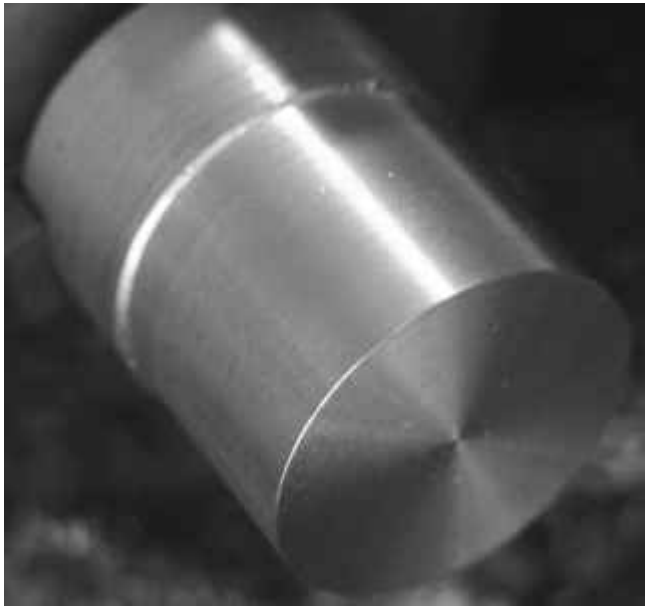
Making Digital Camera Microscope Adapters

This ongoing project produces various adapters to mount digital cameras on various microscopes, using the afocal (through-the-eyepiece) principle.

I started by making an adapter for a Sony DSC-S30 digital camera, mounting to a Bausch and Lomb microscope. This creates a system for high-quality, wide-field photomicrography. Lately I have been custom-making adapters for readers of this page having a variety of cameras and microscopes, for which I typically charge $60 to $80, depending on the complexity.

The lens of the Sony DSC-S30 camera provides a 37 mm inside diameter x 0.75 mm inside threads, and the microscope eyepiece provides a smooth 1.138 inch outer diameter cylinder. Thus the adapter will consist of a turret with outside threads to mate to the camera lens, and an inside bore to slip snugly over the microscope eyepiece.



The first dimensional step is to turn down the cylinder, leaving a raised ridge of 37 mm diameter, ready to take on the outside threads. I chose to thread a length of 5 mm, which was about twice the length of the inside threads on the camera turret. Using the threading bit to turn the smooth diameter makes it easy to leave 60 degree bevels on all the stepped edges. I was happy to find that the 0.75 mm metric thread pitch is available on the minilathe using the standard set of change gears (see the Yahoo 7x10minilathe group files area for tables of using change gears for metric threading). The photos show the work progressing on an aluminum billet I made as a casting experiment, and the casting flaws show up as dark spots or flecks. For later versions, I have been using aircraft aluminum stock.

Next I mounted the tailpiece onto the lathe with a drill chuck and 1/2-inch drill bit, and bored a hole into the center of the piece.

With that 0.500 inch starter hole drilled, I was ready to start boring out the 1.138 inch inside diameter that would receive the microscope eyepiece. For this I used carbide boring bar bits that reached the 1" depth of the finished part. (Making the boring bar tool holder is the subject of another of my project descriptions.) After boring the hole a few thousandths oversize, I had a close fit of the adapter to the eyepiece. I finished the part by cutting it from the cylinder using a parting tool. I cut a length that maximized the fitted depth, but still let the camera lens come to rest on the eyepiece. The photo shows the finished adapter.

Below is a view of the Sony DSC-S30 camera, with and without the adapter mounted.

This is an old Bausch and Lomb inspection microscope. This US-manufactured item isn't made any more, but when new they sold for about $2000. The optics are superb, providing a wide, flat field at a variety of zoom magnifications from 7x to 30x. Today, you can find them used on eBay for perhaps $500 or less, or you can buy a similar imported item for about that price new.

The turrets of the binocular eyepieces have the virtue of being smooth, even aluminum cylinders. This allows a simple cylindrical adapter to nest on top of the eyepiece.

This is the camera mounted on the microscope eyepiece. The adapter aligns and rigidly fixes the camera to the microscope. The camera lens protrudes in such a way as to touch the eyepiece, so I should apply a bit of vinyl tape as a cushion, or perhaps machine a spacer ring to insert as a standoff. I may add winged setscrews in the future to lock the camera on the eyepiece.

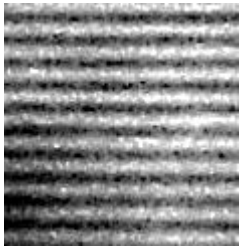
This shows the camera turned on, with the camera display imaging the the microscope's magnified view of a coin. The optical system of this camera is well-matched to the exit pupil of this microscope. By adjusting the camera zoom one can either get a vignetted photo of the full field of the microscope, or a full-framed photo of the center region of the microscope view. Both modes are desirable for various purposes. The photo below shows the full-frame mode.

This is a portion, at full resolution, of a photo taken by the Sony camera in the above setup. The object shown is a Lincoln penny, of which you are seeing part of Lincoln's face. I measured the features shown with calipers, giving a true height of the representation as 0.070 in. The digital image is 526 pixels high. Thus the system resolves about 7500 pixels/inch, which is 7.5 pixels/thousandth-inch, 130 microinches/pixel, or 3.4 microns/pixel. If we assume your display renders 96 pixels/inch, then the effective magnification is about 78x (= 526 pixels / 96 pixels/in / 0.070 in). The camera resolves 1472 x 1104 pixels (not much by today's standards), so the camera and microscope can photograph a physical area of about 0.2 by 0.15 true inches at this level of detail; the full field to the eye view in the microscope is about a 0.25 inch diameter circle. The microscope field zooms from about 1 inch at 7x magnification, to 1/4 inch at 30x. This is an amazing quality of result given that this camera sells for under $200, and the microscope sells used for about $500. Such a system would have cost many $1000s, and required costly film processing, not many years ago.

I don't know the resolution limits of the microscope optics, but they're probably better than what the Sony DSC-S30 camera is resolving in this setup. If that is true, then a higher-resolution camera would resolve more detail. I have a much better digital camera now, but it uses a large-aperture lens that isn't as well-matched to the microscope aperture, resulting in a severe vignette in the image. As a general optical design principle, one would want a small camera lens for this kind of behind-the-eyepiece microscopy. With camera lenses, bigger is usually better, since you can gather more light. But digital cameras can (and typically do) have very small, but nevertheless high-quality, lens systems, because the CCD electronic imaging devices are so much smaller than film formats. The light available is determined by the microscope optics, not the camera.

Many digital cameras today (2004) seem to be using imaging chips and lenses that are very close to the human eye in physical scale. This is a wonderful thing for those wanting to adapt the cameras to microscopes, because no optical adapters (such as a negative "relay lens") are needed, just mechanical arrangements. The pupil of the human eye may be assume to be about 4 to 5 mm in diameter when viewing microscope images. A good microscope will provide an exit pupil of similar diameter, and the camera lens should match this as well. Not so wonderful for the would-be photomicrographer is the trend away from putting filter mount threads on the lens turrets, even on the more expensive consumer models; later versions of my Sony DSC-S30 have a telescoping lens contraption that regrettably features no thread mount. If you're looking to buy a digital camera with hopes of photomicrography, look for one with a fixed, threaded turret, with

the inside thread diameter significantly larger than the microscope eyepiece you hope to use. Even if your camera has an extending/retracting lens turret, you may find an optional adapter tube (see Nikon, Canon, and Olympus examples below) that provides both room for the turret and filter threads for a further adapter. As a last resort, one can fit a sleeve machined just larger than the turret, with one or more screws for clamping to the turret itself.



The original microscopy experiments above were done in 2002. In 2004, I repeated them with the same microscope, but using a higher-resolution camera (Sony DSC-F707, 2560 x 1920 resolution = 5 megapixels) and an Edmund Scientific Co. resolution test target (gratings from 5 lines/mm to 200 lines/mm). This apparatus proved a resolution of 160 lines/mm (4000 lines/inch), or equivalently to 8000 pixels/inch (3 microns/pixel). The photograph shows a contrast enhancement of the 160 lines/mm grating. This is about the same resolution achieved directly viewing into the microscope eyepiece with the naked eye, and is the essential resolution limit imposed by the inspection microscope. Thus a higher-resolution camera does not necessarily translate into higher resolution photomicroscopy images, because the microscope itself introduces the resolution-limiting optical elements. This is a proper approach to the task, where the camera should be chosen to capture an image of some specified area, consistent with the resolution limits and field size of the microscope.

The advantage of a better camera is chiefly the larger field size it can capture at the resolution limits. To the left is a thumbnail of another Lincoln penny image taken with the higher-resolution camera at something less than the maximum magnification. See the full 1600x1600 resolution image here [155 KB JPG file], which makes a 20X image on a typical 96 dpi monitor. We can see a field of up to 0.9 inches diameter at this resolution (2000 pixels/inch), with the whole item imaged at once instead of just the nose. Using combinations of the camera and microscope zoom lenses, the magnification can be increased by another factor of about four to 80X or so, but vignetting will start to reduce the size of the object area.

Here are some more digital camera microscope adapters I made for a customer. These slide over a slightly smaller 1.135" eyepiece on a Bausch and Lomb microscope. The smaller item on the left provides an M41-0.5 thread for an Olympus C-3020 digital camera. The larger item on the right provides an M62-0.75 thread for an Olympus E-10 or E-20 digital camera. I used

commercial 6061 aluminum round stock for these. The threads on the left look uneven because of an interference pattern (moire effect) on the digital photo. Note the optical illusion which makes the bore look larger on the left adapter compared to the right; they are in fact equal.

The photos below show the attachment of the M41-0.5 adapter (above on left) to an Olympus C-3020 digital camera, and to the microscope eyepiece.

This adapter I made for a customer with a Nikon Coolpix 5700 digital camera (reviewed here and here) and a Nikon Labophot microscope. That Nikon camera is unusual because although it is a rather advanced model, the zoom depends on the lens turret extending various distances in and out of the camera body, like many snapshot cameras. While the lens hood provides a threaded ring, because of the turret extension, you cannot mount a filter or adapter directly to those threads; instead you must use a Nikon UR-E8 adapter (shown in the photos), which is essentially a 34mm long step-down tube from male M53.5-0.75 (mates to lens hood) to female M50-0.75 (for further accessories). This tube has an ID=51mm and OD=55.75mm, with a stop ridge of 47mm ID at 5.5mm inside of the female threads. This is the black item in the photos. The aluminum microscope adapter I made mated to the M50-0.75 thread on the UR-E8 adapter and received a 23mm (OD) Nikon Labophot microscope

eyepiece via a slip fit, overall length of 1 inch. After taking these specimen photos, I enlarged the 23mm bore to 29.2mm to slip over the *external* diameter of the Labophot eyepiece.

Another unusual feature of this adapter is that it can be screwed inside the UR-E8 adapter, or reversibly outside, depending on the camera lens turret extension. This allows the microscope eyepiece a 1.75-inch vertex range relative to the camera, to accomodate various zoom settings while minimizing vignetting. The photos to the left show the reversible mounting.

This step-down ring adapter (shown in the center of the photo) I made for a customer who already had a Canon LA-DC52C step-up adapter (left of photo) for a Canon A60 or A70 digital camera, which provides an M52-0.75 thread, which was to be mounted to a C-mount (1"-32 thread) adapter (right of photo) on the microscope. This Canon adapter, like the Nikon one above, provides an offset tube, inside which the lens turret of the camera has room to extend and retract. Both the inside and outside edges of the ring are threaded, although the photo resolution doesn't resolve all the threads.

This adapter is different than the others in that instead of an unthreaded sliding fit to a cylindrical microscope eyepiece, the adapter provides a female thread to connect to C-mount threads on the microscope. It is essentially a 1/4" thick aluminum washer with threads on the inside and outside edges.

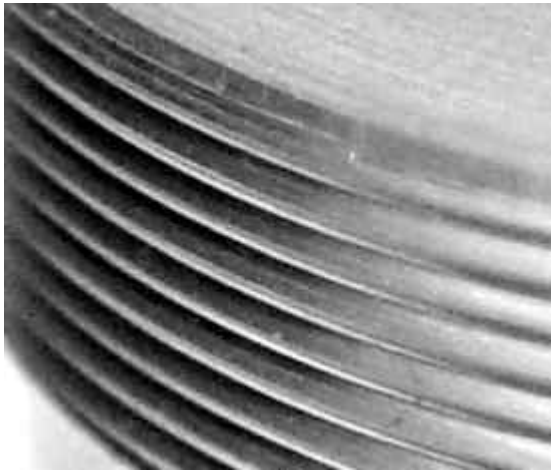
This adapter I made for a customer's Olympus C-4000 camera, which provides a 43mm filter thread mount. The smooth inside bore slips closely over the eyepiece (1.162" outside diameter) of a Bausch and Lomb inspection microscope. The height in the photo shows my standard 1-inch overall length for these adapters.

I have also begun including a rubber O-ring with each of the slip-type adapters. For example, for this adapter with a 1.162" inside diameter, a standard inch-series #213 Buna-N O-ring (ID=15/16", OD=1-3/16", section=1/8") fits snugly into the inside diameter without distorting. This provides a cushion against which one can rest the front of the lens turret to achieve a near-minimal vertex distance to the eyepiece optics. To increase the vertex distance, one can insert more of the same O-rings in a stack.

This adapter also required an additional modification (not shown in the photo above or visible in the assembly photo below) to accommodate the turret lens of the camera projecting 0.050" beyond the end of the Olympus CLA-1 41mm-43mm adapter/extension tube for this camera. Since the step ending the 43mm female threads inside the Olympus tube was 0.115" deep, a total length of at least 0.165" (0.2" in practice) had to be relieved inside the threaded end of the adapter, with an inside diamter of 1.575" (40mm) to allow passage of the 1.45" dia extending lens turret.

This photo shows the completed assembly, consisting of the Olympus C-

4000 camera, Olympus CLA-1 adapter, and custom microscope adapter.



Most camera filter threads have a tiny 0.75mm spacing ("pitch"). This close-up photo shows a threaded section of the C-4000 adapter above. Threads cut properly on a lathe wiil have a smooth finish and correct profile. Good-quality threads attach easily to the camera lens, and ensure a secure attachment.

I usually design the threaded length to span about 1/4", which is about 8 to 10 fully threaded turns, like you see here. Full engagement to the camera lens typically requires only 2 or 3 careful turns. Should the initial threads of an adapter ever be damaged, such as by dropping it or accidentally cross-threading it into the lens, I can repair it on the lathe by simply facing off a bit of the threaded end, exposing new, undamaged threads at the adapter face.

This custom adapter connects the 37mm filter thread on the customer's camera to an American Optical (AO) inspection microscope 10X eyepiece having a 1.180" outside diameter. This adapter is a bit thin, but still strong enough for the mounting task. In cases where the camera threads happen to be smaller in diameter than the outside of the eyepiece, the adapter uses a shoulder to step up the body diameter and maintain strength.

This photo shows how the eyepiece joins precisely to the adapter with a slip fit. This provides an accurate axial alignment, which minimizes aberrations and distortions in the photo images. By having the customer send the actual eyepiece, a very close fit is guaranteed on the first try.

These slip fits are designed to be close enough for a "telescoping" fit between the eyepiece and the adapter, allowing an adjustable range of vertex distance. The adapter can be fixed on the eyepiece by assembling with a bit of tissue paper or other thin shim for a tight fit. Or, a bit of white glue or cyanoacrylate (CA) glue ("super glue") into the gap creates a semi-permanent attachment; since CA glue does not bond strongly to the oxidized aluminum surfaces of the adapter and eyepiece, the bond is more of a wedge casting than a true glued bond, and the pieces can be later separated and the glue cleaned off if needed. We can also add an optional 1/4"-20 threaded hole and nylon thumbscrew to the adapter as a clamp.

This custom adapter mounts a Nikon 4500 digital camera with 28mm threads to an Olympus SZ-CTV microscope adapter. The Olympus adapter provides a cylindrical slip fit with a thumbscrew.

This custom adapter mounts an Olympus C-750 digital camera (via the 55mm Olympus CLA-4 adapter tube) to a cylindrical microscope eyepiece.

Selecting a Camera for Digital Photomicrography

I've had inquiries about what "consumer" or "prosumer" digital cameras are good for adapting to photomicrography. Some criteria of desirability are:

- Accessory threads that permit flush mounting of an adapter (most cameras don't have them, or use some odd non-threaded coupling, or require an adapter tube for an extending turret).
- A non-extending lens turret.
- Optical dimensions close to the human eye, which will permit a direct optical path for through-the-eyepiece coupling. The "Ramdsen disc" produced by the microscope eyepiece is the circular field image formed some distance (the vertex or eye-relief distance) above the top of the eyepiece. A good microscope design forms a Ramdsen disc about the size of the pupil of the human observer's eye, and to avoid vignetting, the diaphragm of the camera must match this presumed pupil size, and the camera lens must be positionable within the eye-relief distance. If the optics are mismatched, the camera will see a vignetted image, either "too far" (the camera "sees" only the center of the field, because the eyepiece masks the edges) or "too close" (the camera can potentially "see" the whole field, but the image sensor crops the edges).
- Settings for manual (or at least fixed) focus, exposure, and zoom.

For laboratory use, it is often necessary to have direct PC control of the camera, and/or image transfer, via protocols over USB connections like PTP (Picture Transfer Protocol). See Figuière's excellent page on Digital Camera Support for UNIX, Linux and BSD.

If you are considering buying a camera for which you will want me to make you an adapter, send me a list of your candidate cameras with links to their accessory thread specifications, and I would be happy to reply with definite advice on what will work.

Links for Digital Photomicrography

- Gregor Overney's "Introduction to Digital Photomicrography".
- Steve Durr's Introduction to Photomicrography.
- Paul James' Mounting digicams with zoom lenses over the microscope.
- Paul James' High Eyepoint Oculars and the Digicam.
- Micrographia's tutorials on optical designs for microscopy.
- Barry Carter's Afocal Photography.
- The Molecular Expressions Web site.
- Modern Microscopy Web site. See the article on equivalency of digital camera photomicroscopy to Polaroid 4x5 film, "Array Size Needed to Replace Photomicrographs on Film", by Ted Clarke. Also his article, "Fitting a Student Microscope with a Consumer Digital Camera" [PDF file].
- Ching-Kuang Shene's discussion of digital camera lens threads and adapters, particularly in regard to the Nikon Coolpix 4500. Also his page Nikon Coolpix 5700 adapters, which illustrates some potential problems with cameras having extending-turret lenses. Both of these are parts of his digital camera page.
- Giorgio Carboni's Pictures and Movies with the Microscope.
- Edmund Industrial Optics.

Have a comment or question about my digital camera microscope adapter project? About digital photomicrography?
Want to purchase a custom-made adapter?
Email me at:
kinch@truetex.com
Richard J. Kinch
Back to Machine Shop page
Back to Home page