (should!) be the case. If you get a "generic" adapter or use other components in a manner not originally intended (such as "elevating" a viewing eyepiece for projection) you usually lose the plug-and-play aspect. Then, you'll need to make spacing and mounting adjustments and modifications to set things up nicely. It is unfortunate that most microscope camera adapters (and the majority of trinocular tubes) tend to be of fixed length. When making a custom set-up it is very helpful to be able to adjust the height of the camera in fine increments in order to make the set-up parfocal. A little ingenuity in designing your adapter can make life much easier.

A more detailed discussion of this subject can be found here:

http://krebsmicro.com/photomic1/photomic1.html

Also of interest might be a procedure to make a trinocular mounted camera “parfocal” with the viewing eyepieces:

http://www.krebsmicro.com/parfocal/index.html

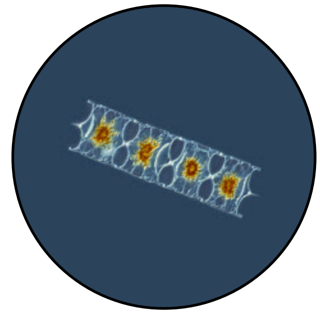
The next, and final page of this document illustrates the need to consider the size of the sensor in the camera in relation to the intermediate image. The physical size of the intermediate image is limited by the physical size of the microscope tubes. (And the objectives are thus designed with this size limit in mind). In compound microscopes a tube diameter of 23mm is the most common. (There are some "super-widefield" heads that have 30mm tubes). Objectives are usually designed to provide a quality intermediate image with a diameter of about 18-20mm. *(Objectives suitable for "super-widefield" use can produce a larger useful intermediate image of about 28mm diameter)*.

The most commonly used eyepieces are 10X. In the 23mm barrel size these will typically accept an image of 18 to 20mm diameter (this is the "field number" value). *(Eyepieces fitting the 30mm "super-widefield" tubes usually accept an image size of about 26.5mm).*

So the intermediate image that will be used for photography is a circular image with a diameter of about 18 to 20mm. It is usually desirable to record use as much of this image as possible. But sensor sizes can vary dramatically. The optics used in the trinocular tube can be used to enlarge or reduce the intermediate image in order to provide a good "fit" to the camera sensor.

The circular image to the right represents the view seen through 10X eyepieces with a FN (field number) of 20mm.

This also represents a 20mm diameter intermediate image as seen in "standard" 23mm microscope tubes, including the trinocular tube.



To record a camera image that corresponds closely to the image viewed, it may be necessary to resize this intermediate image to provide a better fit on the sensor (or film) used. Below can be seen a representation of three commonly used sensor sizes... "35mm full frame" (measuring 24x36mm); APS (measuring 22.2x14.8mm); and 1/2" (measuring 4.8x6.4mm). On the left you see what would be recorded if it were possible to place the intermediate image directly on the sensor. The "full frame" and APS sized sensors are larger than the intermediate image, so there would be vignetting, and the imaging area of the sensor is poorly utilized. The 1/2" sensor is much smaller than the intermediate image, so it would record only a small central portion of the image seen through the eyepieces.

If the intermediate image in the trinocular tube were magnified (or reduced) by the factor seen in the middle column, the resulting composition recorded on the sensor can be seen on the right. This illustrates the importance of matching the magnification provided by the optics in the trinocular tube to the camera’s physical sensor size.

Keep in mind that this illustration represents a microscope with 23mm eyepiece tubes, and 10X viewing eyepieces with a 20mm FN, a fairly common arrangement. With a "super-wide" head with larger diameter tubes, and/or different eyepieces these numbers will change, but the basic concept remains the same.