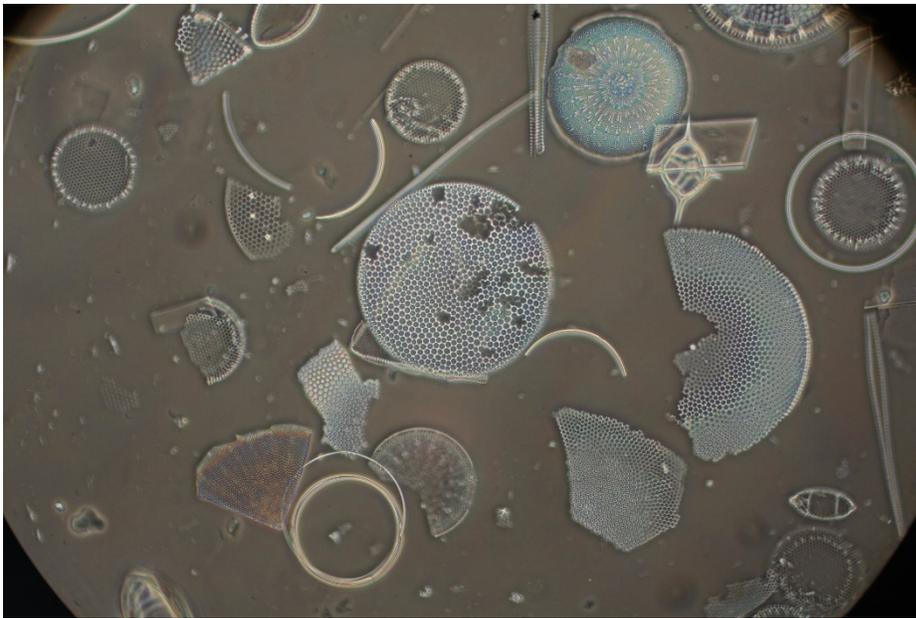


Using a Canon EOS M50 as a Dedicated, Afocal, Microscope Camera

Steve Neeley (USA)

From [Wikipedia](#): “Afocal photography, also called afocal imaging or afocal projection, is a method of photography where the camera with its lens attached is mounted over the eyepiece of another image forming system such as an optical telescope or optical microscope, with the camera lens taking the place of the human eye.”

Except for a very few hours experimenting with a borrowed Canon 40D back in 2011, I had no experience with coupling and using a camera with my Leitz Ortholux I microscope. But I was able to get surprisingly good coverage of its sensor – which was encouraging.



Above: Phase Contrast Image of a diatom strew slide from experiments with a Canon 40D in 2011.

Recently, in trying to rekindle and expand my hobby, I [bought](#) my own camera -- a Canon M50 -- to use as a dedicated microscope camera. This article shares my experience in coupling and using the M50 on the Ortholux.

Disclaimer. As a colleague often says, “I’m not buying or selling here” – meaning, in this case, that I did earnest, but certainly spotty, research before buying the M50, and it was only after I had it in hand and could work with it on the scope, that I finally understood some things, as in ‘Oh! NOW I understand.” I bought what I could afford, not what was the absolute best solution for my priorities. Not ‘selling’ you on the M50 – you might find something better.

Priorities

1. To share my hobby in 'live view', on screen, with family so they do not need to use the eyepieces (this is especially hard for children). There is a little 'betting on the come' here, as in "["If you build it, they will come"](#)"?
 - a. Also, I wanted the choice to use the screen instead of the eyepieces – these eyes are getting older.
2. To have a way of documenting my observations.
3. To share images with other hobbyists.

Disclaimer: I do not aspire to 'professional quality' or 'highest resolution'. I do admire the work of those who do, however. I am not a photographer and I do not want to be one. My iPhone takes more than good enough pictures, but I manage to mess them up anyway. Not a particularly good microscope hobbyist either, for that matter, but I enjoy it.

Why the M50?

Other than being in my price-range, it is newer than some alternatives (The M50 came on the market in 2018). And, like the 40D back in 2011, Canon offers and supports 'live view' software – on the PC, Mac, as well as mobile devices. [LMScope](#) suggests the M50 for use with their custom adapters. [Martin Microscope](#) recommends the similar, but older, Canon EOS T7i for use with their custom adapters.

I have no brand loyalty to Canon, but their remote viewing/control software was their biggest selling point for me.

The Ortholux I

The Ortholux uses Leitz Periplan eyepieces (i.e. compensating) for final image correction. Neither of the two commercial offerings linked above, for example, would keep Periplans as part of the solution. I sought a solution where the Periplans are in place, doing their job, and there are at least two available to me:

1. **Afocal**, with the camera lens in position and taking the place of the human eye. This is the method I experimented with in 2011.
2. **Projection**, with camera body only, enabled by pulling, and securing, the *normal* eyepiece (not a projection eyepiece) slightly out of the trinoc tube to project a real image onto the camera sensor. Charles Krebs explains this method expertly, especially [here](#) (i.e. Step 1-B), but also [here](#).

I wanted to go with solution #1 unless it proved unworkable with the supplied ‘kit’ camera lens, and if it did, I would pursue solution #2. As you can tell from the title of this article, I did not have to.

I have Periplan 12.5x eyepieces in the binoc tubes – I find them easier on aging eyes than the 10x eyepieces I used a few years ago. But I can place any of the following ‘extra’ eyepieces in the trinoc tube to be part of either solution #1 or #2.

Note: the data is from Leitz/Leica catalogs and the notation on the eyepieces themselves. Data in blue are estimates guesses.

Periplan Eyepiece Type	Field of View Index	Angle of View
Leitz 6x	19.5	22 deg.
Leitz 8x	16	33 deg.
Leitz 10x	18	40 deg.
<i>Leica** 10x high-eyepoint</i>	18	40 deg.
Leitz 12.5x	18	48 deg.

*** The Leica is a genuine Periplan from the late 1990’s when Leitz became Leica.*

Charles Krebs writes that for solution #2, those lower power eyepieces would prove valuable, while my 2011 experience showed that a 10x should work for solution #1.

My Ortholux sits on a period-authentic, Leitz ‘ARISTOPHOT’ stand and the camera is secured to the stand’s mounting bracket with a [Manfrotto 454 Micrometric Positioning Plate](#) I bought long ago. I used what I had on hand. The camera and lens are so lightweight that many options should work in positioning and holding the camera over the microscope. Despite the apparent sophistication of the stand and the positioning plate, I use a simple [tool-box level](#) to ‘check’ them into all being straight.

Of note for photography: I have always used an 80B daylight filter over the light-port of the Ortholux to correct to daylight, or at least to supply a more pleasing background to my eyes. The new camera may not need it, but I do.



Above: Afocal is just a camera suspended over a microscope. Not much to see here, folks . . . moving on.

The M50 Camera:

The lens supplied with the M50 'kit' – an [EOS M50 EF-M 15-45mm IS STM](#) lens – has a [35mm-equivalent](#) of 24-72mm. [A review](#) notes that the diffraction limit (i.e. DLA) of the M50 is f/6.0 and so even at max zoom with this lens (i.e. f/6.3) it is not past the DLA of the camera and thus in the area of danger for soft images and 'empty magnification'.

See [here](#) for details, but some basics that might matter on top of the microscope are:

- 24.1-megapixel¹ APS-C size CMOS [sensor](#).
- It is mirrorless, ridiculously small, and light! Body only: 13.7 oz (387g). Body + the standard, supplied lens: 18.29 oz (517 g).

¹ On-line camera stores are taking pre-orders for the next generation cameras . . . with 60MP chips and 8K video!

- Its 3.0" articulating touchscreen LCD monitor can orient to face the microscope user.
- Built-in Wi-Fi, and Bluetooth, and both HDMI and USB ports for wired connection.
- It can record video in 1080p or 4K (albeit with a 0.71x crop).

I have continuous A/C power to the camera via a [power adapter and coupler](#) that replaces the battery in the battery compartment of the M50.

A big worry, that I could not lay to rest until I had the camera ‘in hand’, was that the design of the lens might make it impossible to optically couple eyepiece to camera. Quoting Dave Jackson (from page AI-62, Better Microscopy, Vol III, Digital Photo-Microscopy):

“With many SLR lenses, this (i.e. the ‘entrance pupil’ of the camera lens) will be a short distance in front of the first element of the lens. However, in some cases, the desired point will lie somewhere within the lens. (Lenses of this latter type are much less desirable for “Afocal Coupling” use, and in some cases, they may be entirely unusable).”

Solution # 1 considerations

Page AI-61 of Dave Jackson’s book is helpful. He writes:

“There are two key requirements to make this coupling method work well:

- 1. The ‘eyepoint’ of the eyepiece must intersect the ‘entrance’ pupil of the camera lens*
- 2. The ‘Angle-of-view’ of the camera must be somewhat smaller than that of the eyepiece”*

Then he lays this out in a table, part of which I reproduced here (*the coloring is mine*):

Microscope Eyepieces				35mm SLR Camera Lenses	
Mag.	Field	Angle	Max Rec*	Focal Length	Angle
12.5x	18mm	52 deg.	42 deg.	60mm	42 deg.
10x	18mm	40 deg.	32 deg.	70mm	32 deg.
8x	18mm	33 deg.	24 deg.	105mm	24 deg.

6x	18mm	25 deg.	20 deg.	135mm	18 deg.
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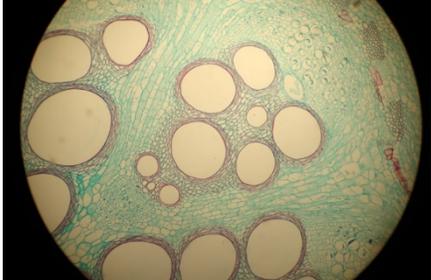
* Max Rec = Maximum Recommended, which results in 75 – 80% image coverage and no vignetting².

Note the figures in green. What this means is that the M50’s kit lens (i.e. which has a 35mm-equivalent of 24-72mm) should be adequate to use with the 10x and 12.5x eyepieces. That 8x eyepiece yields beautiful, crisp images. But per Dave’s table, If the goal is -zero- vignetting, I would need another camera lens with greater zoom (which I do not have).

For Solution #1 to work, the top of the microscope eyepiece and camera lens must be close to make a good coupling. Because of this, immediately on taking delivery of the new camera I mounted the kit lens and screwed on the provided UV filter. Not as a dust screen – although it is that – but more as a ‘this far and no more’ barrier to protect the camera lens from ~~erashes~~ mistakes I might make in positioning.

Results:

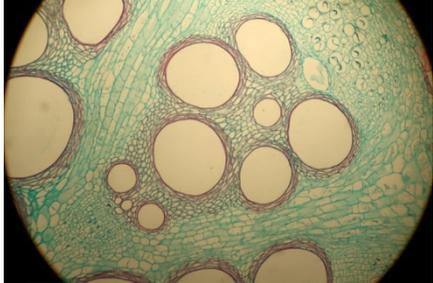
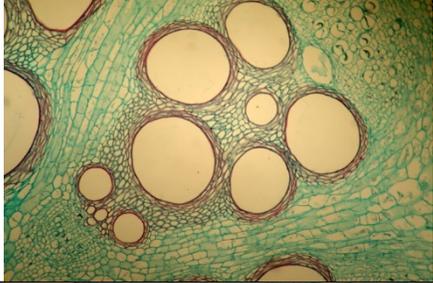
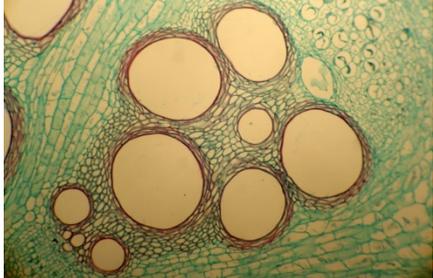
As expected from Dave Jackson’s table:

Eyepiece	Result	Comment
6x		Cannot fill the sensor @ 45mm max zoom.

² Dave also notes that there are two kinds of vignetting, and both can occur separately, or together (from page AI-41):

“Symptoms and Causes of ‘Vignetting’ Problems

- *When true ‘vignetting’ occurs, due to a spacing error between eyepoint and the camera lens, the effect usually shows a “ragged” (poorly-defined) black edge around the desired image. Also, the actual image will cover less of the object than expected.*
- *When the effect is due to the “angle-of-view” problem, the black edge is actually the Field Stop of the eyepiece and therefore is often sharply defined. Also, the full image of the object is seen (plus . . .).*
- *When both problems exist at the same time, it is often due to using a “zoom” type camera lens, usually set to too short a focal length.”*

8x		Closer to filling the sensor @ 45mm max zoom.
10x & 10x high-eyepoint		Full coverage @ 45mm max zoom.
12.5x		Full coverage @ <45mm max zoom.

Note: The slide used here is 'The Stem of a Pumpkin' from the DIY-Science set – see below in 'Test Slides'.

Decision: I went with the 8x.

“What!” you say. There is vignetting! And not minor either. But for me the field of view I have here matches most closely what I see through the 12.5x eyepieces in the binoc tubes -- and I sort of like seeing the field stop (Just like I do through the binoc eyepieces).

Still focused on priority #1 . . . and wasting sensor pixels . . . *sigh*.

So, yes, 8x is a better ‘live viewing’ set-up to my tastes, but 10x (or 12.5x) is better to get full resolution from the camera for photos and videos. Happily, I can swap in the 10x (or the 12.5x) quite easily.

Note: In ‘best set-up’, the 8x has slightly less than 2mm separating it from the UV filter of the camera lens. The 10x high-eyepoint offers a more breathable 5mm. A consequence of this is that you really do not need bellows or light barriers of any kind as light leakage through the ‘gap’ is not a problem.

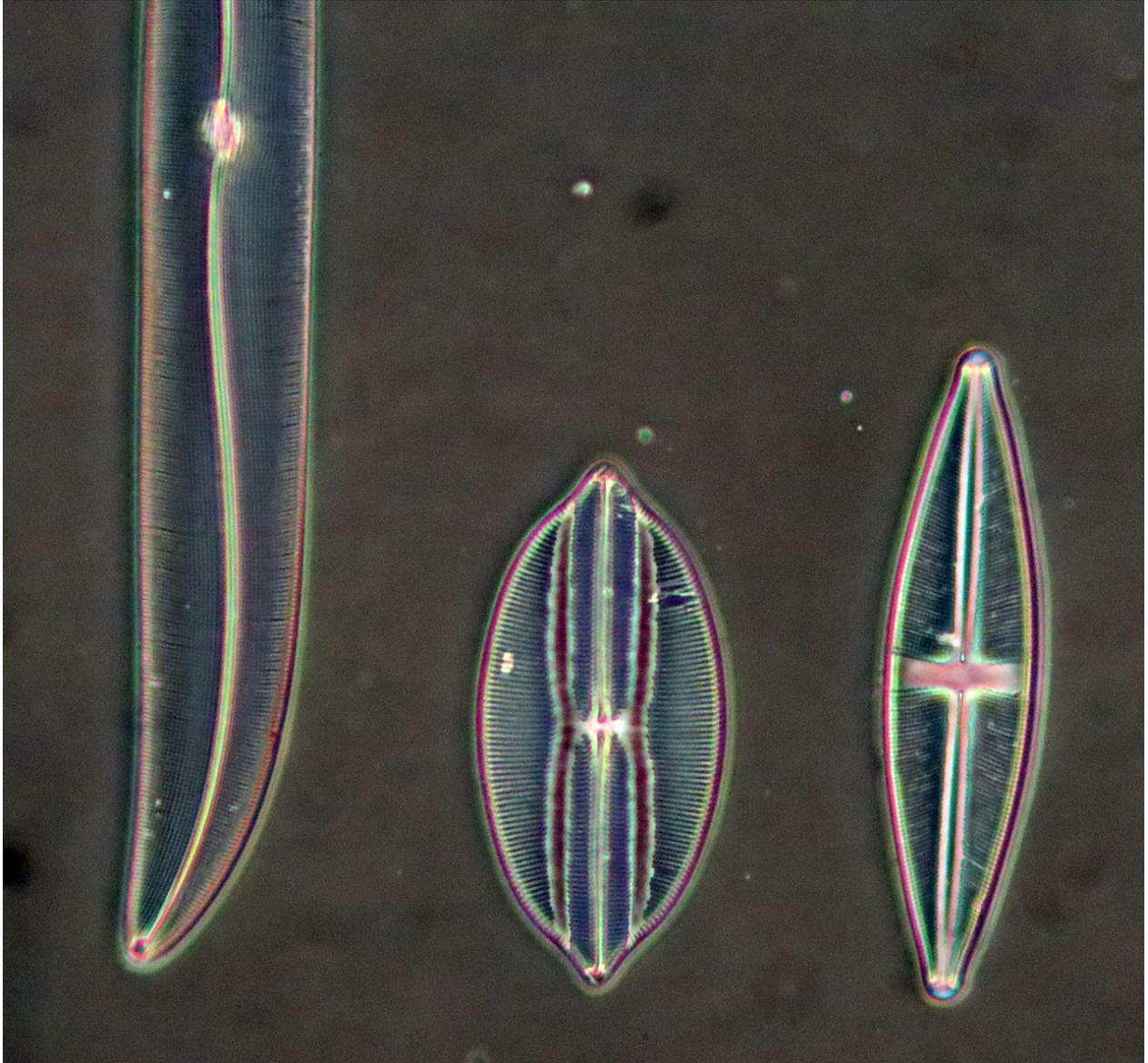
Test Slides

I am a 'pond water' hobbyist³ and spend my time at the scope in Phase or DF, rather than BF. But pond-water specimens are changelings -- will-o-the-wisps -- and for my own sanity I need permanence and reproducibility when testing microscope optics. For this I have a [Klaus Kemp 8-form slide](#), as do many hobbyists. I also have some inexpensive, commercially prepared slides from [DIY-Science](#) with stained specimens with reds, blues, and greens.

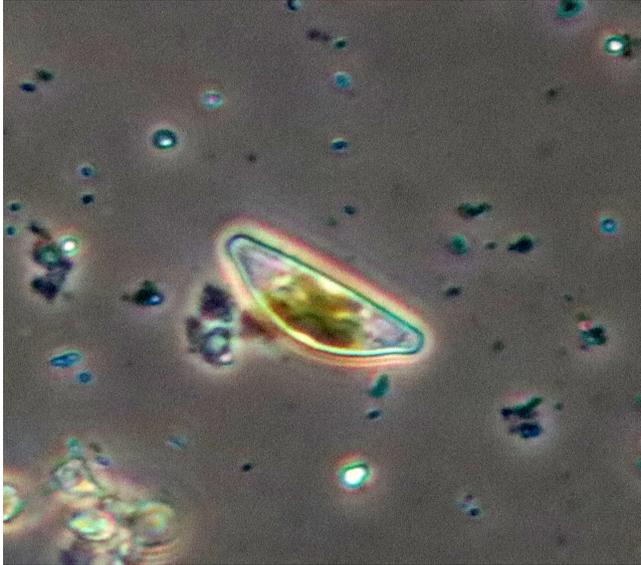
These are never changing slides that I am familiar with and after examining them on the stage and reviewing the camera images, I was pleased with results. I felt the color handling was fine (as compared to what I see through the binoc eyepieces) and the resolution of the Klaus Kemp diatoms was good (Remember my disclaimer above: I am not a photographer, nor am I a very good microscope hobbyist).

Below: Klaus Kemp Diatoms; Phase Contrast; 8x eyepiece, 40x objective; Photoshop's Auto-Contrast applied.

³ Which means that I never use the 100x Oel objective, and 40x? Not all that often. I usually have 6.3x, 10x, 16x, 25x, and 40x objectives mounted in the nosepiece, and when you apply the 1.25x magnification added by the Ortholux head, these end up spanning (i.e. with the 12.5x eyepieces) 100x – 625x.



Below: A living diatom, [Cymbella](#)? Phase Contrast; Photoshop's Auto-Contrast applied.



Practicalities

Standard set-up: The zoom ring of the kit lens has markings for 15, 18, 24, 28, 35, and 45mm – and no markings in between. If your chosen zoom setting is one of these, fine. If not, and you want to always keep the same zoom setting (e.g. you want to use standard scale bars for your photos), you are going to have to set it at the exact same zoom setting each time and keep it there. A way of doing this is to determine your chosen setting and then place a white tape arrow on the lens housing opposite one of the markings above. That way you can ‘check and correct’ back to standard as needed.

Finding Not Finding infinity: Technically, afocal requires that the lens be focused at infinity. Yet, there is no infinity setting on this kit lens. I guess that this is quite common for lenses made for newer cameras that have sophisticated auto-focus features and the M50 certainly has that. [“Who Killed Infinity Focus?”](#) opines one author. My experiments with the kit lens show that ‘focusing on the moon’ and then marking ‘that spot’ doesn’t work well – the infinity point is different at different zooms and sometimes even at different points between power-down and power-up it seems. Astronomy hobbyists [struggle](#) with this much more than we have to.

Bottom line: Do not worry about it.

If your eyepieces –those in the binoc tubes and the one in the trinoc tube -- are parfocal, and you have live-view enabled (see below), you have what you need. First, focus through the binoc eyepieces. Then with manual focus (note: I always keep the camera on manual focus⁴) use the

⁴ Dave Jackson writes (page All-5) “. . . this (i.e. Autofocus) may work splendidly in normal picture-taking situations (where light is reflected off the subject), it can easily lead to false focus settings in photo-microscopy (where the subject is typically strongly ‘back-lit’). Because the contrast details within an object are usually lower than the contrast between the object and the background illumination, most cameras will optimize the latter, and the expense of the former(desired) condition.

focus ring to ‘dial in’ the best focus as viewed on your ‘live view’ device(s). Do this just once a session -- the M50’s digital zoom (i.e. 5x, 10x) helps a lot here. I do not keep checking back as long as I do not bump the focus ring. From that point on, drive focus on the sensor with the fine focus of the microscope.

Magnification

It seems a simple topic, but one I had never thought about before having actual ‘live view’ on a monitor: People viewing the monitor image ask about magnification (e.g. “Grandpa, what power is your microscope?”).

What do you say? For photos you avoid the question by including a scale bar. But in monitor viewing the best you can do, I think, is just to reply with the normal, expected optical magnification.

Example: $8x \text{ eyepiece in the trinoc tube} * 1.25x \text{ Ortholux tube mag} * 10x \text{ objective} = 100x$.

For this same example, If I use a micrometer slide as a specimen and measure the magnification right there on the screen with a ruler, I find a .1mm length becomes 40mm which means it is 400x! That objective’s N.A. is 0.30 and so I certainly do not have 400x of detail there. But I suppose that is not what they are really asking. They are looking at the monitor image as if it were a view down the binoc tubes of the scope, and with the outline of the eyepiece field stop showing in the image (like I have with the 8x eyepiece), that point-of-view becomes even more natural.

Camera Set-up

The [manual](#) supplied with the M50 explains the setting options fairly well, and there are web resources available like the one [here](#). I also bought EOS Magazine’s guide ‘[Understanding the EOS M50](#)’ so I would understand a little better and avoid making a misstep, or very many at least. This was all new to me.

You may not care unless you too have an M50 or similar camera, but just for completeness, here are the important settings for use over the microscope:

Menu and Page	Setting	Suggested Choice	Comments
	Camera Mode	‘P’ – Program Mode	Set this with the ‘Mode Dial’ on top of the camera
Camera / 1	Image Review	Off	
Camera / 6	AF operation	One Shot AF	
Camera / 6	AF method	[] – Zone AF	
Camera / 6	Continuous AF	Disable	
Camera / 6	Focus Mode	MF	Manual Focus.

Camera / 6	AF-assist beam firing	Off	
Camera / 8	Sound Recording	Disable, unless you want to do commentary on your videos	
Utility / 2	Eco mode	Off	If you have continuous A/C power.
Utility / 2	Power saving	Disable, set to max 30min for 'Display off'	If you have continuous A/C power.
Utility / 5 Custom Functions (C.Fn)	Retract lens on power off	Disable	You want the lens to stay put!

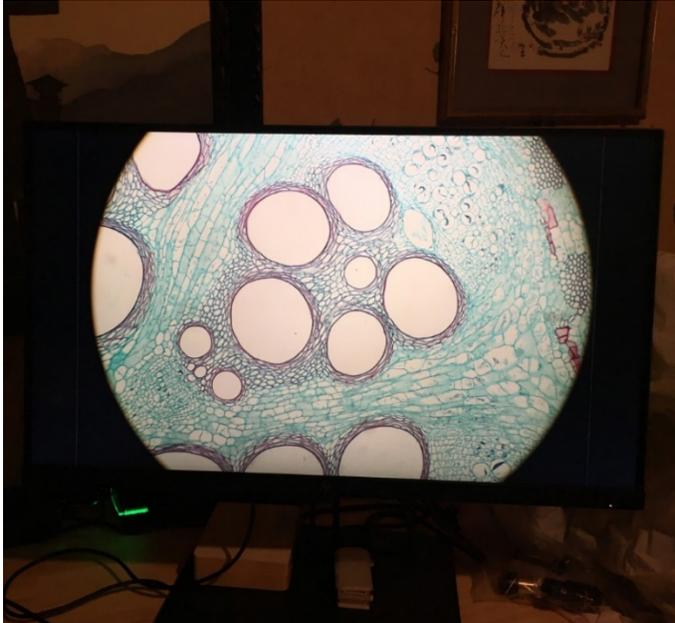
Camera 'Live Viewing'

You do not need a PC/Mac or a mobile device to see the image on the sensor. The M50's LCD monitor can be angled towards the microscope user giving a 1MP view of the sensor image.



Above: The 3" LCD monitor angled towards the microscope user.

Alternately, you can use the [micro- HDMI](#) port to feed a TV or monitor with a 2MP⁵ view of the sensor image. If you do this the camera turns off the LCD monitor.



Above: A stand-alone monitor showing the M50's HDMI 'feed'.

If you want to remote control the camera and see a 2nd 'live view' image on your device – and you do! -- Canon offers:

- ['EOS Utility'](#) (and a companion piece called ['Image Transfer Utility'](#)) for PC/Mac.
- ['Camera Connect'](#) for mobile devices.

Tethering can be via Bluetooth, Wi-Fi, or [micro-B USB port](#) cable.

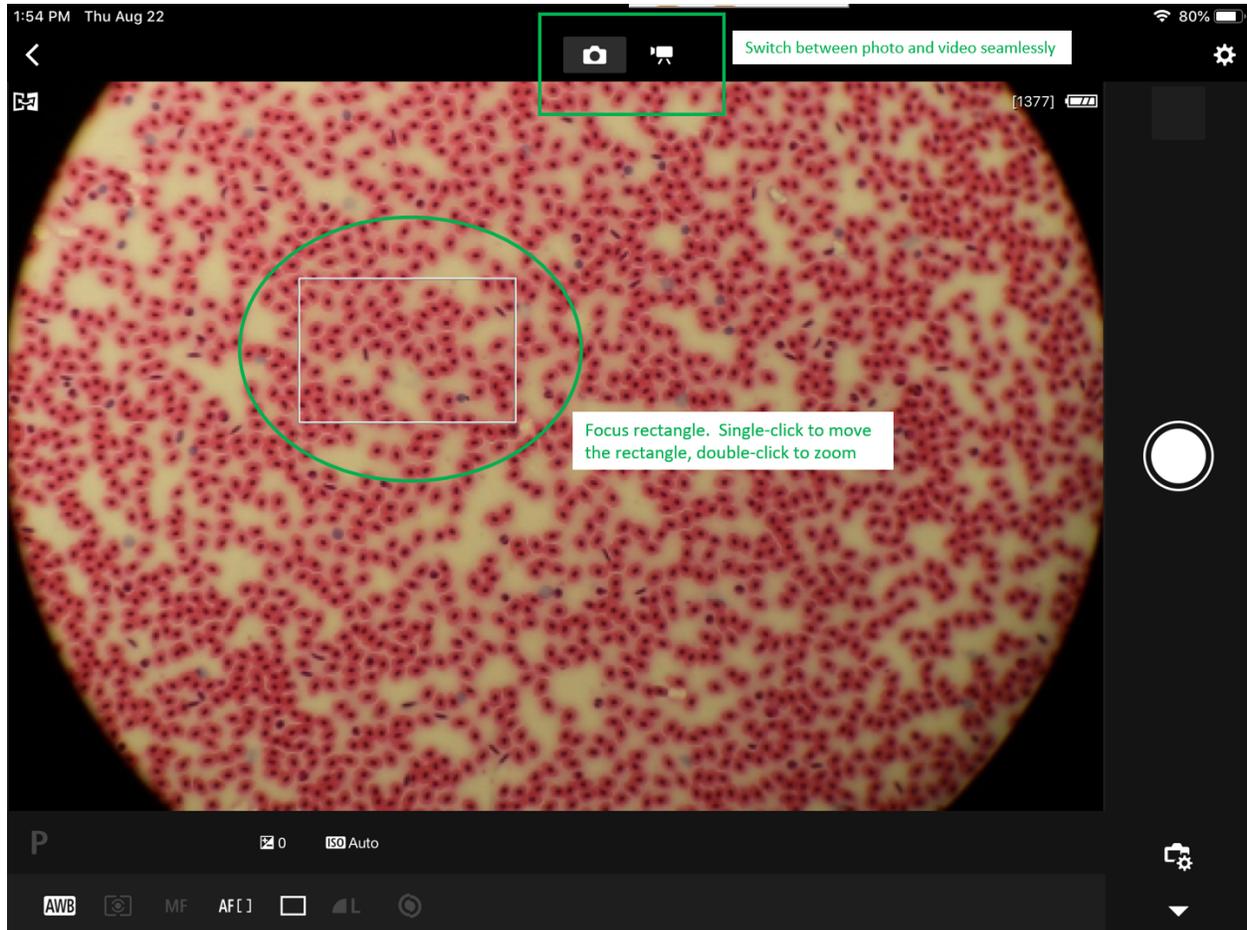
'EOS Utility' seems offers more 'bells and whistles' than 'Camera Connect' for general photography, but for the microscope hobbyist both offer all you need:

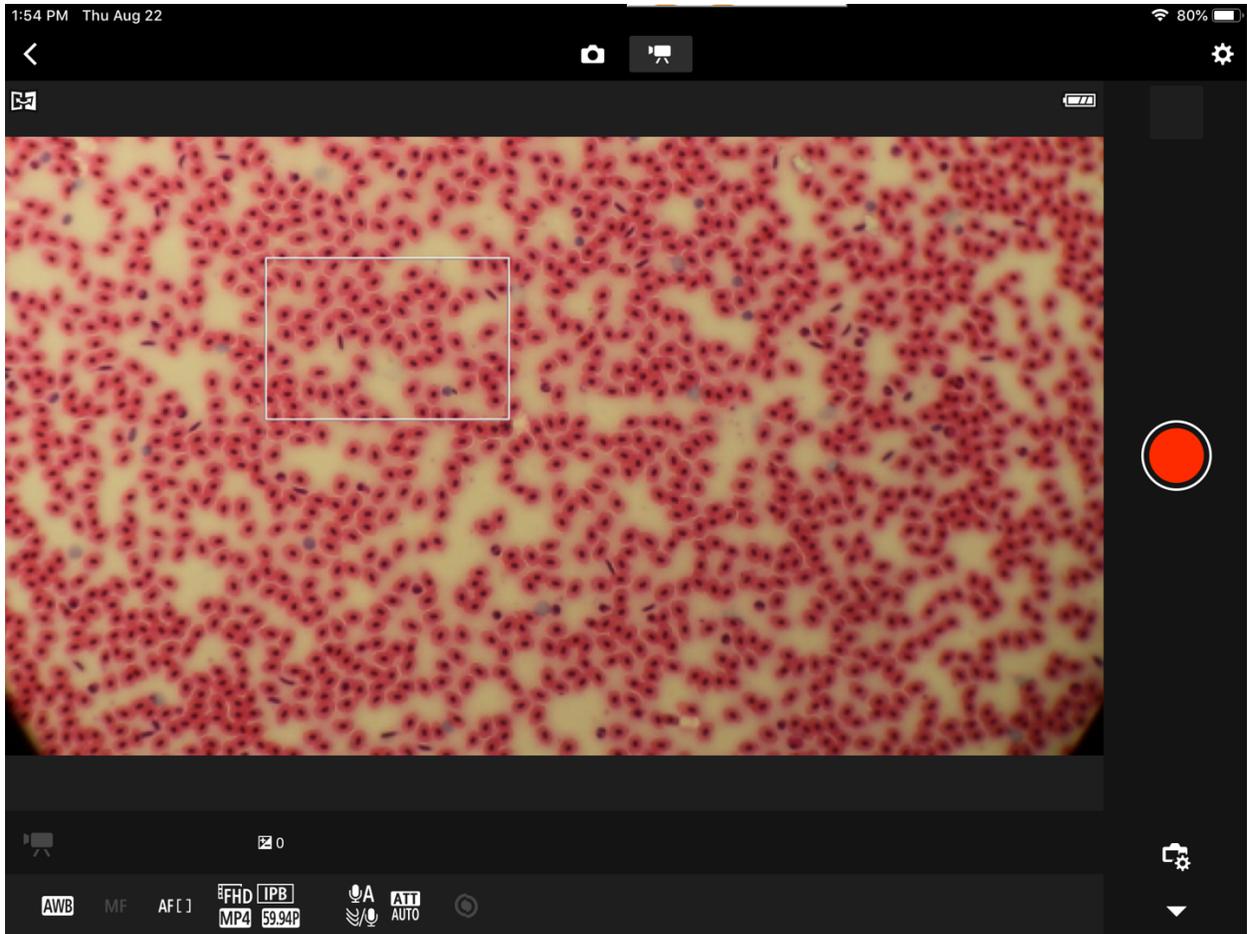
- Take a camera shot with a click of a button.
 - The photo (or video) is stored on the camera's memory card but can easily be transferred to your mobile device.
- Start/Stop a video with the click of a button.

5 i.e. 1080p – The M50 does not support 4K 'live view'. But Canon tech support did reply to my questions as follows: "With the EOS Utility the resolution depends on your screen and how large you have the window. If you are doing 4K recording through the USB to the EOS Utility the live view screen can match a 4K display if it is full screened. Depending on the computer you may see stuttering displaying it at that resolution."

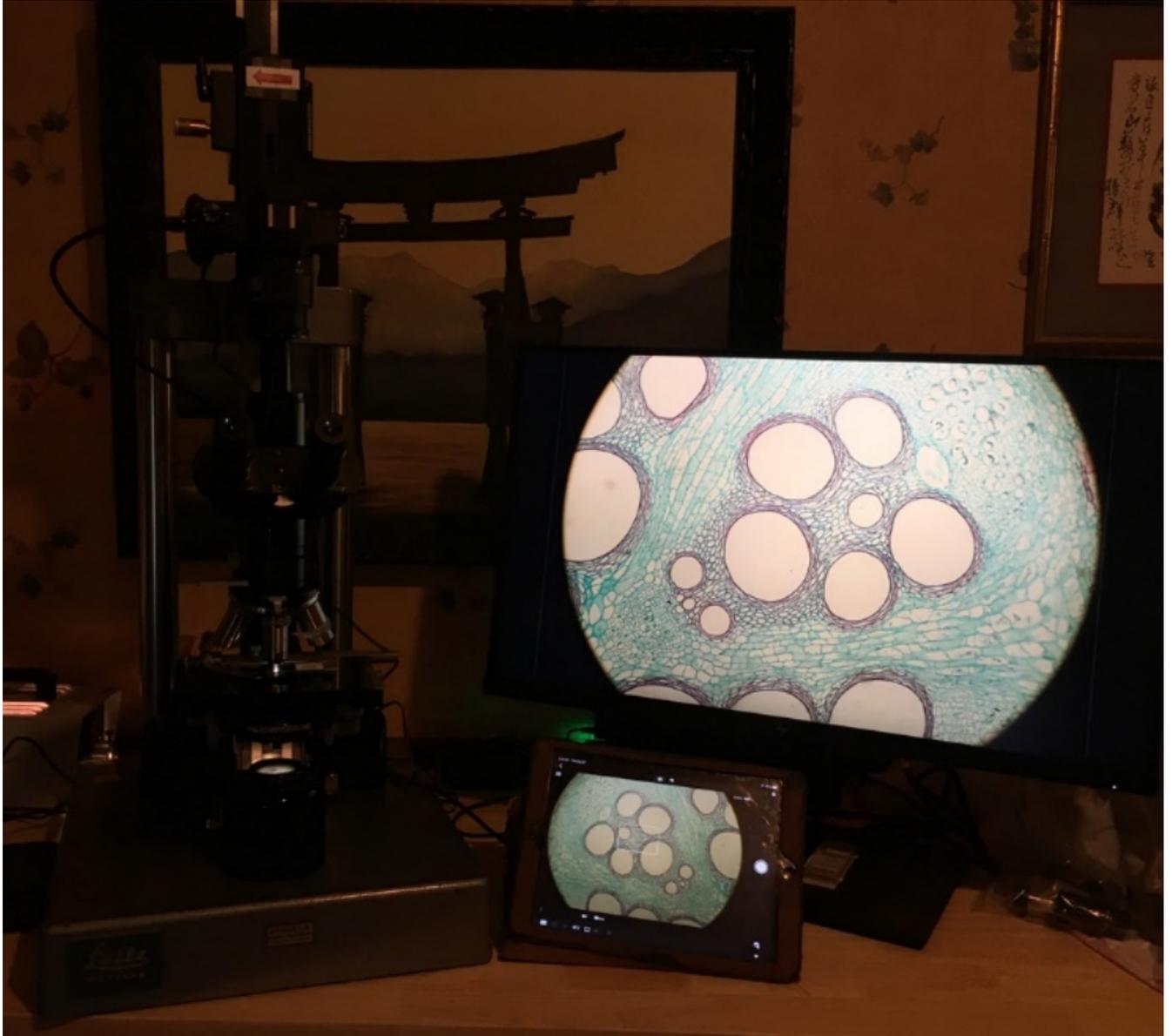
- And, YES! . . . you can switch back and forth easily from photo to video mode, and back to photo mode, very quickly, and without touching the camera.
- You can also change the quality of the video setting – FHD vs. 4K, fps, etc.
- Digitally zoom into a part of the image (e.g. for fine focusing, or just to see something a little bigger).
- View the photos stored on the M50's chip and transfer to your device as needed (You can also delete unwanted photos/videos on the camera from your device).

Below: 'Camera Connect's Photo and Video screens. The 'Frogs Blood' slide is from the DIY-Science set.





Below: I use 'Camera Connect' on an iPad Air via Bluetooth and feed HDMI from the camera to a monitor.



Final Comments

Yes, it works well for me. But I would love to stream 'live view' 4K. The monitor sitting beside the Ortholux does 4K, yet the M50 only streams 1080p. Give it a couple of years. Right now, a camera that streams 4K in 'live view' is beyond my budget.



Above: Worm; DF; 8x eyepiece, 6.5x objective.

End Notes

The M50 's 'Power Saving' menu setting has a 'Display off' value you can set. If you set it to the max -- 30 minutes – it means that your display will go to sleep after 30 minutes of inactivity. If 'sleep' happens, just reach up and turn the main dial (around the shutter button) or half-depress the shutter button, or something as innocuous. That wakes it up. It would be better if the camera had a 'disable' mode for this setting, but it does not. This is to protect the sensor?

Canon has done an excellent job with connectivity and I had no trouble tethering through Bluetooth or Wi-Fi (and of course, USB cable worked well). The camera menuing system walks you through this so I do not think it will be a challenge for you.

In Bluetooth, as well as Wi-Fi, there is noticeable lag (latency) in the live view image. You refocus, or move the slide, and there is lag in response on your device – not unworkable, but noticeable. BUT there is no latency in shot taking (pushing the shutter release) or video

capturing. Watch your camera LCD monitor, or external TV/monitor, while you take a shot or video if the latency bothers you (there is no latency there).

A single tap on the screen of your mobile device moves the focus rectangle to the tapped position. A double tap anywhere on the screen, optically zooms into that rectangle. You can turn the M50's main dial (i.e. the dial around the shutter button) to switch between 5x and 10x zoom as you need.

'EOS Utility' has the annoying habit of hiding the actual 'take the shot' screen behind the 'live view' screen. Usually you can get them to sit side-by-side. If you lose the 'shot screen', the alt-tab keystroke combination is your friend. 'Camera Connect' for mobile devices does not separate the two screens, so that is not a problem.

The 'live view' image will be necessarily a 180-degree rotation of your view through the eyepieces. After all, the M50 is 180-degrees rotated as it looks down the trinoc tube. But if you look closely in the photo (above) you'll see that the iPad is showing a 180-degree rotated and mirrored image. My iPhone does not do this. So, it must be some setting on the iPad that I haven't discovered yet? It's not a problem, but I thought I would note it here.

Obvious, but . . . you cannot have two tethers going at the same time (e.g. Bluetooth and Wi-Fi, or Wi-Fi and USB cable, etc.) on separate devices trying to control the camera (yes, I tried this).

You cannot transfer 4K video to your mobile device, and if you try, the camera will show a helpful error message. But you can transfer any photo or 1080p video. To transfer 4K videos you will have to take the memory card out of the camera and use a card reader (if you buy a kit, you'll have a card reader included). Then again, video files get HUGE and your iPad or iPhone may not be able to 'swallow' a big file?

A small but frustrating point: I mentioned above that you can switch, at will, between taking photos, to videos, and back-and-forth all right there in either of the software solutions. But in 'EOS Utility' it appears that you are switching between two tabs. If you are on the 'video' tab, you can get back to the photo tab by tapping the video tab again – it acts like an 'on'/'off' button.

Comments to the author Steve Neeley are welcomed, email psneeley AT xmission DOT com

Published in the September 2019 issue of *Micscape* magazine.

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