Afocal Photography

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Digital camera photography is still evolving, albeit rapidly. The situation is akin to 35mm photography in the 1930 - 1940's time frame, when camera lenses were not removable. In order to take a picture through a telescope or microscope, the concept of "Afocal Photography" emerged. In this case the user will focus (20 - 20 corrected if required) the telescope to get the image. The camera will be independently set at infinity focus, so that when both the camera and telescope are coupled, one can take a picture. The "Real" image for the camera is the "Virtual" image projected by the telescope eyepiece. Results are best confirmed by using the Liquid Crystal Display (LCD) screen at the rear of most digital camera's. The Equivalent Focal Length (EFL) is given by:

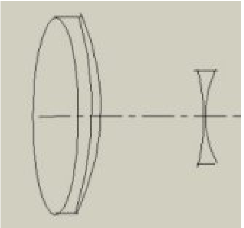
EFL = Telescope (microscope) Power x Camera Focal Length

f / ratio = EFL / Aperture of telescope

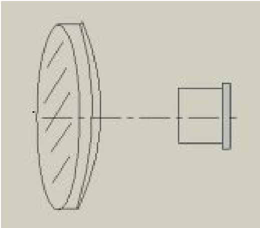
In order to minimize vignetting, the camera should always be set a full zoom (for the Olympus C2000/C2020/C3040 this is 105mm). The Afocal hookup is rather easy. In fact some users have handheld the camera up to the eyepiece when the shutter speed is rather fast. The Olympus camera's have a remote control, so handholding is feasible.

Afocal Types

Any system that provides a virtual image of parallel light rays can be photographed afocally with a digital camera. This includes binoculars, spotting scopes, telescopes, and microscopes. Most of the low power (< 3x) commercial teleconverters, are really small Galilean telescopes, consisting of a positive achromat and a concave rear element. These devices are easily made using surplus optics and PVC plumbing fixtures.

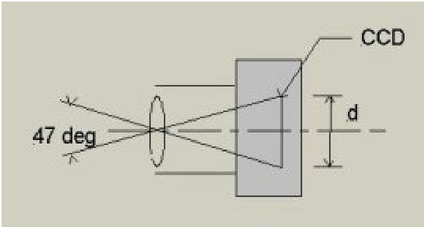


The teleconverter magnification consists of dividing the focal length of the achromat by the focal length of the negative rear element. the galilean (named after the astronomer Galileo Galilei) is a negative afocal system (because the image is virtual and projected between the lense elements), and produces an erect image. A positive afocal system covers those designs that produce a projected image outside the system (e.g. telescopes, binoculars). One of the easier ways of making an afocal system is by coupling an eyepiece to any of the those 35mm SLR (or photo enlarging or copy lenses) lying around. Typically, a 135mm telephoto lens and a 25mm eyepiece will provide a 5.4x telescope. The following diagram shows a method than can be used to couple T-mount telephoto lens to an Olympus C2000 - C3040 digital camera, with some of the components available from Edmund Industrial Optics (e.g. extension tube, , eyepiece adapter):

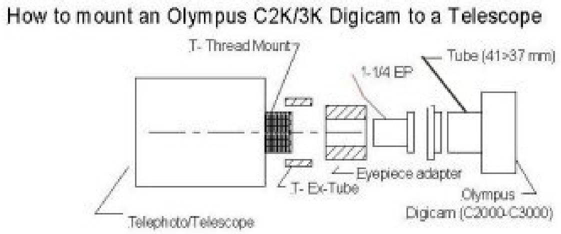


Angle of View

Lenses are designed to cover the area (diagonal) of a specific film (or CCD element) type. The field angle (FA) of a "normal" 35mm still camera is 47 degrees; corresponding to a lens focal length of approximately 50mm. Most camera makers use the 35mm FA to compute the focal length of lenses for a digital camera. Thus a 1/2 inch CCD (8mm diagonal) digital camera would have a "normal" lens focal length of:



FL = (d/2) / TAN 23.5 degrees for 1/2 inch CCD
FL= 4 / TAN 23.5 = 9.2 mm



Most digital camera's have a zoom lens, so FA is variable. For example, on the Olympus C2000 digital camera, the lens FL range is 6.5 to 19.5mm (equivalent to 35 to 105mm on a 35mm camera). This variable field angle can cause a loss of light when attaching lenses afocally; a phenomenon called vignetting.

Vignetting Issue

If one understands angle of view, then the vignetting issue and causes will be easier to comprehend. Vignetting is the failure of the image to fully illuminate the area of the film or CCD element when small telescopes are added to a digital camera. Most of these lenses were designed for video camera's, which typically have 1/4 to 1/3 inch CCD elements. The lenses for these CCDs are designed with a smaller FA in mind, and the result is some vignetting. The photo on the left illustrates vignetting. Even at full 3x zoom, this vignetting results, because the teleconverter lens was designed for an 8mm Sony video camera. But for digital camera's with a zoom lens, the effect can be minimized as the FA can be adjusted to lessen any illumination loss. When eyepieces are used with positive afocal systems, the selected eyepiece should have long eye relief (> 15mm) and an apparent field (> 47 degrees). Some other ways to reduce vignetting is to insure the camera is mechanically coupled to the telescope to avoid misalignment, and adhering to the following:

- **Use an eyepiece with long eye relief.**
- **Couple the end of the camera lens as close as possible to the eye lens of the telescope eyepiece.**
- **Set the digital camera at macro mode rather than infinity.**
- **Use digital camera at full optical zoom.**
- **Purchase lenses specifically designed for the type of digital camera used.**
- **If possible, use a camera lens with a focal length longer than the eyepiece focal length.**

More Afocal Calculations

In astronomy, one always want to know how "fast" the optics are; especially if deep sky astrophotography is of interest. Suprisingly, some digital camera's make this kind of picture taking feasible, even without the long exposures attainable using film. The speed of the system is represented by the f / ratio:

f / = TELESCOPE POWER per inch of aperture X CAMERA FOCAL LENGTH

PROJECTION MAGNIFICATION (PM) = CAMERA FL / EYEPIECE FL

EFL = FL of TELESCOPE X PM

f / = f / TELESCOPE OBJ X PM

For example, using a popular 8 inch (203 mm), f/10, FL = 2000 mm, Schmidt Cassegrain Telescope, coupled to a Olympus C3030 digital camera (zoom range of 6.5 to 19.5mm), and a 25 mm eyepiece, we have:

f / ratio = f / 10 x PM = f / 10 x 19.5/25 = f / 7.8

Thus a digital camera can serve as focal reducer of sorts.

Eyepieces Matter

Unlike direct projection (used when camera lens is removable), afocal projection requires an eyepiece to provide a virtual image to the digital camera. Since there are a plethora of eyepieces, how does one decide which is best for afocal imaging? Well, the quickest and most direct way is ask others who have been there. It seems that most concerns are with vignetting (although that should be a lesser concern for planetary imagers). Vignetting has many faces, so each camera and eyepiece combination can produce different results. The only way to minimize or eliminate the vignetting is to use an eyepiece where the apparent field of the eyepiece matches that of the camera. If the field is too large or small, or the coupling is mis-matched, vignetting will likely occur. This problem has not gone un-noticed, thus a line of eyepieces have been developed to deal with this issue. Unfortunately, the primary recipients are Nikon Coolpix (e.g. 950, 995, 4500) and Olympus (those that take the CLA-1 43mm adapters) digital cameras. The eyepieces from Scopetronix and Williams Optics (WO) can screw directly into the filter threads of these camera's. The WO DCL-28 (24mm), Scopetronix 18mm, and WO DCL-4337 40mm are illustrated. The common design feature to notice is the larger the camera lens, the bigger the EP eyelens. Note: the WO 40mm has both 43mm and 37mm threads, so it is a good choice for use with camcorders (higher magnifications can be obtained by using an appropiate barlow lens.

Make Your Own Afocal Adapters

For under $500, one can own a lathe that will allow making your own camera couplers and adapters. In the life of an amateur astronomer, the camera and telescope can have many faces. If you are serious about astro-photography, the lathe will pay for itself posthaste. Classically, astronomical observatories included a machine shop, because some thingy was always required to mate this to that. For the amateur astronomer, the same thing applies. There is no need to spend hundreds of dollars on adapters, when they can be made for a fraction of that amount. The lathe shown below sells for about $450. This lathe can be used on wood, metals, and plastics; and it also cuts screw threads.

Sources for Hookup Stuff

The following sources have the hardware to make the above discussions reality:

- Mounting accessories, T-adapters, Projection Adapters.
- Adapter tubes, Lenses, Monoculars.
- Adapter tubes, Step Rings, Filters.
- Everything and more for the mini-lathe user.
- Digital Camera Stuff for Astronomers.
- Digital Camera adapter Tubes, Helical focusers, converter rings, Borg telescopes.
- Mother of Digital Camera Links.
- Teleconverters and a cornucopia of items for afocaling!
- Teleconverters and Accessories for Digital Cameras.