

Optomechanix

Goals of OMiD museum

Fluorescence Microscopy

Olympus Design

Nikon Design

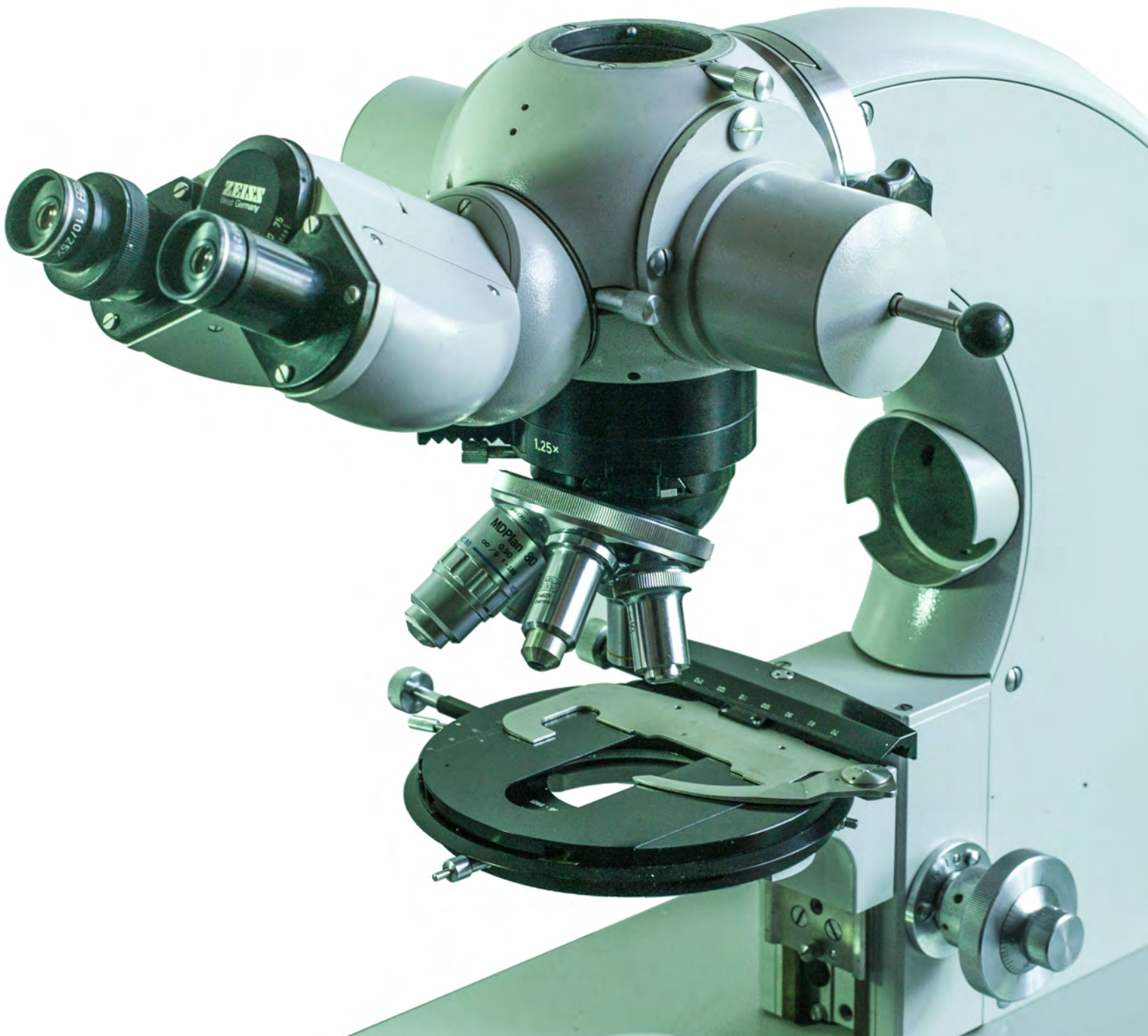
Leica Design

Zeiss Design

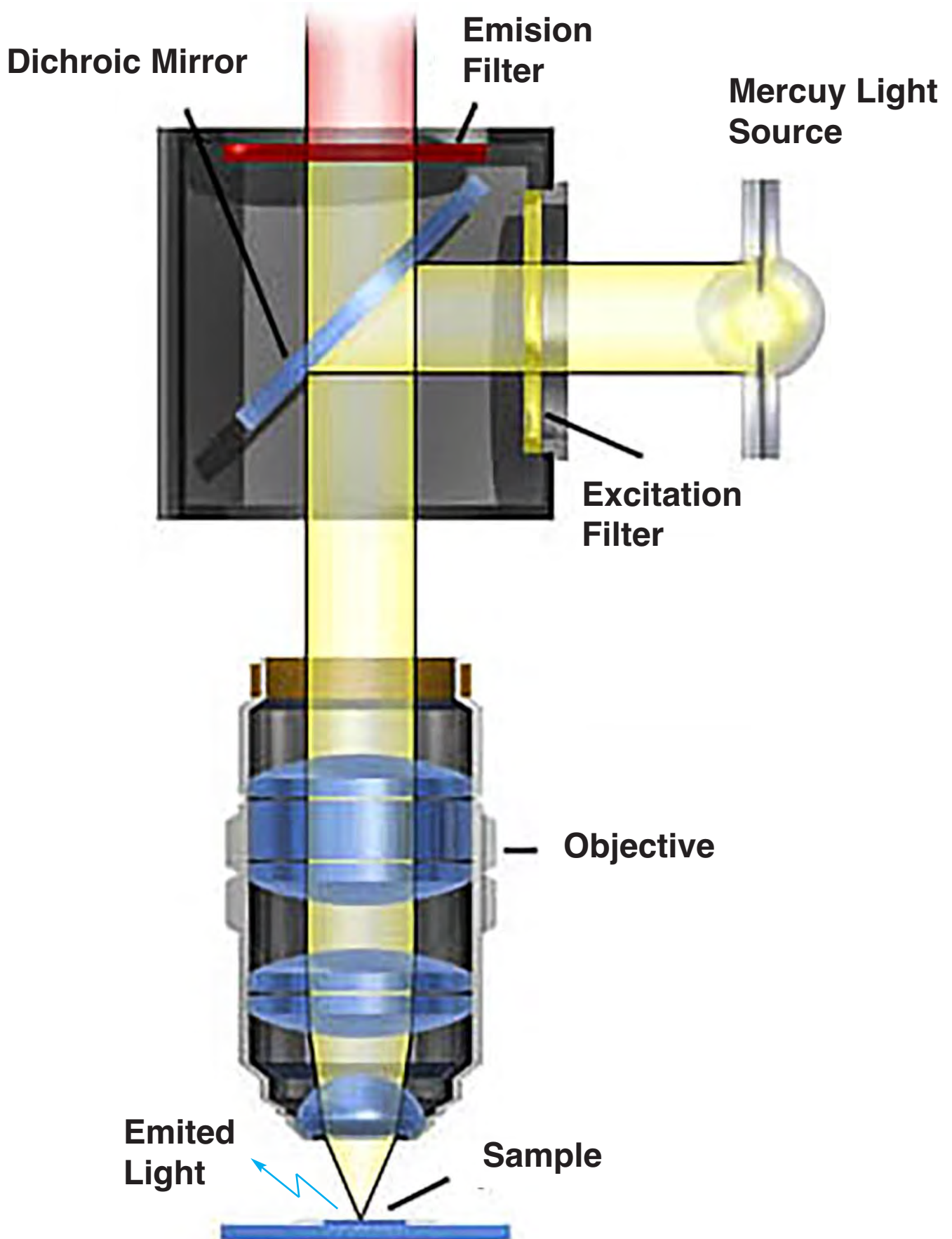
Understanding Enneagram

April-June 2021

Fluorescent Microscopy
Explained



Technical journal of OMiD, Opto-Mechanical Institute of Design

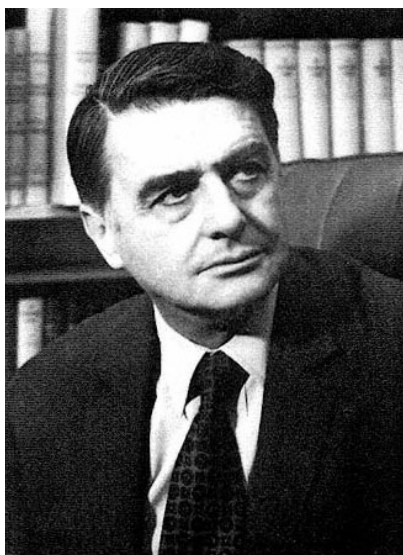


Fluorescent Microscopy: Basic concept of Fluorescence microscopy consisting of a UV light source, Excitation filter, Dichroic mirror, and a barrier filter. Several filter/bemsplitter combinations are offered to work with specific sample types.

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Edwin Land

This issue Dedicated to:

Dr. Edwin Herbert Land (1909 – 1991) was an American scientist and inventor, best known as the co-founder of the Polaroid Corporation. He invented inexpensive filters for polarizing light, a practical system of in-camera instant photography, and the retinex theory of color vision, among other things. His Polaroid instant camera went on sale in late 1948 and made it possible for a picture to be taken and developed in 60 seconds or less.

In 1932, he established the Land-Wheelwright Laboratories together with his Harvard physics instructor, George Wheelwright, to commercialize his polarizing technology. Wheelwright came from a family of financial means and agreed to fund the company. After a few early successes developing polarizing filters for sunglasses and photographic filters, Land obtained funding from a series of Wall Street investors for further expansion.

The company was renamed the Polaroid Corporation in 1937. From the beginning of his professional career, he hired women and trained them to be research scientists. In 1957, Harvard University awarded him an honorary doctorate. Following the assassination of Martin Luther King Jr. in 1968, he led Polaroid to the forefront of the affirmative action movement. Source: Wikipedia



Polaroid SX-70 (right) was one of the most remarkable cameras inventions of 20th century. With passing of film cameras, the digital age generation is still fascinated by his camera's film ejection, and the 1-minute wait to see the image developed.

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Optomechanix is a quarterly journal of Opto-Mechanical Institute of Design (OMiD), with technical articles for practical, hands-on opto-mechanical engineers. This magazine is privately founded.

Cover page photo: Zeiss Universal microscope of 1957 offering many techniques into one microscope.

Front back: The conceptual anatomy of a Fluorescent microscope.

The foresight at OMiD

OMiD museum has been beating the path to bring Optomechanix within reach for university students who are developing products, and perhaps building their own start ups. The tool we offer for it is Optoform. Invented 25 years ago, its goals were to enable lab technicians to build a product using pre fabricated pieces that are reasonably affordable. The new Optoform is based on an entirely new concept, which is to fabricate the pieces out of extruded Aluminum rather than CNC machined components. This drastically reduces cost, and is a game changer in rapid prototyping. It is now a higher level system design rather than putting parts together from individual components. We are also focusing on applications to appeal to high school students, and even children.

Fab Lab factories have also been around for at least a quarter of a century. They are now being established at many university campuses to help students build their ideas using 3-D printing. FAB Labs are mostly into design, and artistic form of products. OMiD is different in that it offers much higher precision components, so essential in building opto-mechanical products. A computer screen can't offer you the Erector-Set experience. You'll need to have both the hands on creativity, and computer aided design. 3D printers come after the inspiration in our minds. OMiD is also taking steps in helping students to have marketing in mind, and provides self development skills to be successful in launching products.

Building a microscope with Optoform requires full understanding of how microscopes are designed, and that's where an in house opto-mechanical museum plays a big role. The goals of Opto-Mechanical Institute of Design is really to understand opto-mechanics by studying prior art, and applying it to making instruments built with Optoform. It takes watch-making skills to be a true opto-mechanics engineer. Many people still think we are camera or pocket watch fans. It's all about design. It is through appreciating old ideas that one could invent new products with an empowering, and clear vision.

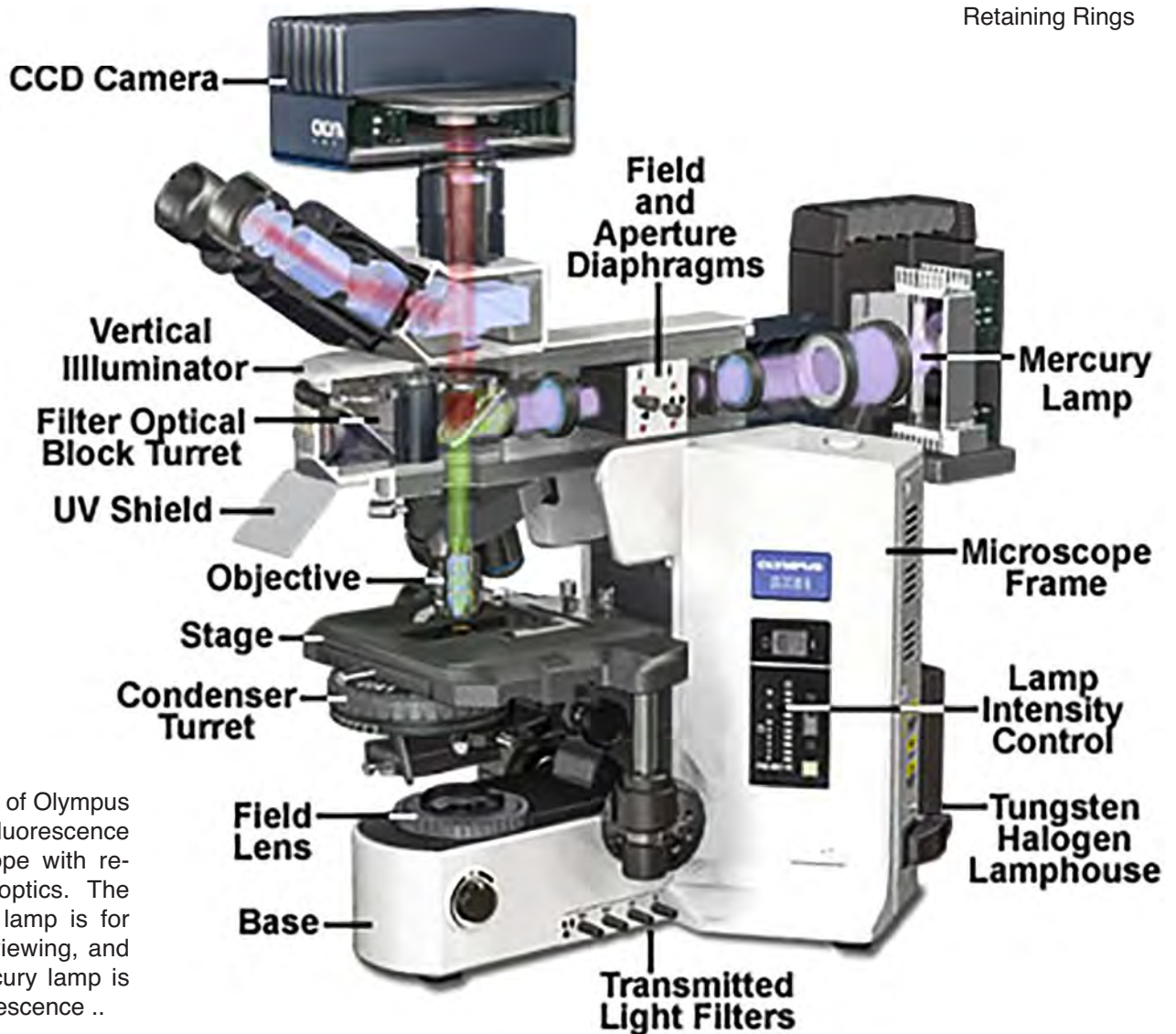
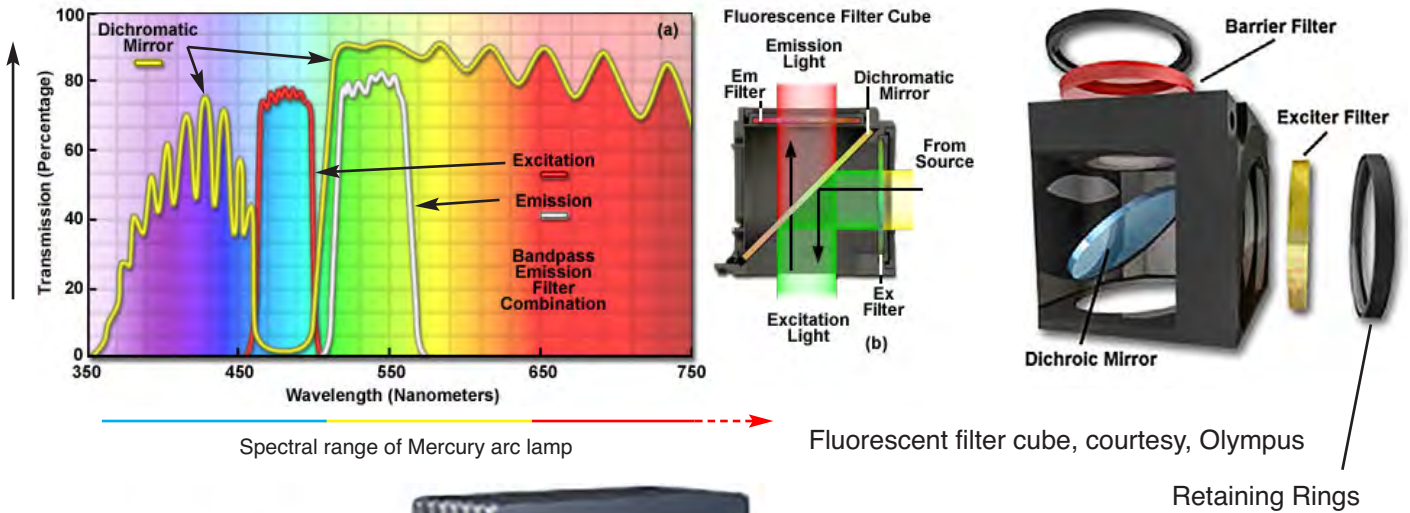
The focus of this issue will be to study the design style of the big 4 microscope manufacturers, and then building a Fluorescent microscope using Optoform. We'll be creating new Optoform parts as needed.

Ali Afshari
 Contributing Editor,
 Opto Mechanical Institute of Design

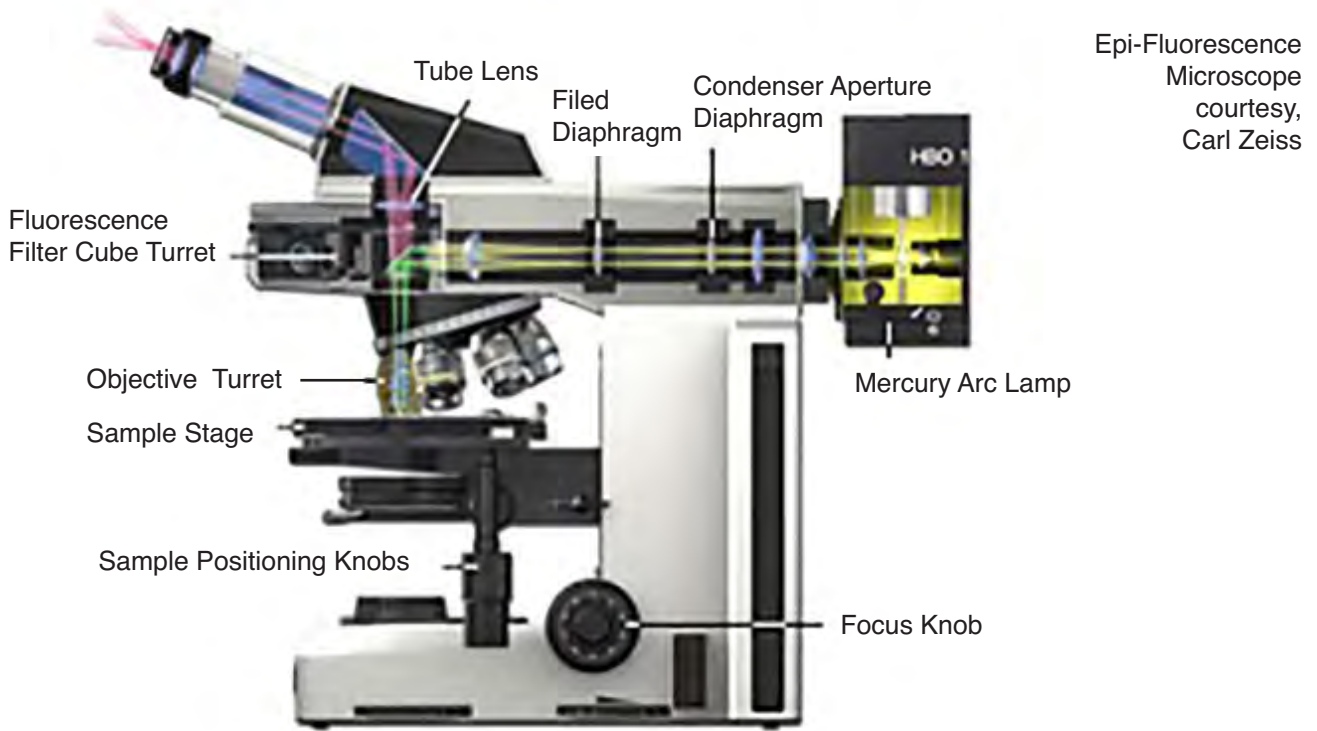


Flourescence Microscopy Explained

Flourescent microocopy is a method of collecting data from the sample using Flourescence phenomenon. The light from the lamp (usually a powerful Mercury or Xenon arc lamp) passes through condenser lenses and a variable, centerable aperture diaphragm, then through a variable, centerable field diaphragm. It then passes through a band pass filter (or Excitation filter) which selects those excitation wavelengths that are wanted to reach the specimen, and blocks all other wavelengths (see below). This light reaches a dichromatic beamsplitting mirror. This mirror (also called dichroic mirror) is a special type of interference filter which efficiently reflects shorter wavelengths while passing through longer wavelengths. Light is reflected off of this mirror at a 90 degree angle directly through the objective and onto the specimen. The flourescent light emitted by the specimen is gathered by the objective, and because the emitted light consists of longer wavelengths, it is able to pass through the dichroic mirror to form an image on the CCD.



Anatomy of Olympus BH 51 Fluorescence microscope with reflective optics. The halogen lamp is for normal viewing, and the Mercury lamp is for Fluorescence ..



Olympus Uplan Microscope Objectives



Leica HC PL Fluotar DF/BF Objectives



Zeiss LCI Plan DF/BF Objectives



Nikon 60X Apochromat Objective

Microscope Designs

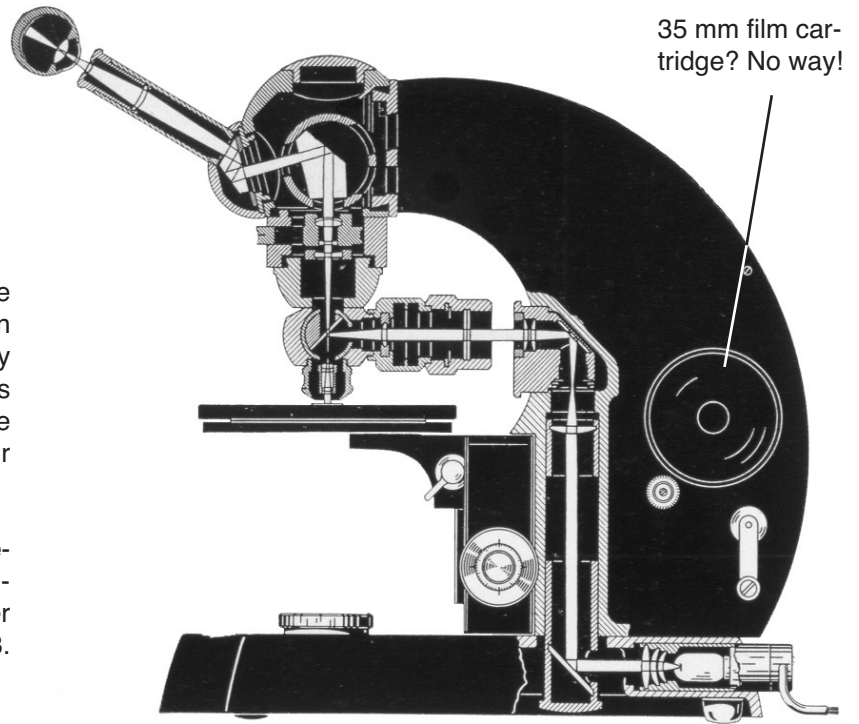
1 Carl Zeiss

Carl Zeiss has contributed immensely to the field of microscopy starting with the introduction of their first microscope in 1847. We'll first study one of its older designs, and then discuss its newer Axioplan series introduced in 1986 at the end because we are going to use it to build our own microscope.

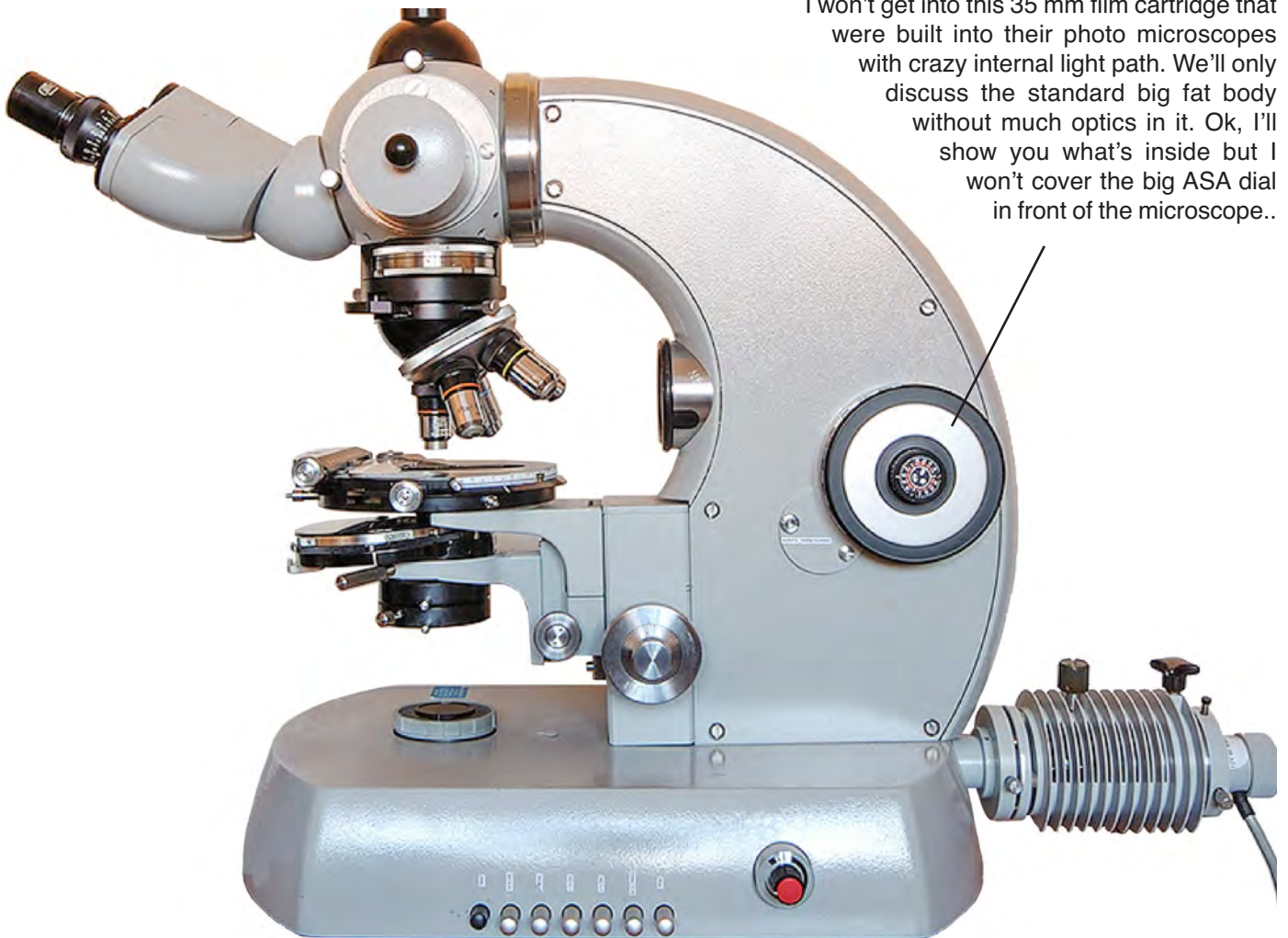
The most timeless microscope design Zeiss developed was the Universal series with the Lumipan stand in 1958 that you see here. Another revolutionary design was the Axiomat in 1973. It had a futuristic cubic design.

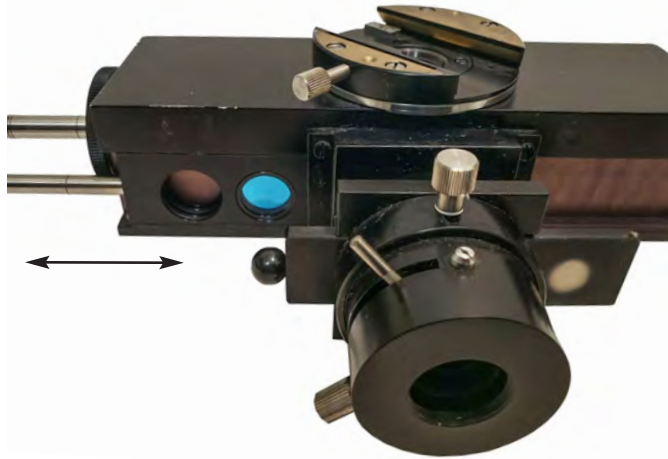
A Curvy Look

Light path in Zeiss Universal microscope with internal lamp (above), and external lamp (below) reveals the overall look of this microscope. The Zeiss design has always been uniquely curvy until the introduction of Axioplan, and Axiophot series which we'll discuss next. Most of Zeiss microscope designs are elegantly classic but remain timeless.



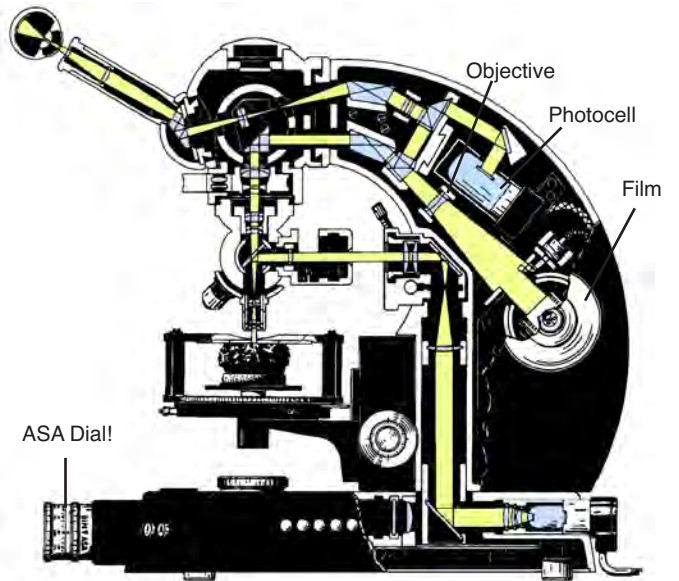
I won't get into this 35 mm film cartridge that were built into their photo microscopes with crazy internal light path. We'll only discuss the standard big fat body without much optics in it. Ok, I'll show you what's inside but I won't cover the big ASA dial in front of the microscope..





;Y]ebRcPR[PRONddNPURZR[d

Fluorescent attachment (above) is an optional accessory for the Universal microscope. Taking off the attachment (above left), shows its five position nosepiece turret. Its top view (middle left) shows the dovetail interface to the microscope. Various beamsplitters inside the fluorescent slider can be seen (left) switched together with emission filters to select various wavelengths.



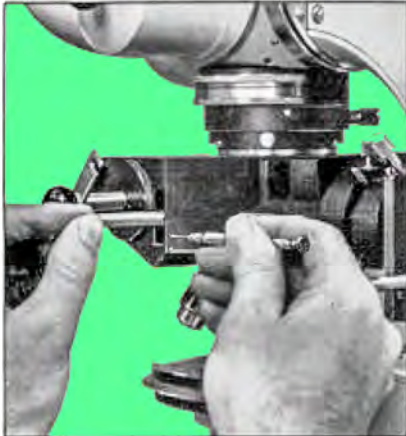
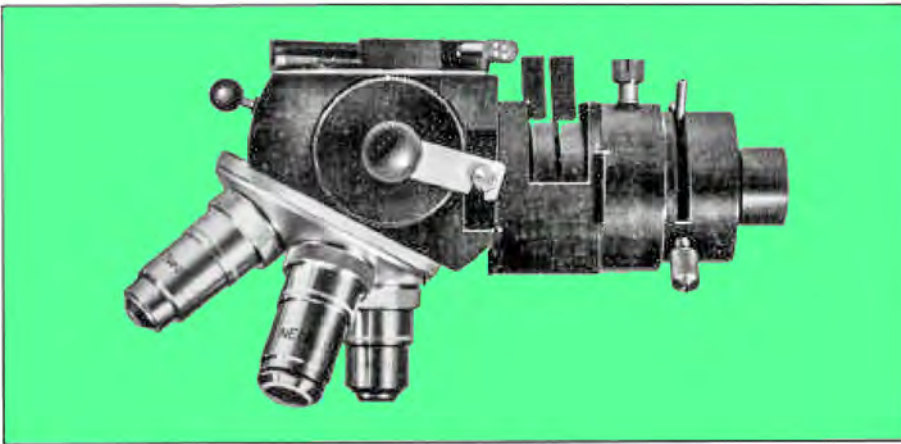
Ok, here's the crazy light path in Zeiss Photo Microscope. Film loading is explained on the next page.



Transmission filters (above), that swing in and out by push buttons, placed at the right bottom side of the microscope (previous page). They accept standard 32 mm filters for contrast enhancement.

Zeiss Universal continued

More details on Zeiss Universal microscope if you are curious about the film magazine, and the Fluorescent filter housing. Here are the instructions to replace filters, and how the Emission, and Absorption sliders are oriented with respect to the beamsplitter block, shown in section drawing view below.

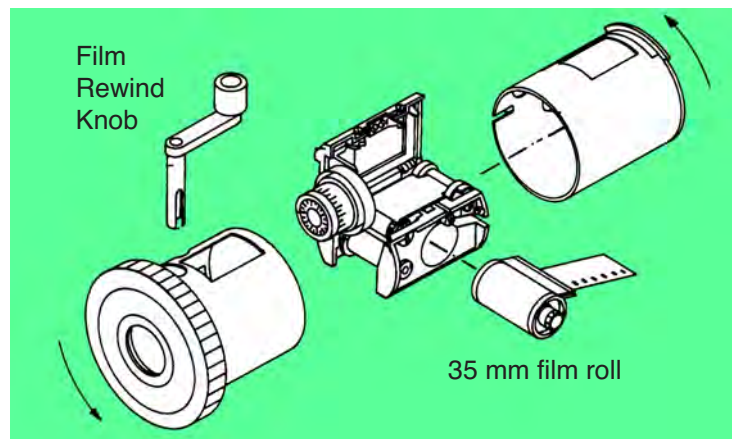
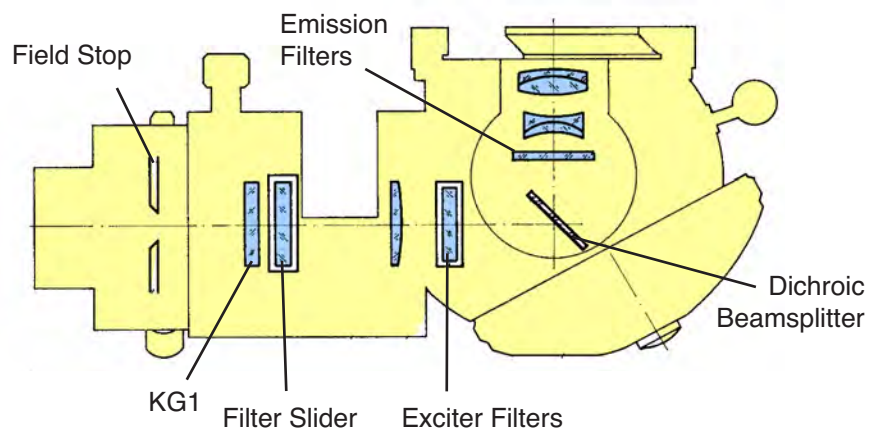


Emission filter slider

Loading of film, see below for details



Beamsplitter Slider



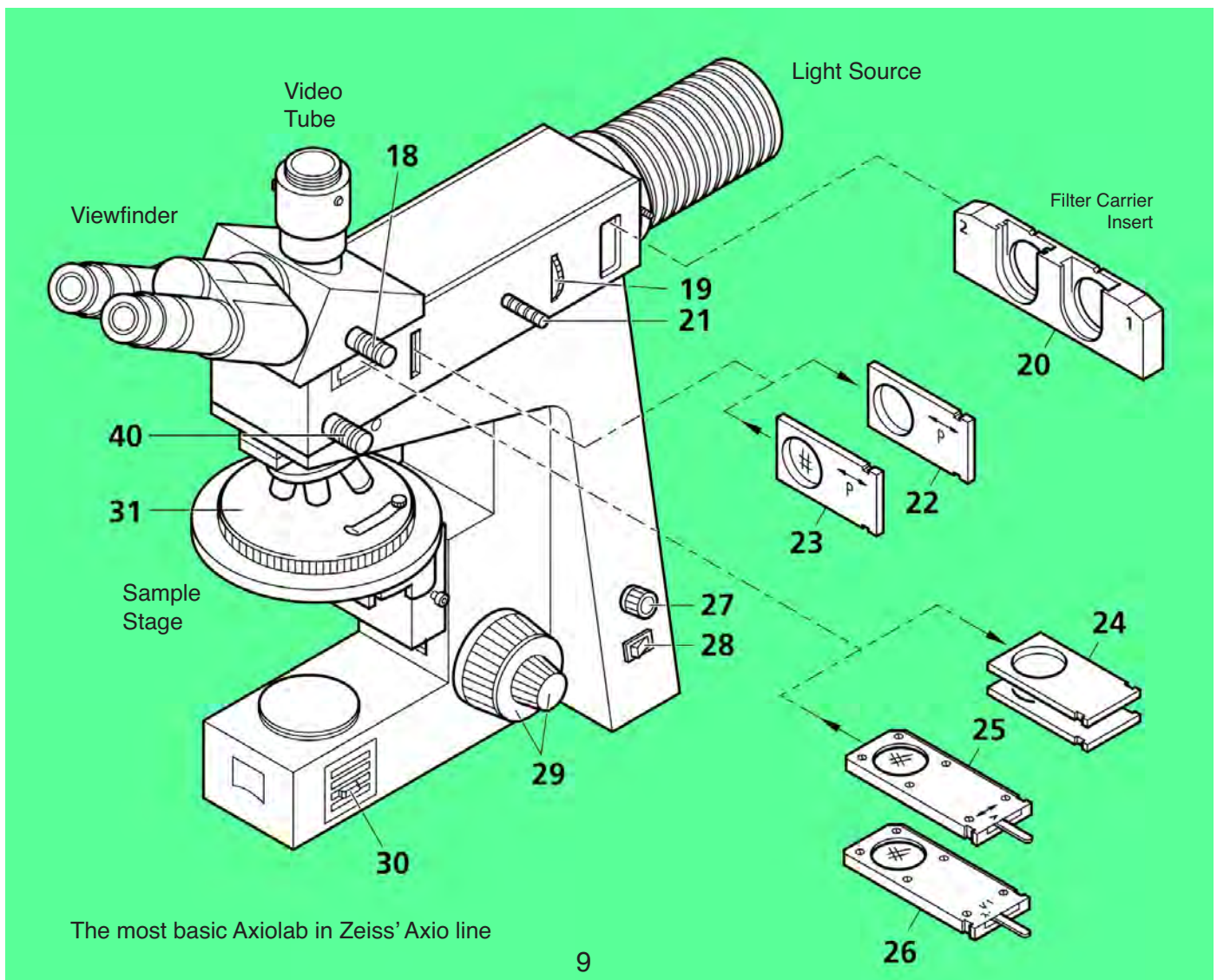
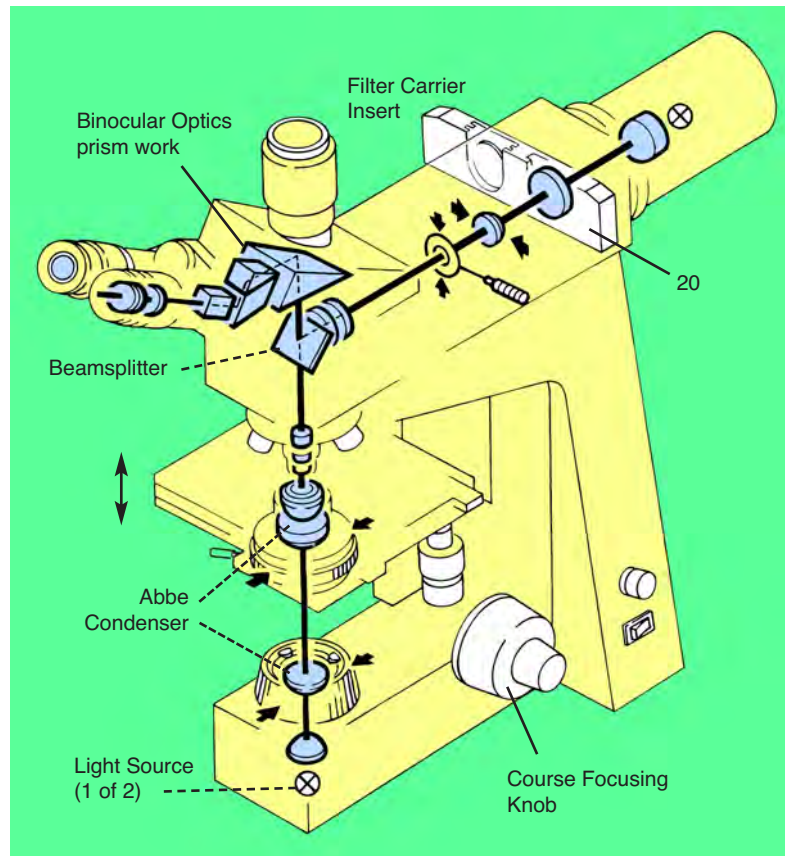
Zeiss Universal Photomicroscope: Here's the 35 mm film being loaded onto the film cartridge insert that goes into the middle section of microscope's main body to record images.

Zeiss Axioplan

We discussed Zeiss Universal microscope, and how sophisticated it could get, but that's not where Zeiss left it. There was the fantastic Axiomat design that we'll discuss later, but the latest from Zeiss are the Axiolab shown on this page, Axioplan, and Axiovert discussed on the next page.

Note transmission filter 20 on both illustrations. I am discussing the filter insertion on these microscope because we are going to use the same concept in construction our Optoform microscope. Note how some of these filters are inserted horizontally (24,25,26), while others are inserted vertically (20, 22,23) depending on their orientation with the beamsplitter mirror below the viewfinder.

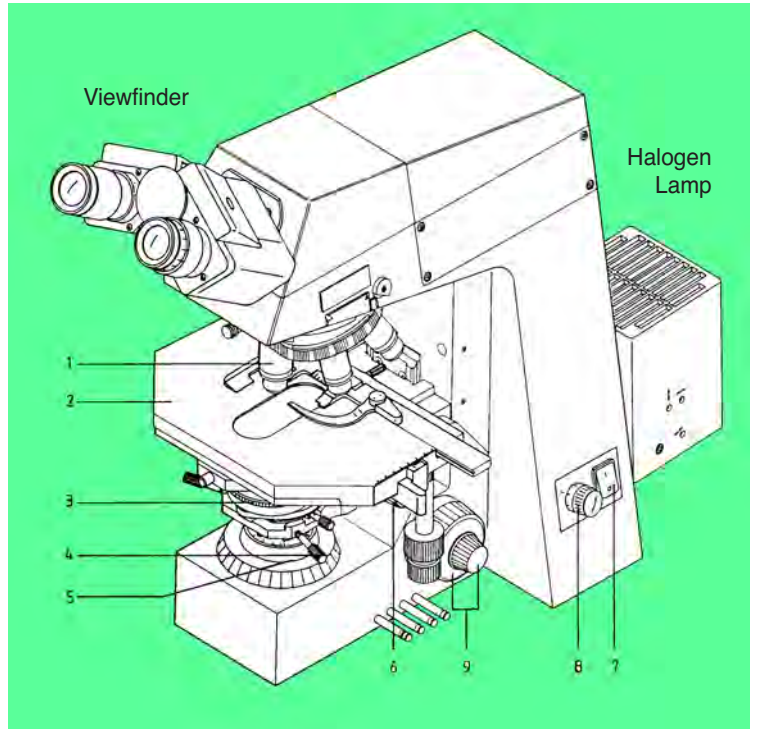
Zeiss also offers beamsplitter cubes that are inserted in place of the sliding beamsplitter. For our Optoform construction, we'll utilize the sliding concept. The best choice would be to have at least three sets of beamsplitters, and absorption, and transmission filters so they could be mixed in any combination or linked together with a linking arm.



The most basic Axiolab in Zeiss' Axio line



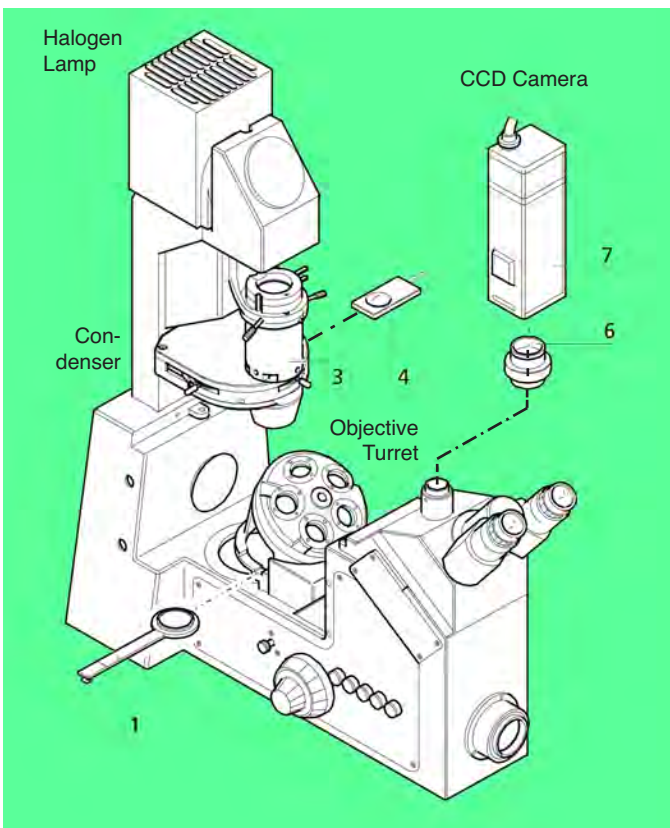
Zeiss **Axiolab** with rotary beamsplitter turret .



Axioplan accepts a huge number of attachments for industrial applications such as DIC for semiconductor inspection.

The Axio series use straight line body contours, while they are designed as a solid body, unlike the Nikon, and Olympus where their illumination head could be taken off for use in OEM applications. Both Leica, and Zeiss would only allow third party stages to be mounted on their microscopes but nothing more.

The infinity focus objectives would also allow attaching instrumentation on top of the body, below the viewfinder, the most common being the autofocus modules that are offered for all four manufacturers.



Zeiss **Axiovert 200** (above), and with Confocal capability (right) is mostly software driven. We'll build a scanning Confocal microscope in our next issue.



2 Olympus

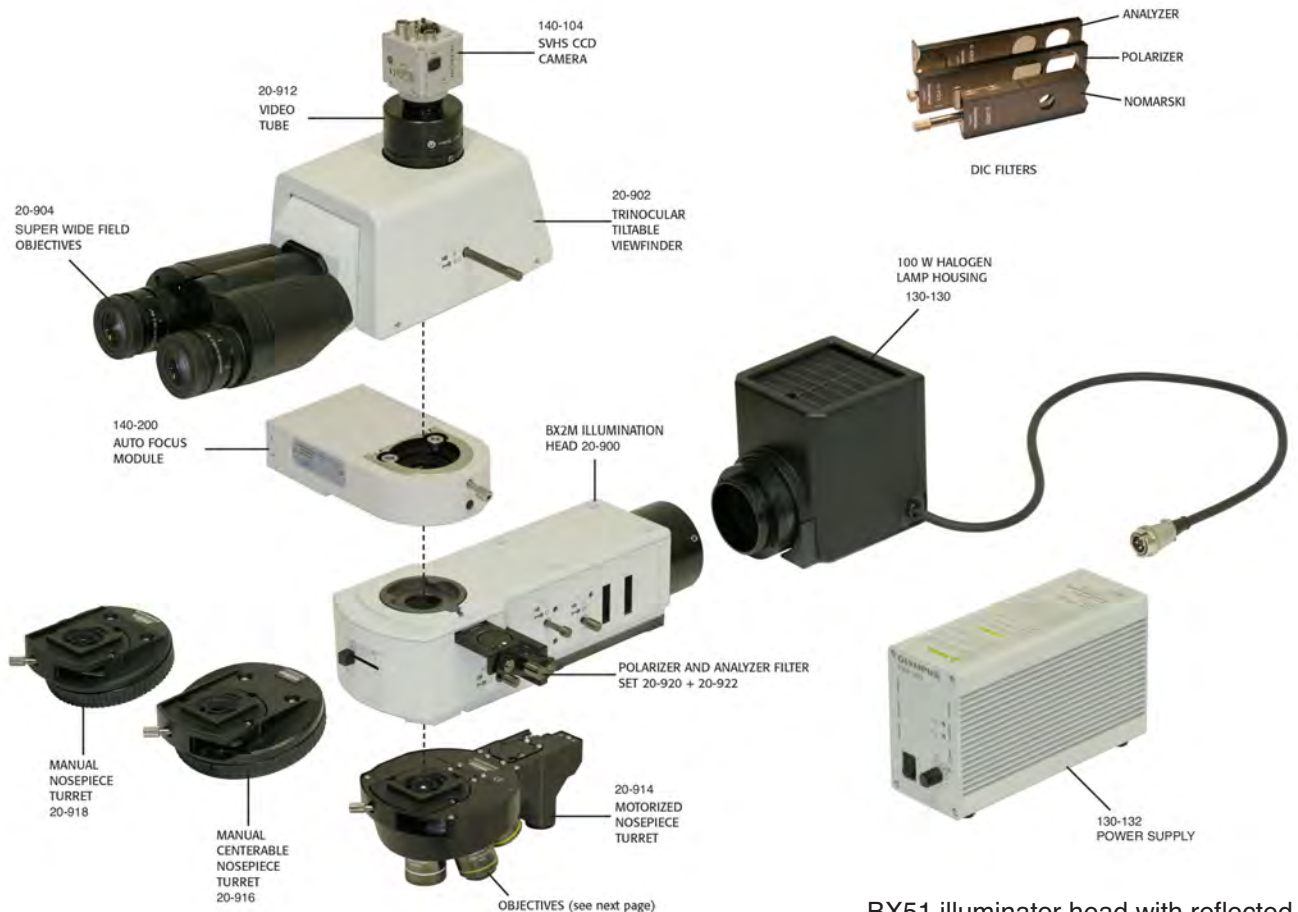
Olympus has been taking the modular design approach in building four generations of microscopes starting with their BH series. They consisted of basically, a stand, interchangeable sample platforms, and interchangeable illumination heads, and viewfinders.

The nosepiece turret was initially attached to the main body but that also became part of the illumination head, and was made detachable (below). I believe their microscope division was greatly influenced by the designers in their photo division lead by Maitiani.

They have been in favor of utilizing beamsplitter cubes in Fluorescent microscopes, mounted on a rotary turret. All modern microscopes featuring rotary beamsplitter turrets are fully motorized.

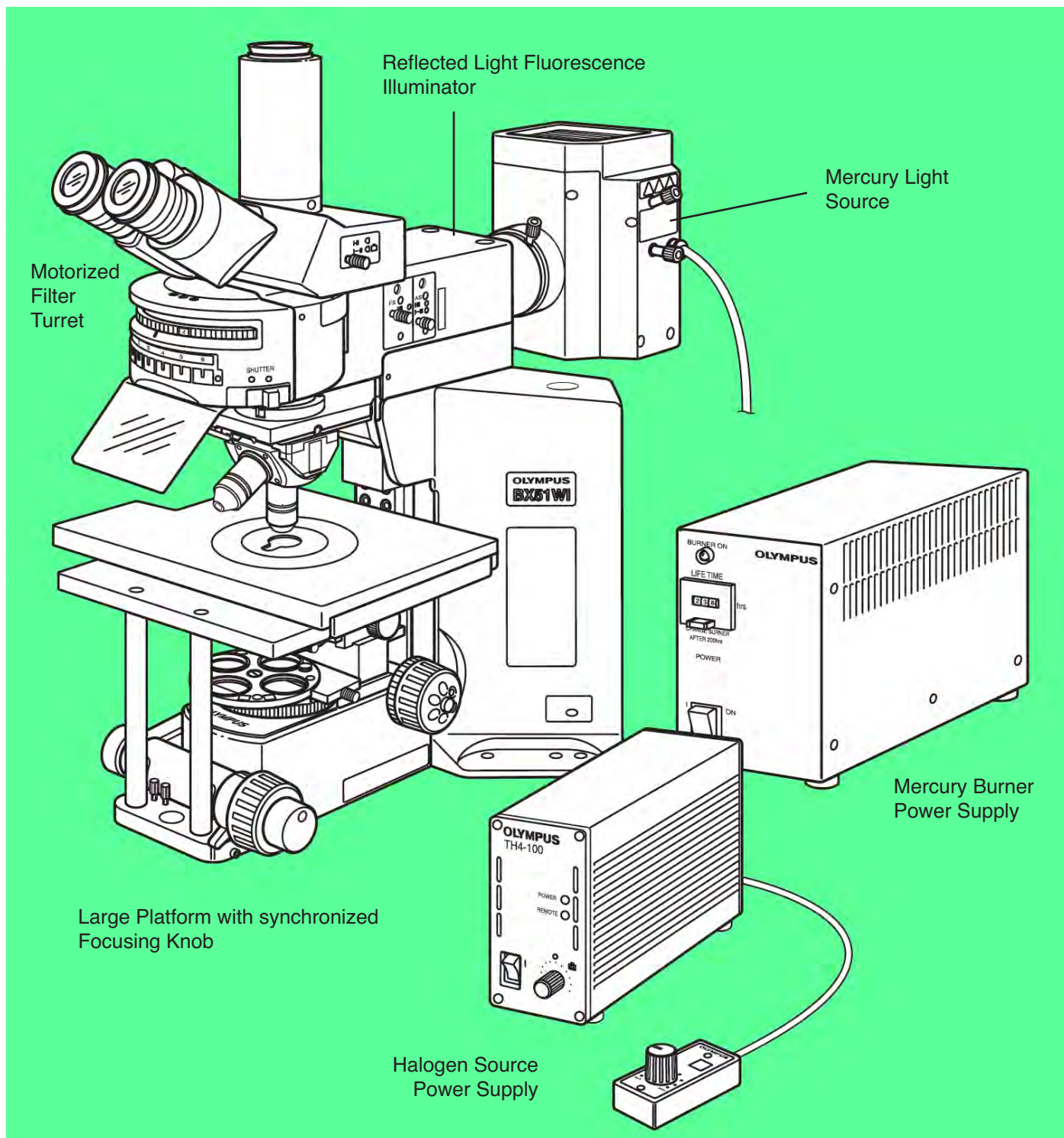


Modular design of microscope components not only allowed manufacturers to offer fully integrated microscopes like Olympus BX51 (right), but also offer them to OEM use such as wafer inspection workstations, and other more advanced microscopy like the AFM. The infinity objective design also allows adding third party accessories like auto focus heads.



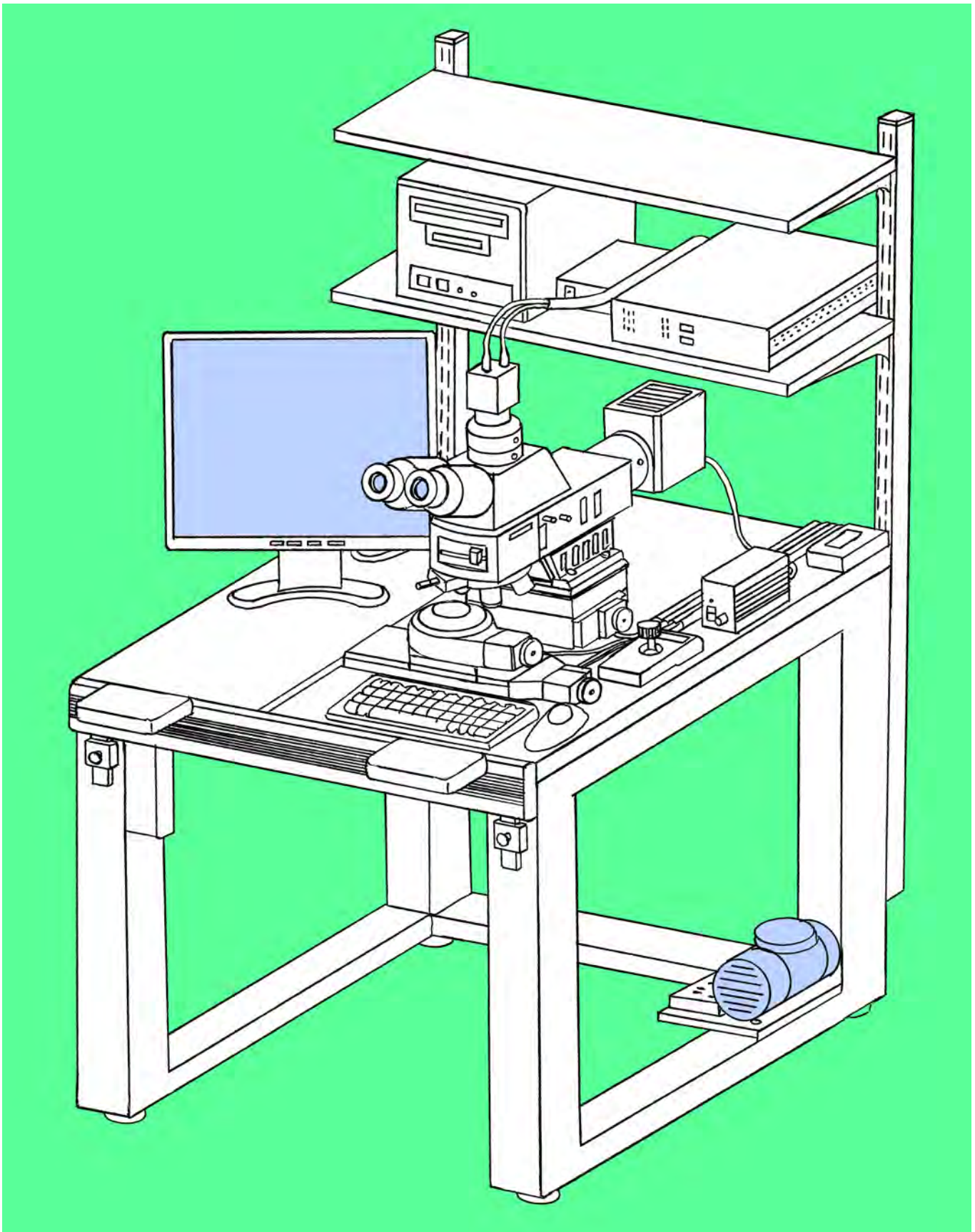
BX51 illuminator head with reflected light DIC filters for Metalurgical use

Olympus offers a fantastic line of high resolution objectives with low numerical apertures, packed in relatively small housing. The opto-mechanical challenge in constructing modular microscopes is the optical centration of all the components along the imaging axis starting from the lamp to the sensor. This includes the lamp centering stage, the condenser lens, the nosepiece turret, the illumination head, and the video tube. All microscopes utilize a conic dovetail interface. This interface acts as both a clamping device, and the centering ring. Any misalignment in the system adds up so rapidly and in addition to image degradation, and even vignetting, there will be increased image shift during magnification change.



Olympus BX2M

Olympus offers various options for OEM applications (next Page), such as this option to mount large platforms. Third party motorized platforms is a dilemma for microscope manufacturers because the heavy stage adds a huge strain on the focusing gears. Zeiss offers a heavy duty focusing rack for this purpose. In this design, Olympus solves it by adding two additional support rods in front. The front, and back focusing knobs are linked together to provide a three-point focusing support. Mechanically, this is much easier said than done.



OEM Design Example

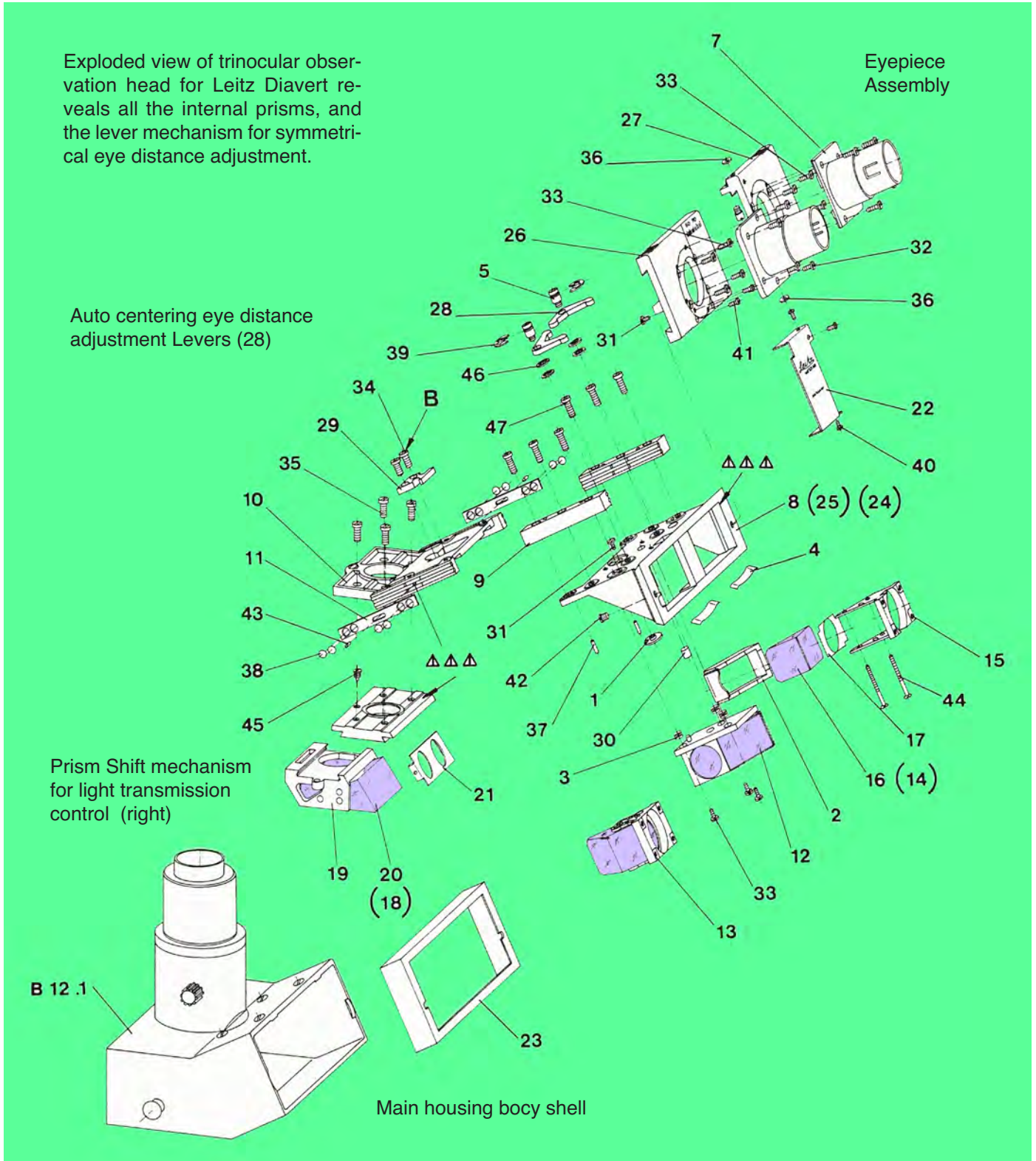
Microscope workstation designed with Olympus BX51 featuring a vacuum chuck with its pump installed at the base of the vibration isolation table. We incorporated Micos three axis stages for motion control, and a computer interface for live viewing, and image capture. Various automation options are available for auto scribing the sample, pattern recognition, auto image capture, and precise image centering at all magnifications. Design Courtesy, Optomechanix

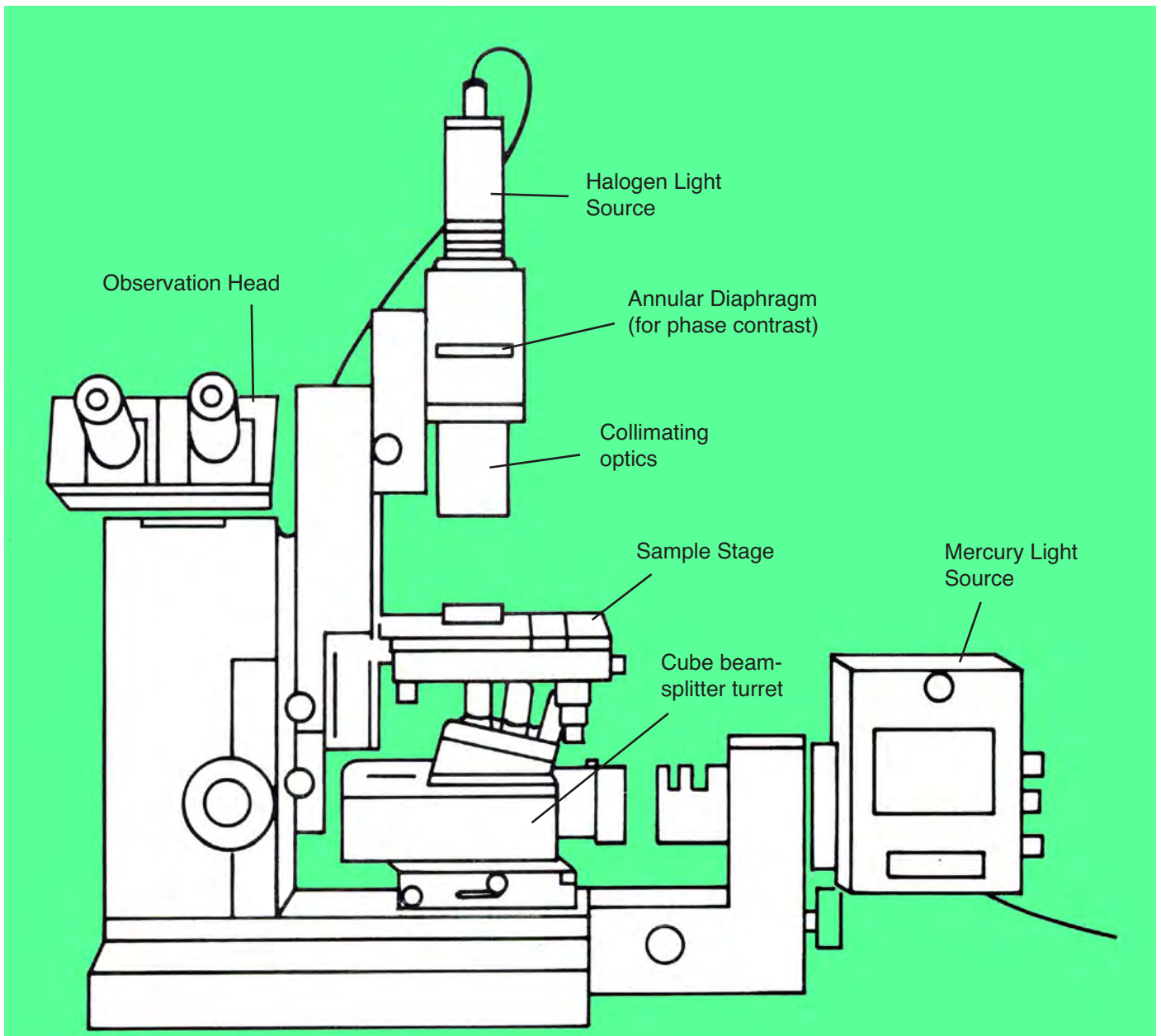
3 Leica

Leitz was known to build some of the best microscopes of its time long before becoming famous for their cameras. I am going to discuss one of their inverted Fluorescent designs (Leitz Diavert) utilizing beamsplitter cubes (left) mounted on a rotary turret (next page, bottom) in contrast with the sliding filter holder discussed in Zeiss Universal.



One obvious advantage of the Zeiss approach was any combination of Excitation, and Emission filters could be used because they each have their own control knobs. In the turret design, like in this example of leitz Diavert, the cubes are already assembled with filter pairs. We have a detailed article describing the Leitz Diavert on Jan-April 2019 issue of Optomechanix.





Leica Diavert inverted microscope with mercury light source for fluorescence microscopy, and Halogen lamp source for phase contrast observation. A close-up of the beamsplitter turret for beamsplitter cubes is shown on below, right.



Close up view of cube beamsplitter turret showing beam-splitter cubes inside the turret behind the objective turret.

4 Nikon

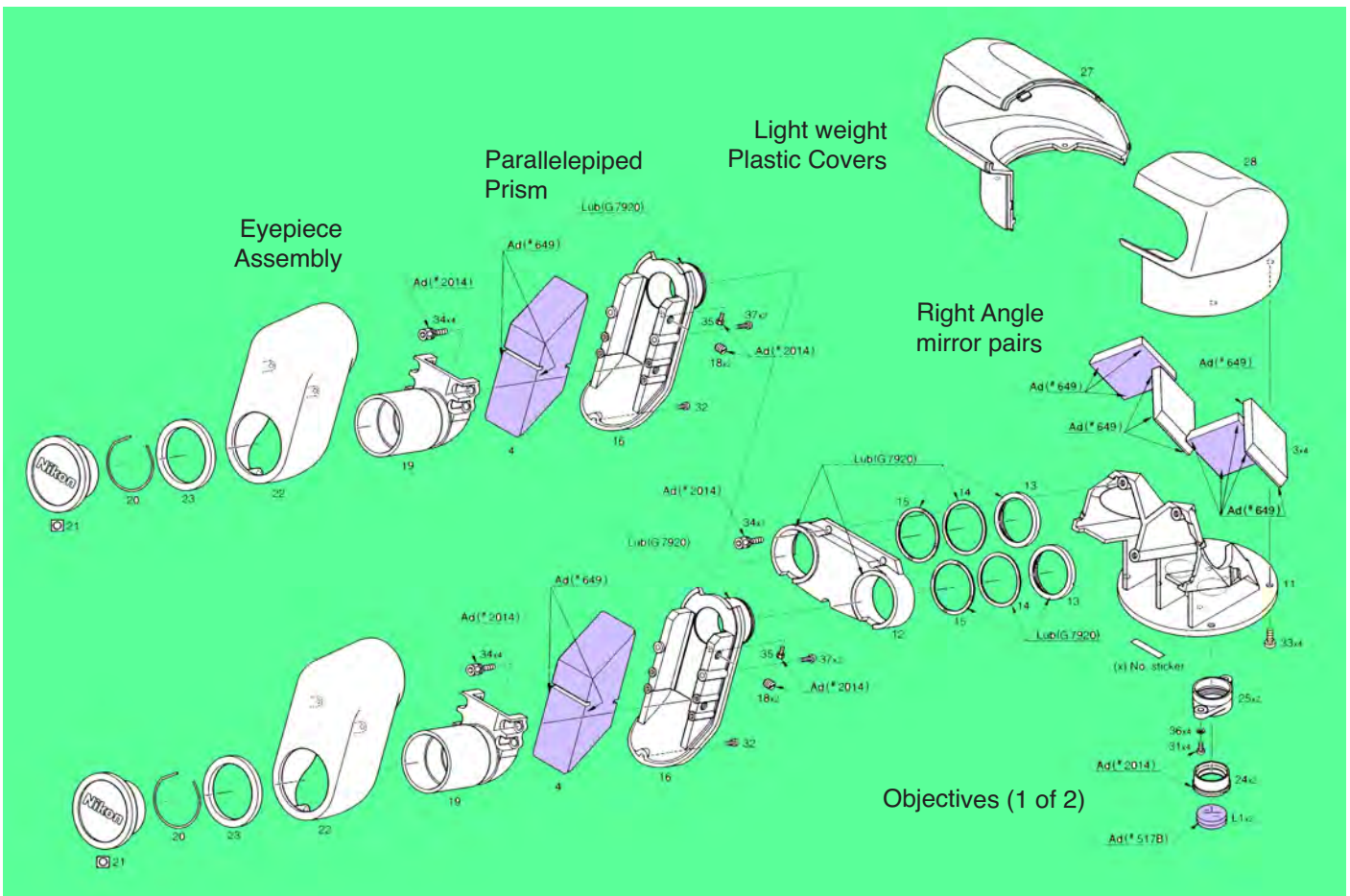
Nikon's microscope division began long after their success in photographic cameras. One would have expected robust opto-mechanics from them similar to their Nikon-F cameras but their microscopes looked slim in the beginning with a lot of plastic in them. Their quality has improved drastically over the years.

Nikon objectives are notably much bigger, and longer than other brands. I am particularly impressed with their motorized nosepiece design for handling the magnification change with feather-light, low noise operation. You could also change the objectives by hand, and the drive system would still know where each objective is. That's so different from Olympus' motorized nosepiece that sounds more like a coffee grinder, and you'd break it if you try to turn it by hand.

Nikon uses too much plastic as their microscope coverings, and that's not my favorite choice. This is specially annoying when the entire body shell around their stereo microscopes (see below) are plastic (same goes for Olympus). In any case, plastic filter carriers would be out of question. May be ok for less frequently used filters such as ND filters, but I have often seen polarizers housed in plastic.



Nikon Eclipse LV150N

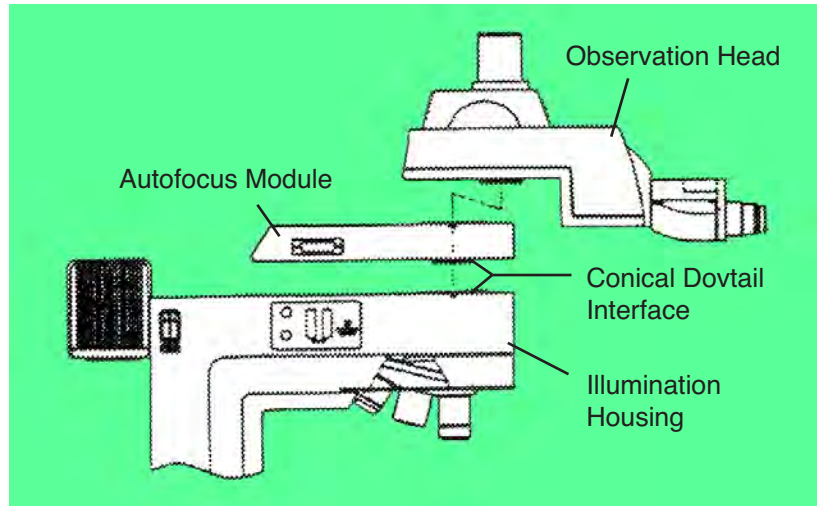


Inner construction of Nikon B-PTL low profile stereo head reveals an innovative solution to allow two independent beams be brought to the eyes utilizing multiple mirrors, and prisms. In opto-mechanics, it takes courage to bend light in such complex fashion. It can be accomplished after a concept is built, well proven, and then the natural "next step" can be taken to do it better.

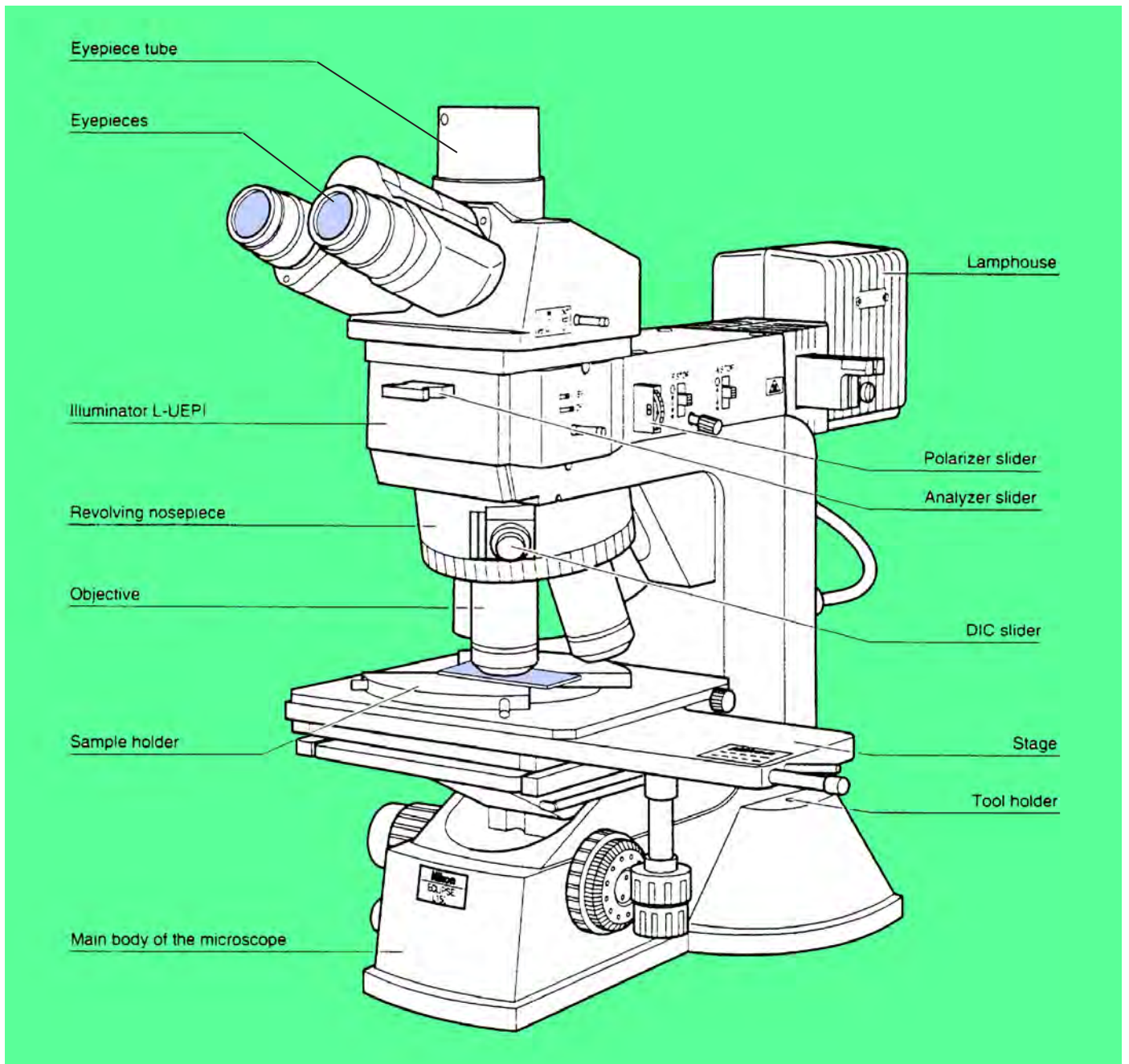
Big Fat is better

All microscope manufacturers have learned to grow fat in their designs. Fat microscopes look better, and they appear to have larger inner optics, and brighter images. In many cases, that's not necessarily true. Thin-barrel illumination heads, like older generation microscopes gave away the truth about their small inner optics. Fat is probably better because it looks more stable, and is protective of the inner optics

One thing that bothered me with Nikon's design was their small diameter conical dovetail interface between the observation head, and the illumination housing (right). Over time, there were significant improvements in both Nikon, and Olympus. Notably the slide-in filter insets that became precision metal filter carriers.



Centration of components in Nikon Eclipse L2A-AF

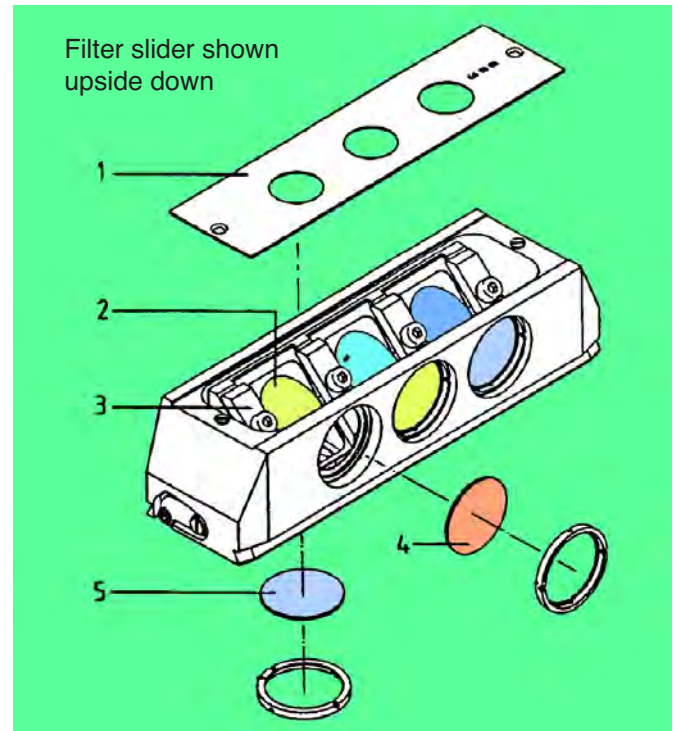


Designing a Fluorescent Microscope

By Ali Afshari

Utilizing Optoform to construct a Fluorescent microscope requires adding more mounting plates to the system. Although it could still be accomplished with existing mounts but we should think of a more professional looking microscope with simple user interface, i.e., to be able to switch between several filter sets for optimum image clarity, and contrast.

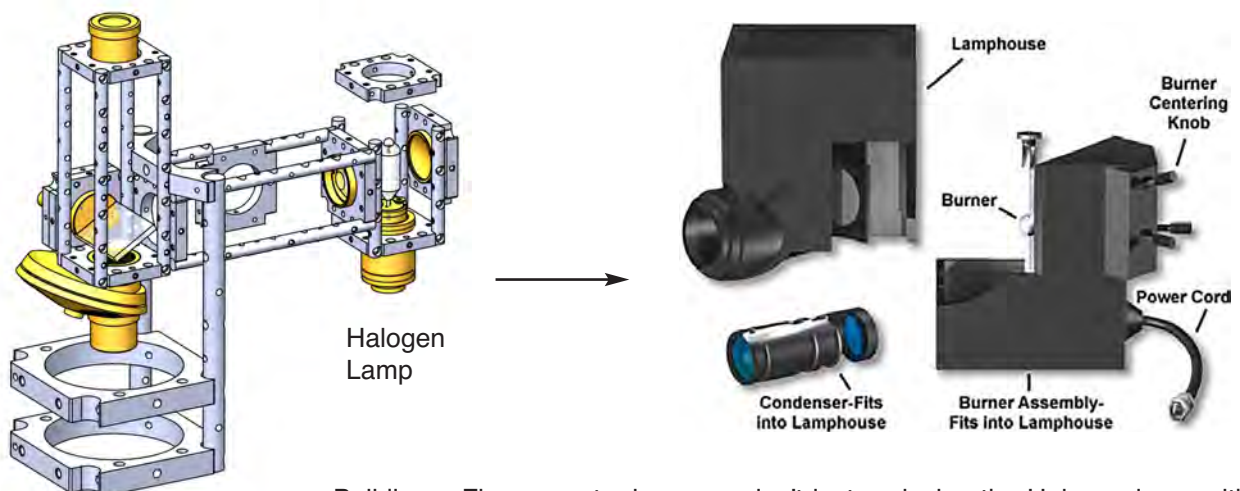
As we saw in our short study of prior art, the best choice would be the beamsplitter slider design because any combination of emission, excitation, and beamsplitters could be arranged for achieving the desired contrast.



Zeiss AxiosKop Fluorescent filter slider consists of Emission filter (5), Excitation filter (4), and Dichroic beamsplitter (2). The filter block is identical to slider in Axiovert 100.

Designing the new Mount

A new mount will be needed to implement the beamsplitter slider so it will be built using Optoform's frame structure. We'll need to compete with existing microscopes on cost, and versatility. Once we implement it with Optoform, it will exceed in flexibility among other microscopes because it will provide a completely open architecture design.

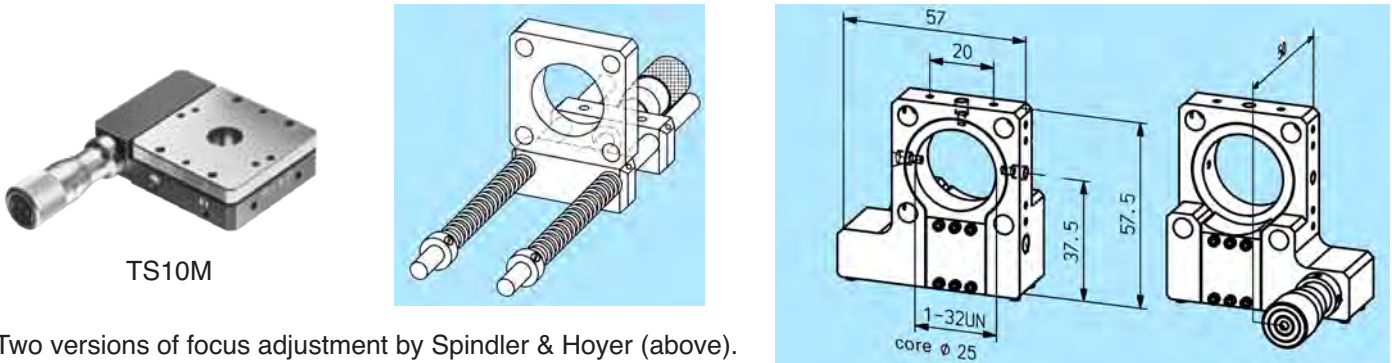
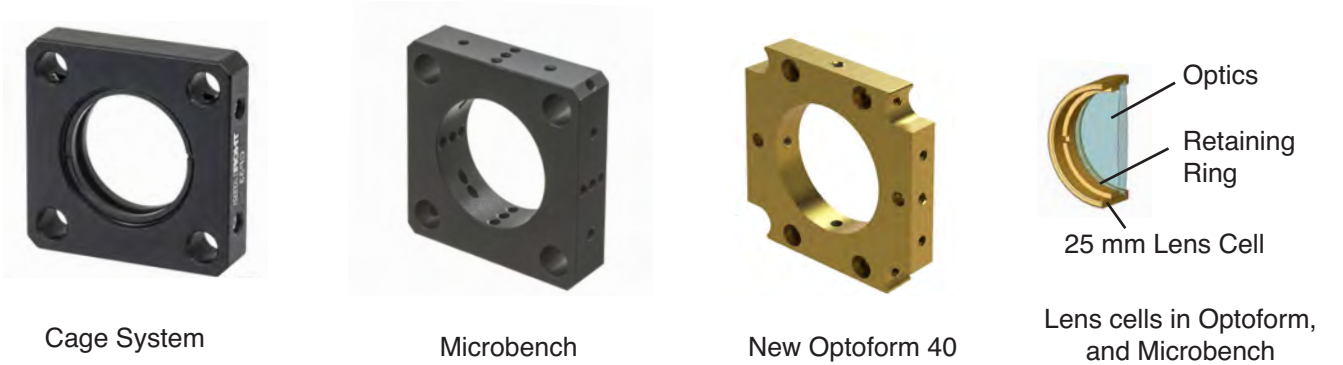


Building a Fluorescent microscope isn't just replacing the Halogen lamp with an arc lamp, and adding filters. That would be silly. Let's build a real microscope.

Before we introduce this new mount, it seems Thorlabs has been offering their own version of my design ideas. Copying has become a trend in our industry. Spindler and Hoyer (now Linos) who was the original manufacturer of Microbench couldn't complain for their Microbench line being copied by Thorlabs after their patent expired some 20 years ago. Microbench was a great idea but wasn't received so well in US, and what Thorlabs did was they brought it to all optics labs across US. They then began adding new components to the system, one being their Z-stage unit that utilized flexures. A year later, I saw Linos copying Thorlabs with their own Z-stage. Incidentally, some great contributions of Thorlabs' design team has been their Z-Stage, and a very compact X-Y stage, and their rotary stage that utilizes rod bearings. Other than that, it has essentially remained unchanged. I wonder now how they'll copy my new idea discussed in this issue.

For those who are familiar with Microbench, and the Thorlabs' version, in both systems, the mounts slide along the rods, and are secured by set screws. But one major difference is in Microbench, optics are housed in circular lens cells that could both rotate, and slide within the mounts. In the Thorlabs version, the circular apertures in the mounts are threaded, and the optics would not slide or rotate. Thorlabs has put more emphasis on securing the optics directly on the mounts.

Optical mounts in Optoform are compatible with Microbench, and that's the way every lens cell or mirror holder could be



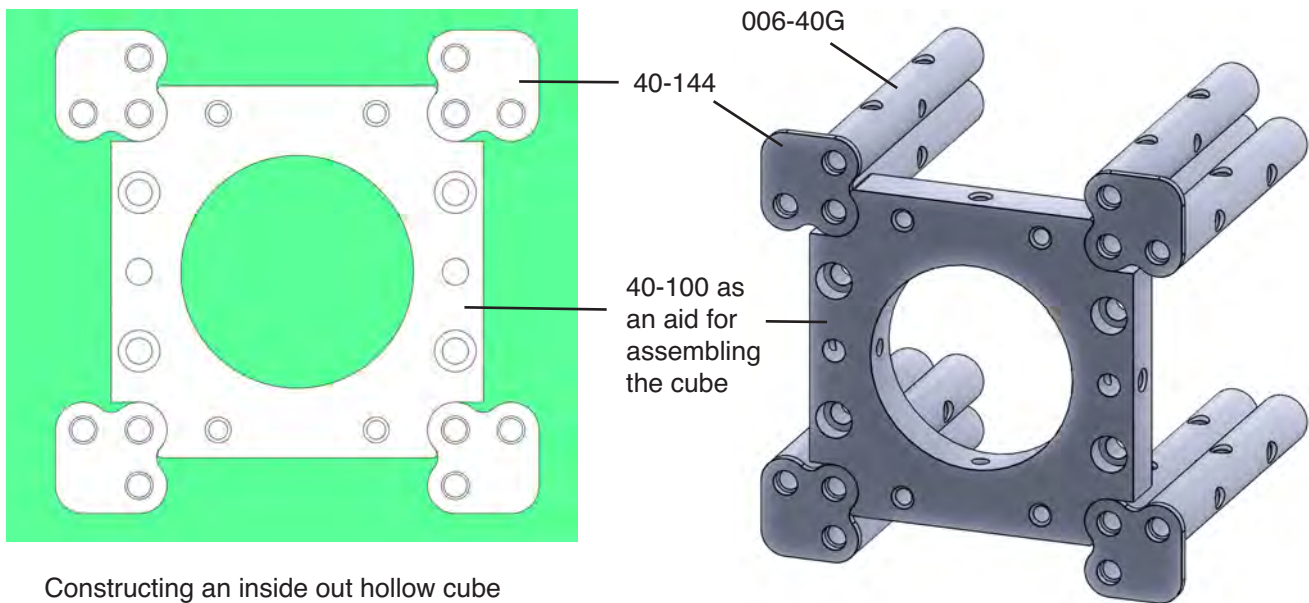
Two versions of focus adjustment by Spindler & Hoyer (above). Linos' copy of Thorlabs' focusing unit utilizing flexures (right).



Thorlabs' versions of Optoform mounts: We were the first to slide the mounts side ways along the rods (40-110, right).

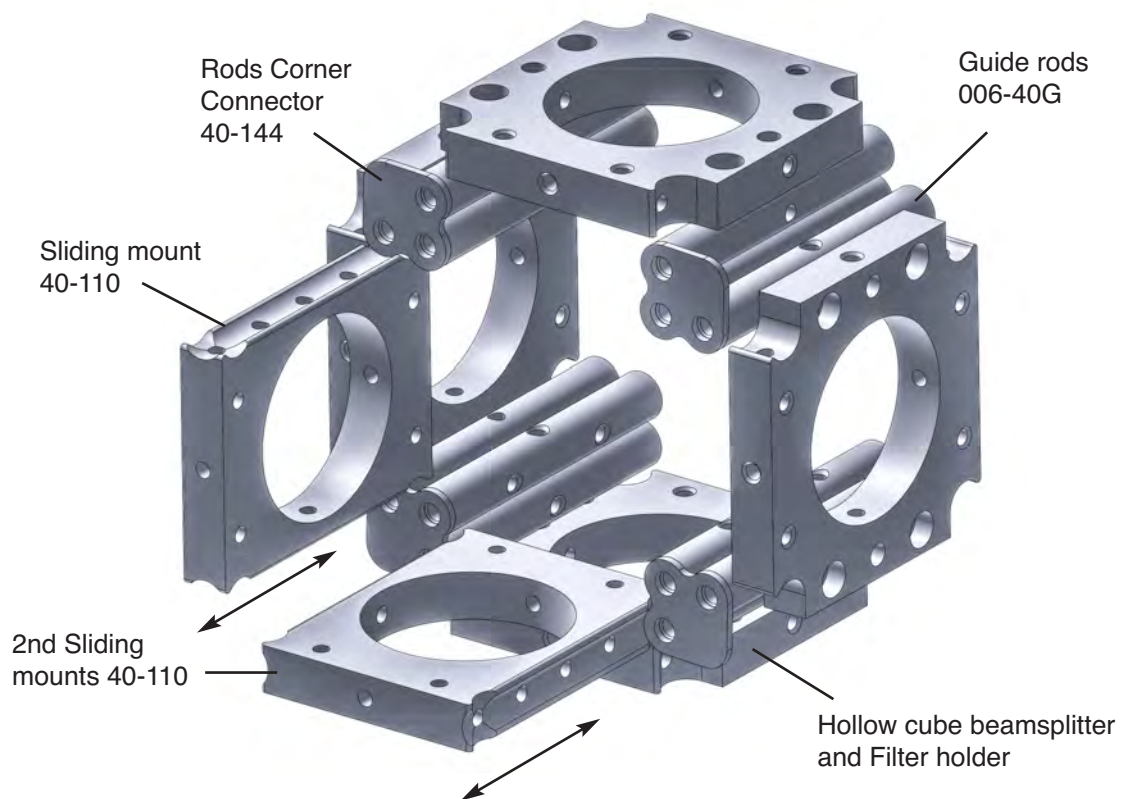
translated or rotated along the optical axis. Additionally, Optoform 40 only utilizes lens cells for focusing, not the rods. Competition is good because it doesn't allow favoritism, and it's eventually leads to better products for the customer. We are no competition for Thorlabs' marketing power house but in Optical Erector Set design, I think Optoform has a fresh idea that the industry has been waiting for: A drastically more affordable optical construction system that may be produced by extruded Aluminum.

Designing the beamsplitter housing for Fluorescent filters

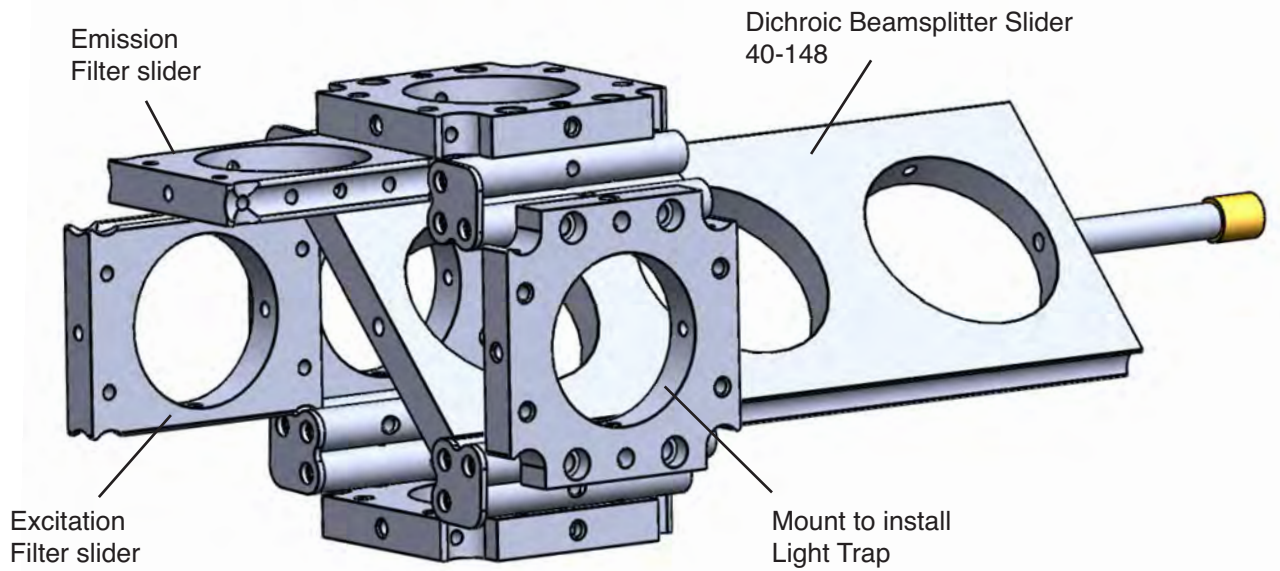


Constructing an inside out hollow cube

The idea would be to have a means to form a cube that is hollowed from inside out so it would allow mounts to slide in and out without obstruction. Let me show you what I mean: What we need to build is a beamsplitter housing that would



accept any number of filters on its four faces around a central beamsplitter (above). This is accomplished by side mounting the rods by a corner connector 40-144 that basically secures three rods side by side to provide clearance for sliding mounts 40-110 to be inserted without collision with the neighboring mounts. It would therefore allow inserting a multiplicity of beamsplitters, and filters without any obstruction. We could either side connect the sliding mount 40-110 to insert various filters or to switch between filters very rapidly, we could make an extended version. We'll also need to design a diagonal sliding mount to secure various beamsplitters, mounted in 30 mm lens cells. The 30 mm lens cell provides a 28 mm clearance aperture to provide the necessary beam path clearance when mounted at 45°.

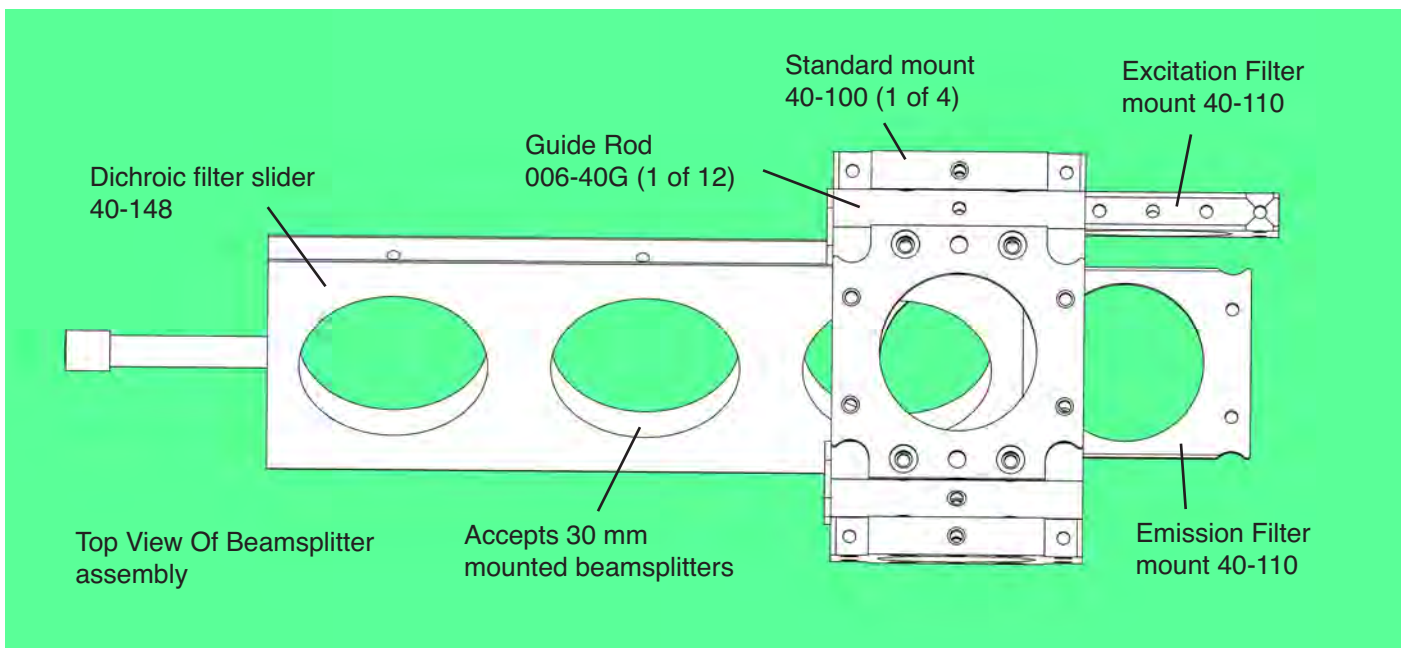
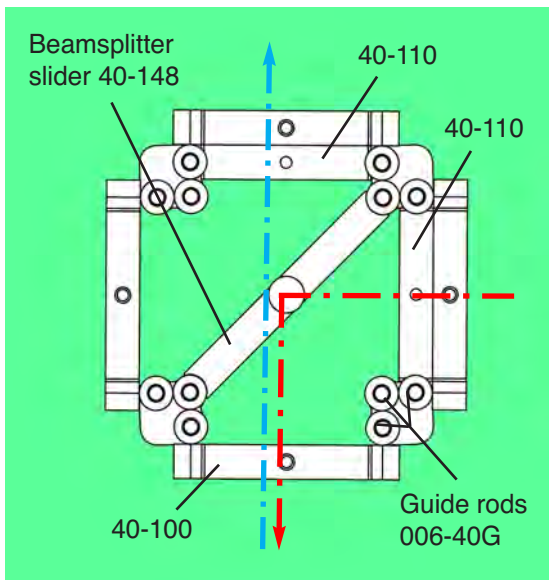


Sliding Beamsplitter 40-148

I think we are there now to start constructing our beamsplitter assembly. Let's view the assembly constructed above. It takes 8 Rod Corner Connectors 40-144 to construct this cube.

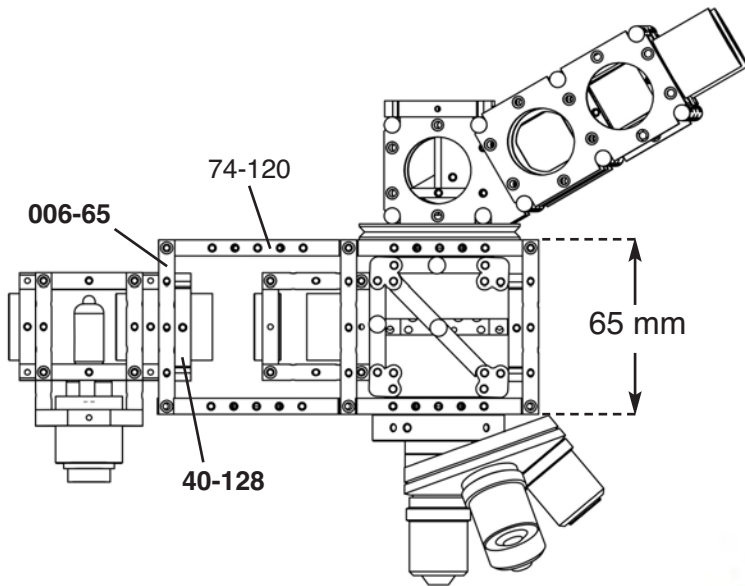
Several sliding mounts 40-110 could be side connected to add as many filters one would wish to have, or a 3-position filter holder could be designed for securing a set of 3 filters for Emission, and another set to secure Excitation filters. If you notice there are four sides to the beamsplitter cube, securing the emission, transmission and the objective lens. What could we use the 4th aperture for?

The fourth side is utilized to secure a light trap. The light trap is the most crucial part of the beamsplitter assembly. It would influence the image contrast. Several designs are offered for light traps. One simple example would be a small can, painted dull black on the inside, filled with black anti static sponge.



Building our very own Fat Microscope

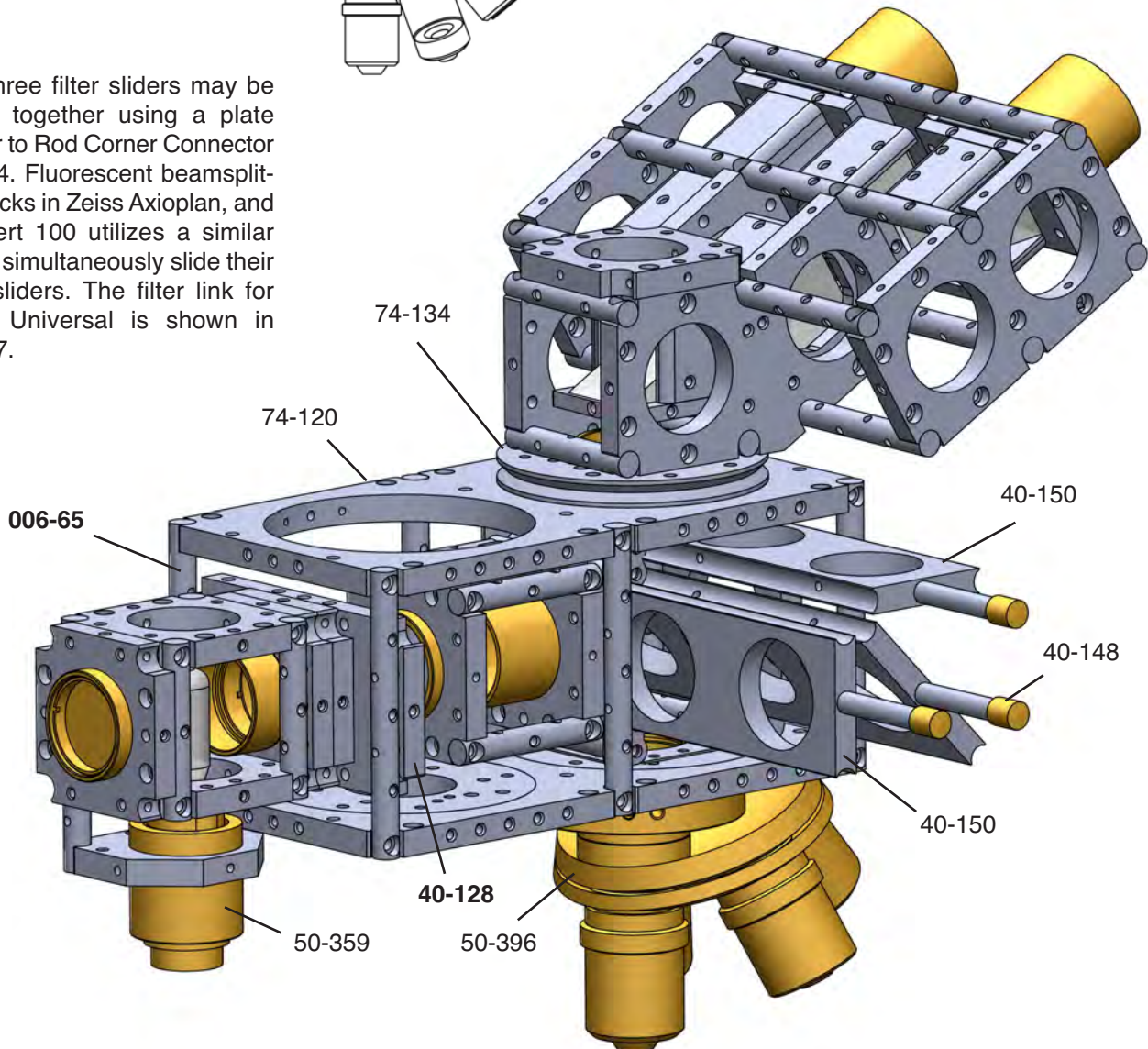
Lets now integrate our beamsplitter assembly with other sub assemblies we had constructed in past issues. The filter sliders are also shown. The light source could be Halogen but a high intensity Mercury or Xenon lamp is recommended. We'll be making one later. We now have to decide where we'll mount the beamsplitter assembly. The best option would be to mount it inside a larger housing to light seal the beam path. So we'll remove the upper, and lower 40-100 mounts,



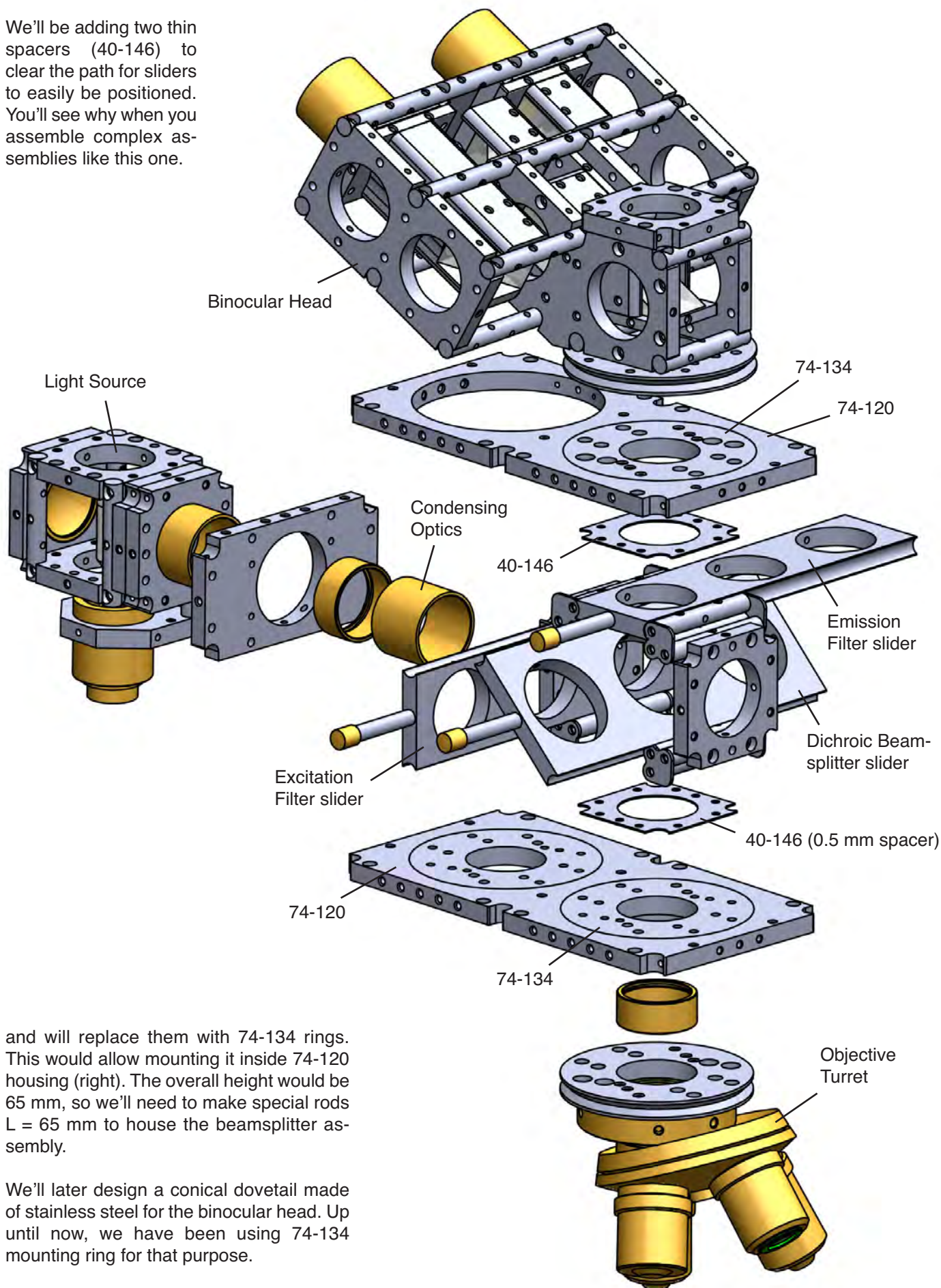
Note in spite of the height difference in this illumination assembly with standard 40, and 74 mounts, mount **40-128** is mounted at the center of rod pair **006-65**.

In this case, 40-128 is secured to 006-65 from the inside. This allows cover plates to cover the illumination housing without any mechanical conflict with its lamp housing.

The three filter sliders may be linked together using a plate similar to Rod Corner Connector 40-144. Fluorescent beamsplitter blocks in Zeiss Axioplan, and Axiovert 100 utilizes a similar link to simultaneously slide their filter sliders. The filter link for Zeiss Universal is shown in page 7.

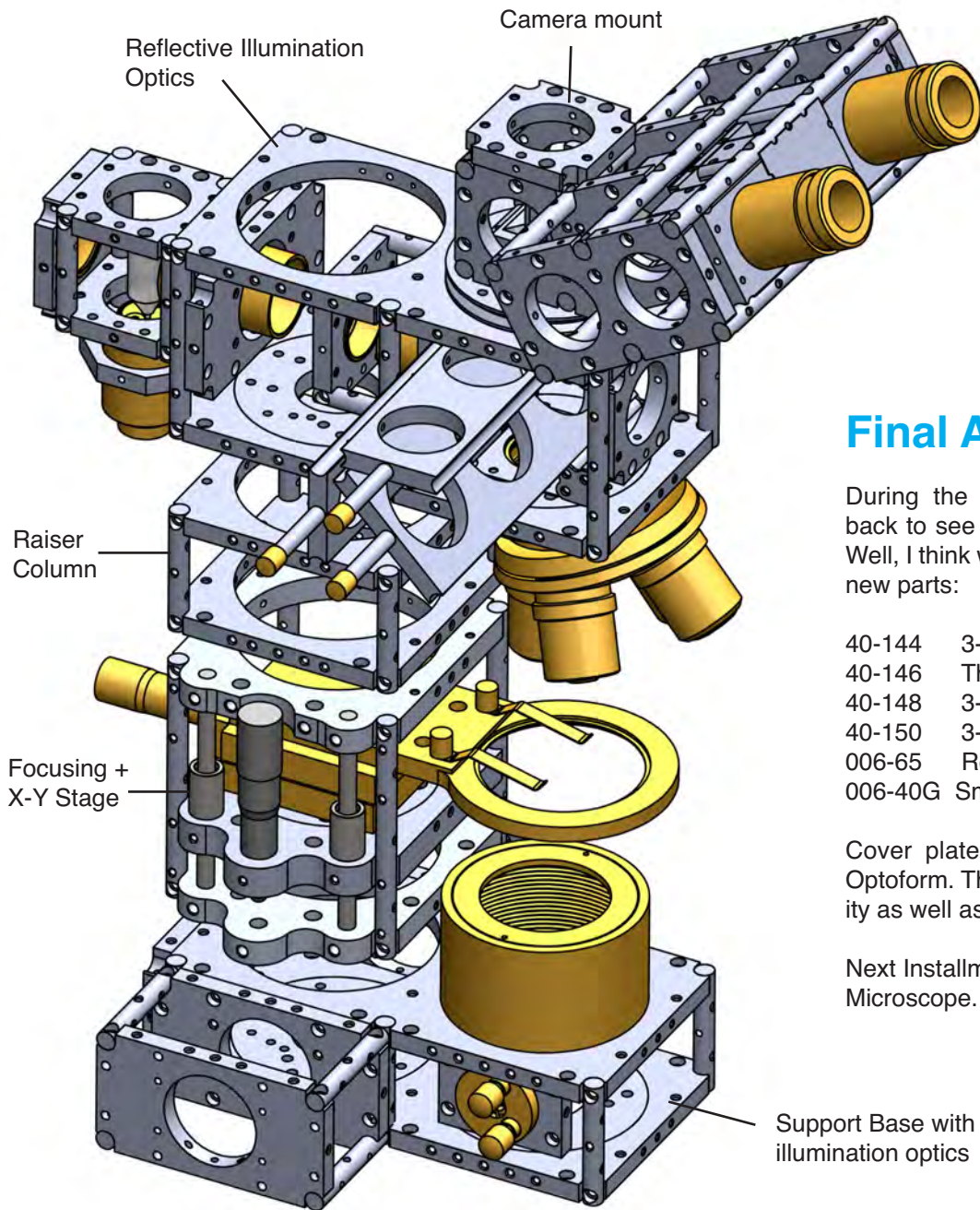


We'll be adding two thin spacers (40-146) to clear the path for sliders to easily be positioned. You'll see why when you assemble complex assemblies like this one.



and will replace them with 74-134 rings. This would allow mounting it inside 74-120 housing (right). The overall height would be 65 mm, so we'll need to make special rods $L = 65$ mm to house the beamsplitter assembly.

We'll later design a conical dovetail made of stainless steel for the binocular head. Up until now, we have been using 74-134 mounting ring for that purpose.



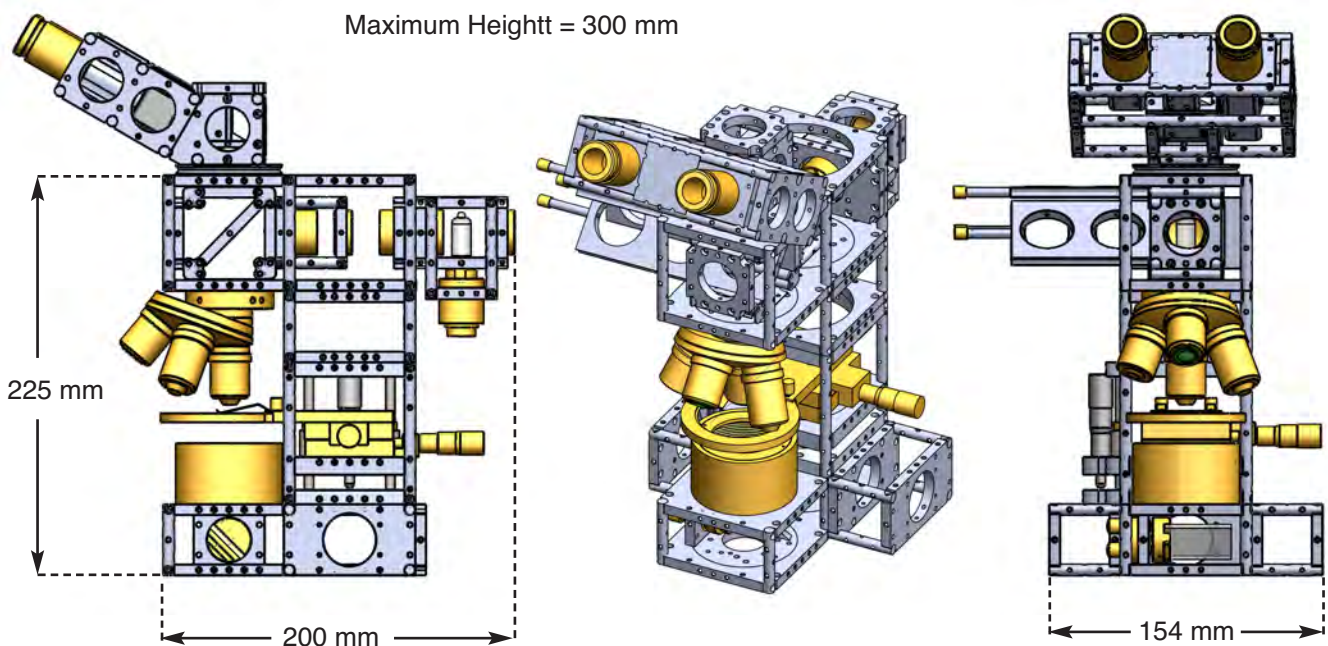
Final Assembly

During the final assembly we'll look back to see how we did in our design. Well, I think we did ok by just adding six new parts:

- 40-144 3-Rod Corner Connector
- 40-146 Thin Plate 0.5 mm thick
- 40-148 3-Position Diagonal Slider
- 40-150 3-Position Filter Slider
- 006-65 Rod L = 65 mm
- 006-40G Smooth Guide Rods

Cover plates play a big role in new Optoform. They provide structural rigidity as well as light seal the assembly.

Next Installment: Scanning Confocal Microscope.



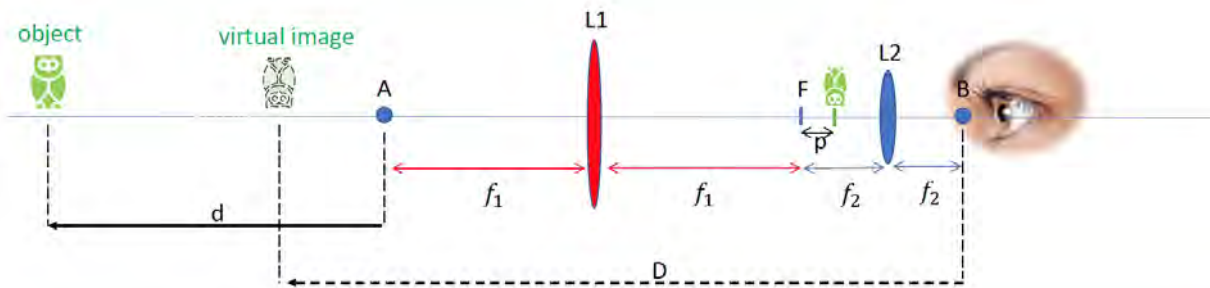
Basic Theory of a Focused Keplerian Telescope

By: Omid Jahromi, Ph.D.



Image position calculation requires some assumptions:

1. The target distance "d" is measured from the front focal point A of the objective lens L1.
2. The virtual image distance "D" is measured from the back focal point B of the eyepiece lens L2.
3. L1 and L2 have a common focal plane at F (thus forming an afocal Keplerian telescope).
4. Eye is positioned at the back focal plane B of the eyepiece lens L2.



Laws of Physics:

Newtonian lens law for L1:

$$d \times p = f_1^2$$

Newtonian lens law for L2:

$$D \times p = f_2^2$$

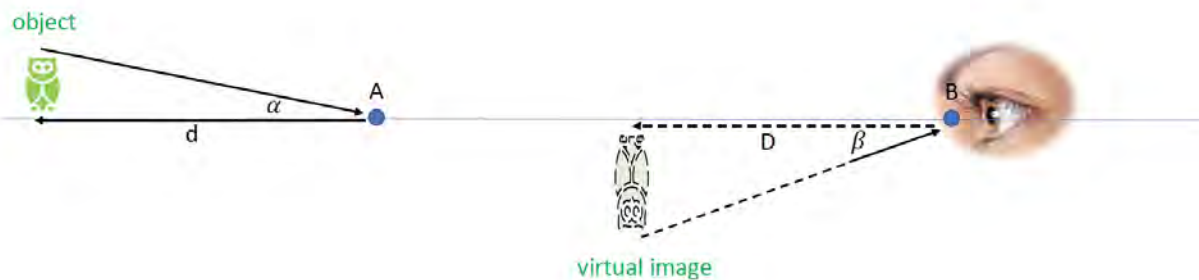


Image position from eye:

$$D = \frac{d}{M^2}$$

Image size (hence linear magnification) follows geometrically from the previous slide's result

$$D = \frac{d}{M^2} \quad \frac{\tan \beta}{\tan \alpha} = M \quad \Rightarrow \quad \text{Image size} = \frac{1}{M} \times \text{Object size}$$



Summary of Afocal imaging formula

$$\text{Angular image size} = M \times \text{Angular Object size}$$

$$\text{Linear image size} = \frac{1}{M} \times \text{Object size}$$

$$\text{Image distance} = \frac{\text{Object distance}}{M^2}$$

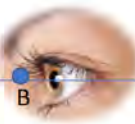


object



virtual image

A



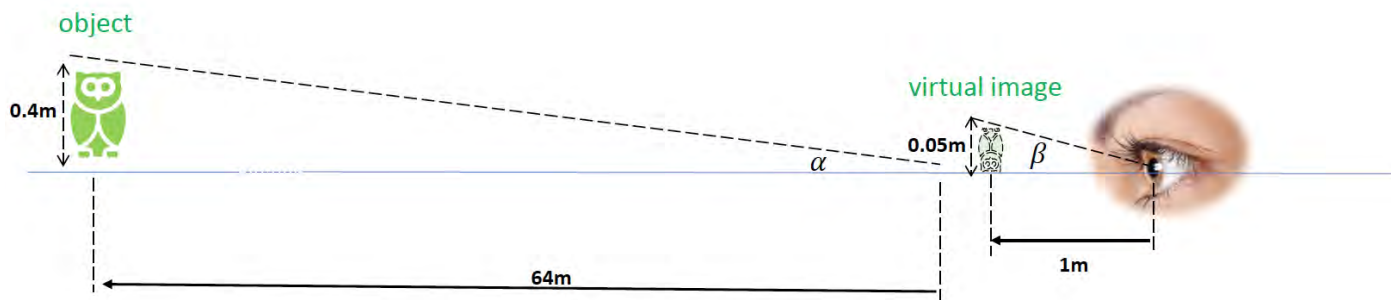
B

Note: These simple and beautiful formulas are obtained thanks to choosing distinct reference coordinates for the image space and object space: The reference point for object distance is the front focal point of the objective lens (point A) whereas image distance is measured with reference to the back focal point of the eyepiece (point B).

Example:

Question: If we use an 8X telescope to look at an owl who is 40cm tall and is sitting on a tree at a distance of 64m, what do we see?

Answer: An 8X afocal telescope forms a reduced image which is 5cm tall but is located only 1m away from the eye.



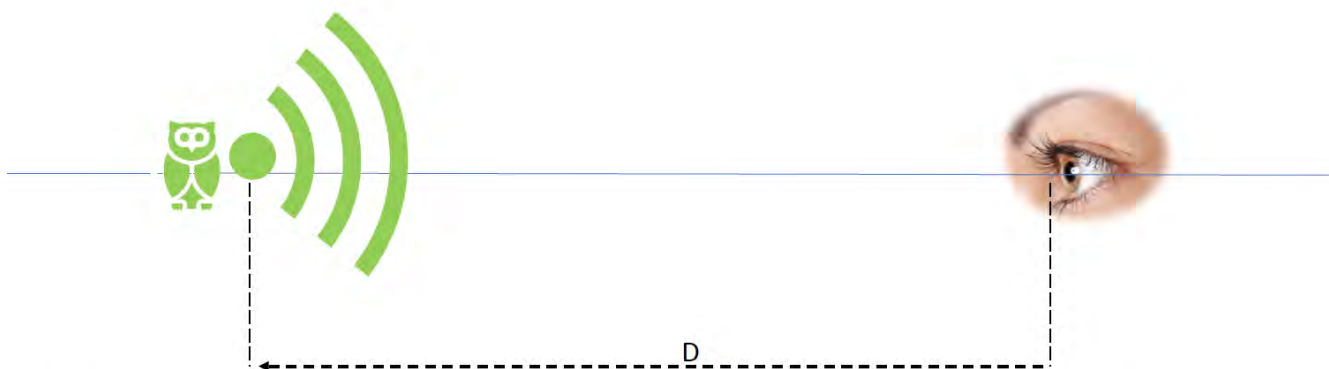
$$\tan(\alpha) = \frac{0.4}{64} = 0.00625 \quad \tan(\beta) = \frac{0.05}{1} = 0.05 \quad \Rightarrow \quad \text{8X angular magnification}$$

Part II Light Vergence Formulae for AFOCAL telescope

Definition of Light Vergence

Vergence (expressed in Diopter) measures the curvature of a light beam.

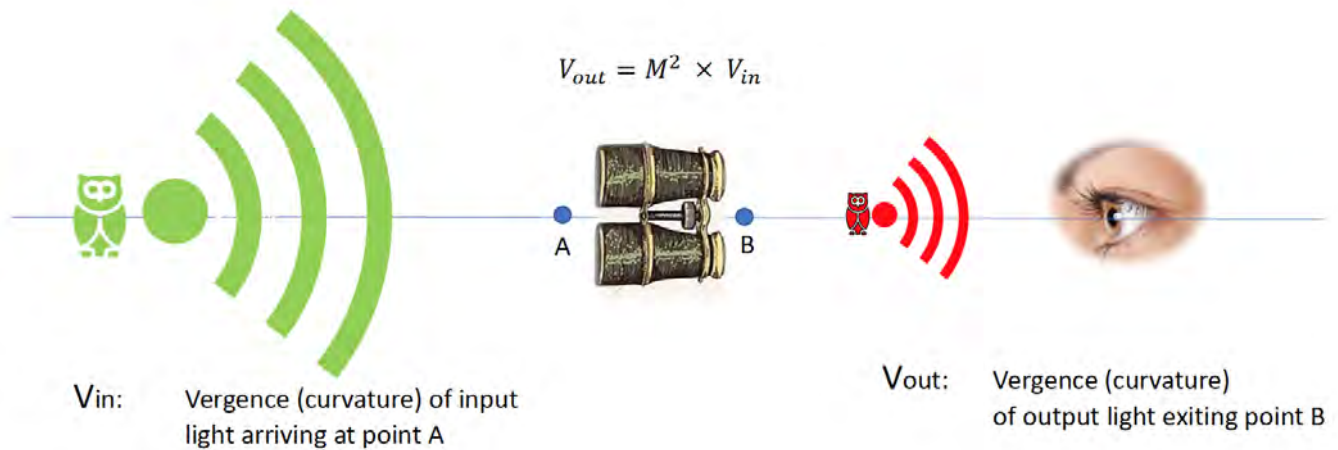
A divergent beam is assigned a negative vergence value. A convergent beam will have a positive vergence value.



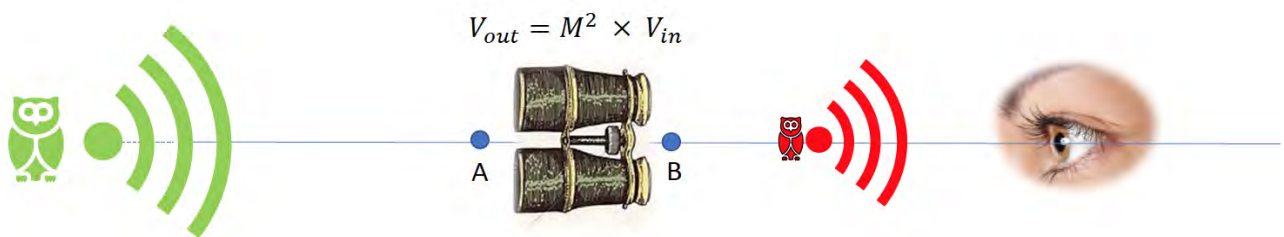
A natural "point object" located at a distance D from the eye will reflect a diverging light beam whose vergence upon arriving at the eye pupil is:

$$V_{eye} = \frac{-1}{D}$$

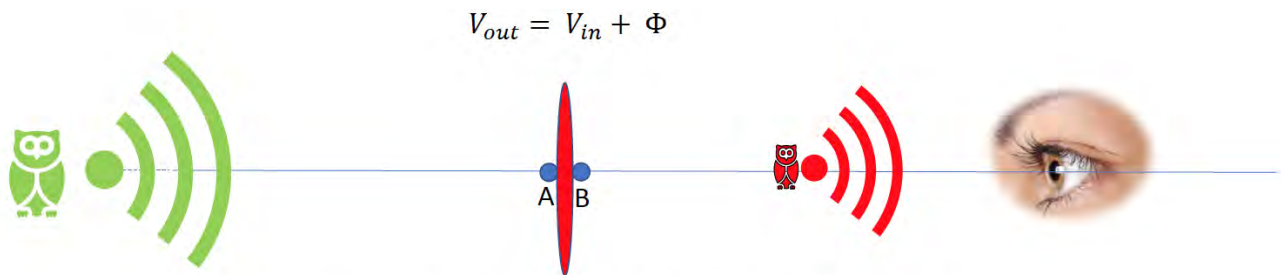
How does an AFOCAL telescope manipulate light vergence?



An afocal telescope multiplies object light vergence by a constant:

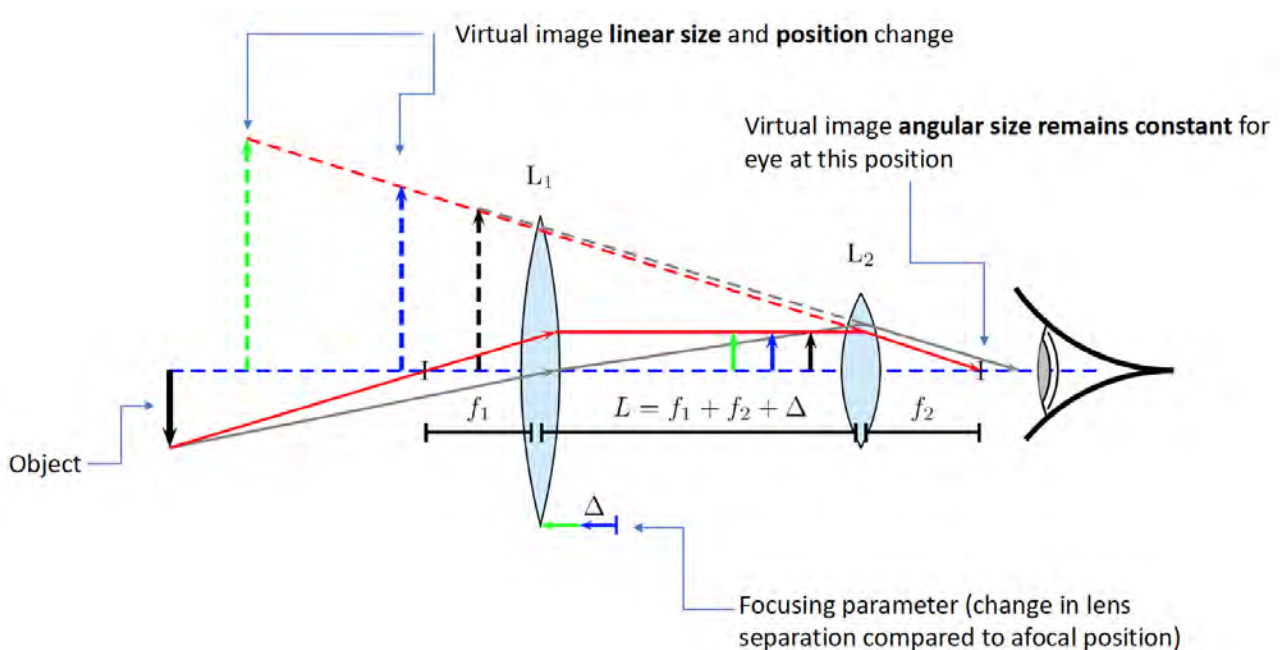


where as a thin lens adds a constant value to the object light vergence:



Φ : lens power in Diopter, can be positive or negative

Part III Effect of Focusing

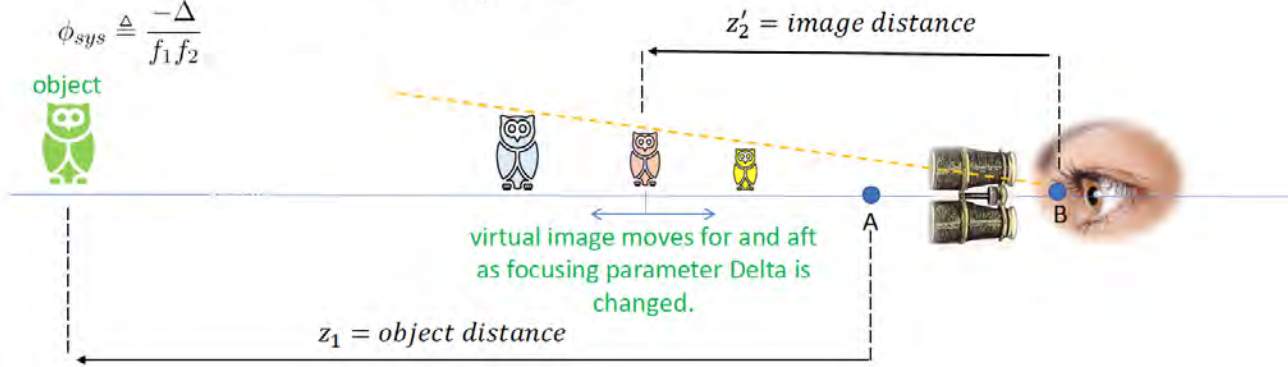


Focused telescope imaging formula

Angular image size = $M \times$ Angular Object size (constant, not affected by focus)

Image distance: $z'_2 = \frac{1}{M^2} \times \frac{z_1}{\phi_{sys} z_1 + 1}$

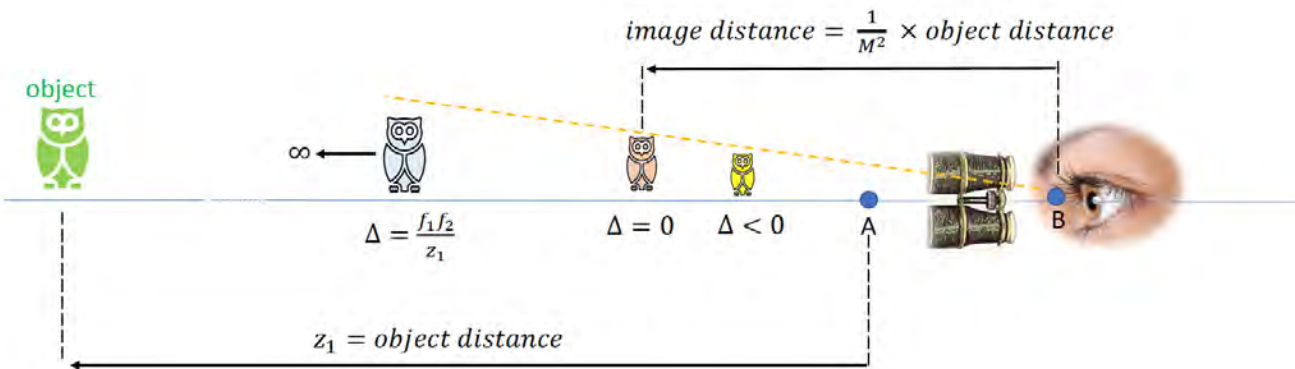
$\phi_{sys} \triangleq \frac{-\Delta}{f_1 f_2}$



Two Special Cases

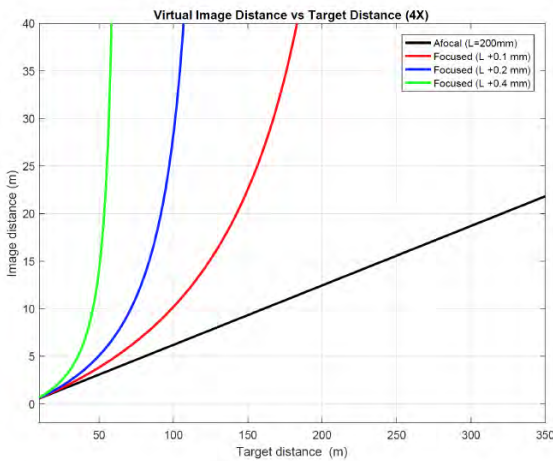
$\Delta = 0 \rightarrow \Phi_{sys} = 0 \rightarrow$ image distance = $\frac{1}{M^2} \times$ object distance (afocal telescope)

$\Delta = \frac{f_1 f_2}{z_1} \rightarrow \Phi_{sys} = \frac{-1}{z_1} \rightarrow$ image distance = ∞ (image focused to infinity)

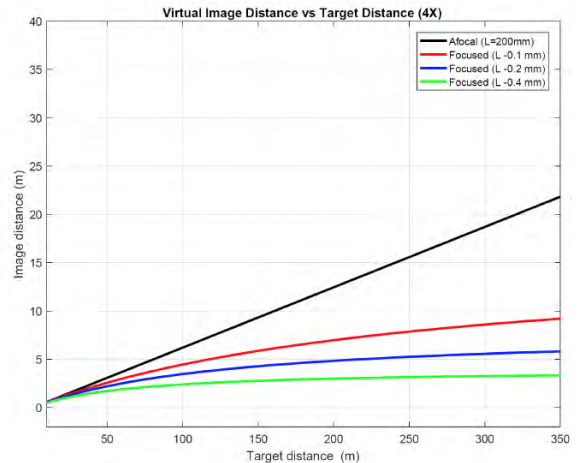


For a focused telescope, image position is a non-linear function of object distance:

$$z'_2 = \frac{1}{M^2} \times \frac{z_1}{\phi_{sys} z_1 + 1}$$



(a) Positive focus ($\Delta \geq 0$)



(b) Negative focus ($\Delta \leq 0$)

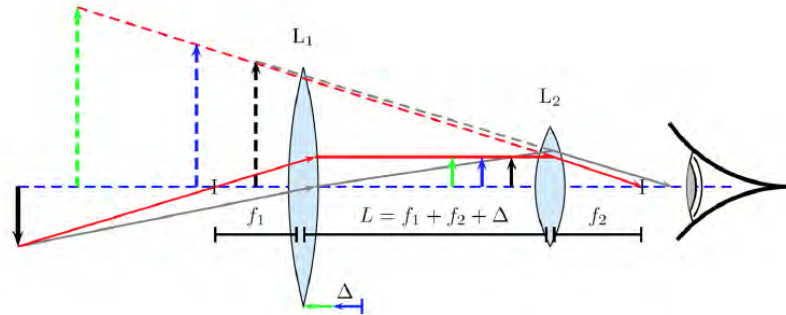
A focused telescope is a FOCAL instrument

A focused telescope is a “focal” optical system (like a lens) for which characteristics such as dioptric power and focal length can be defined:



$$\text{System Dioptric Power} = \Phi_{sys} = \frac{-\Delta}{f_1 f_2}$$

$$\text{System effective focal length} = \frac{1}{\Phi_{sys}}$$

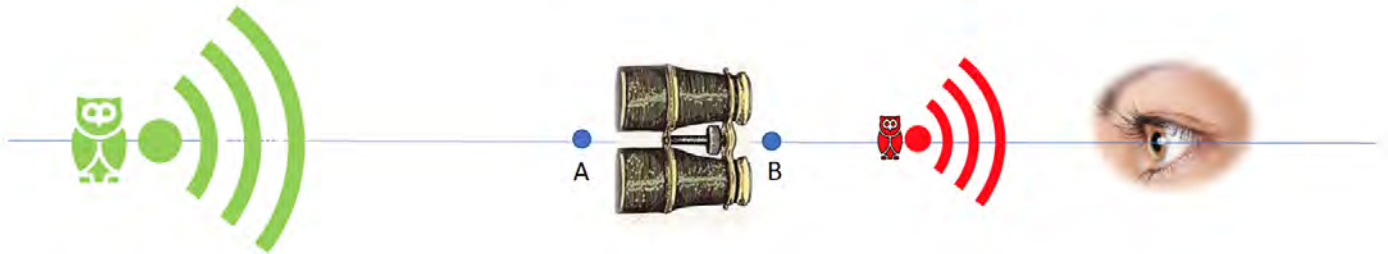


Important note: A focused telescope does not form images like a thin lens of the same effective focal length. The principal planes of a focused telescope are widely separated, creating imaging characteristics which are drastically different.

Part IV Light Vergence Formula for a focused telescope

How does a focusable telescope manipulate light vergence?

$$V_o = M^2 \times V_t + M\phi_{sys}$$



A focusable telescope first multiplies object light vergence by a constant (which only depends on magnification) and then adds a constant value (which depends on state of focus).

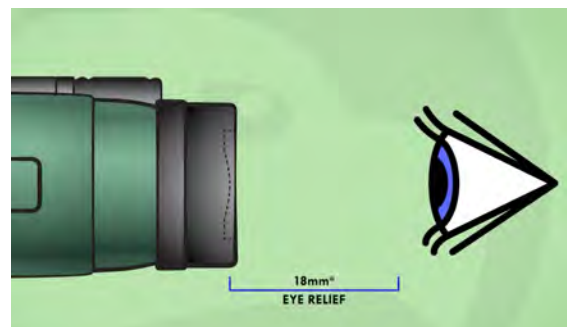
An afocal telescope amplifies input light vergence by a constant factor:

$$V_{out} = M^2 \times V_{in}$$

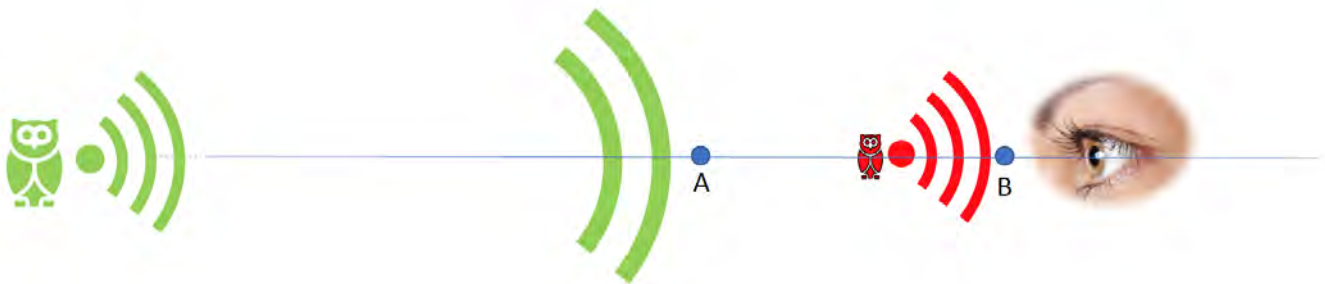
A thin lens adds a constant value to input light vergence:

$$V_{out} = V_{in} + \Phi$$

A focusable telescope first amplifies the input vergence then adds a constant (which can be positive or negative) to it:

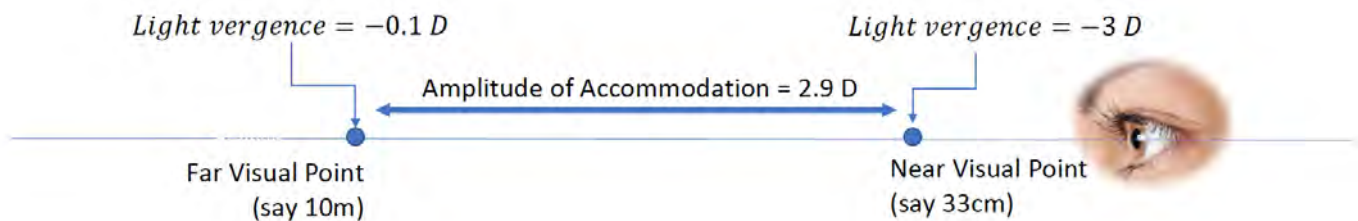


$$V_o = M^2 \times V_t + M\phi_{sys}$$



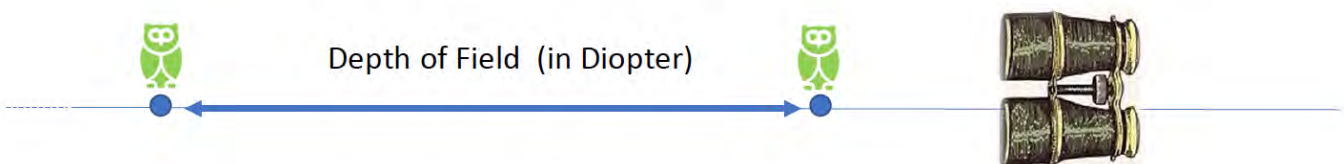
Part V Depth of field for a focusable telescope

Assume that a particular observer's eye can accommodate from a "near point" corresponding to a maximum acceptable vergence value to a "far point" corresponding to a minimum acceptable vergence value. The difference between maximum vergence and minimum vergence that a person can accommodate to is called "Amplitude of Accommodation".



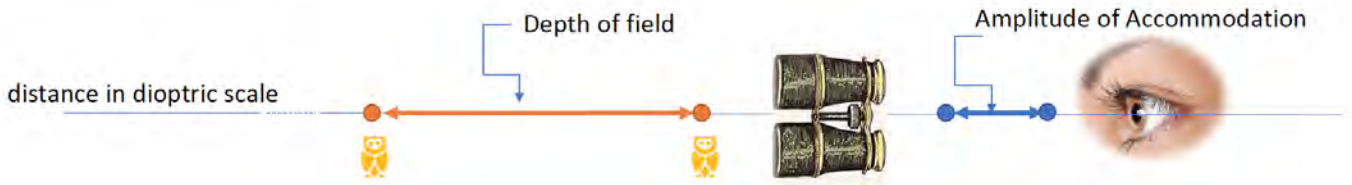
If this person looks through a focused telescope, he will be able to see various objects sharply and clearly as long as the output light vergence for those objects fall within his amplitude of accommodation.

We define Depth of Field as the dioptric range of objects that a person with a given amplitude of accommodation can comfortably see through the telescope:



- Depth of field of a focusable telescope measured in diopter scale is constant.
- Depth of field is reduced proportional to magnification squared.

$$\text{Depth of Field (in Diopter)} = \frac{1}{M^2} \times (\text{Amplitude of Accommodation})$$

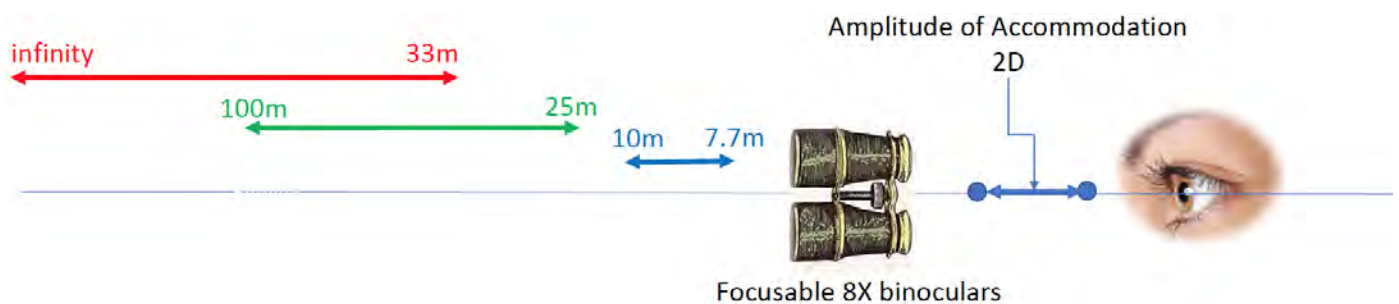


Focusing can not change depth of field (in dioptric scale) but can change the near point and far point of viewable distances in object space.

Example:

A person with 2 Diopter amplitude of accommodation looks at a natural landscape through his 8X binoculars.

His "dioptric" depth of field will be 0.03 Diopter. This he can not change. But he can choose the near point of his object space by focusing. This allows him to observe ranges such as [0 to 0.03D] or [0.01 to 0.04D] or [0.10D to 0.13D], etc. These sample ranges are shown below.



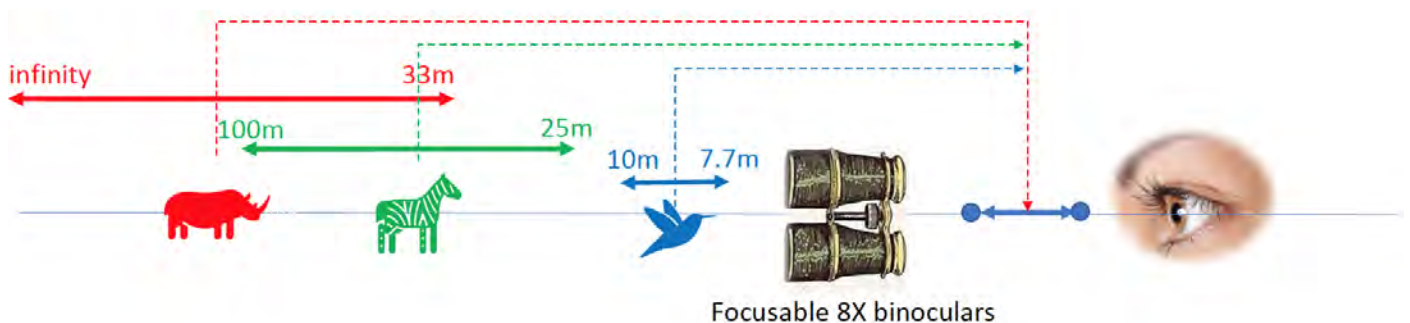
Part VI Why telescope images are never observed at "infinity"

Human eye is used to seeing objects in their natural environment where they are surrounded by a "fore ground" and a natural "back ground".

The most natural view through a telescope occurs when the object of interest is positioned in the "dioptric center" of the instrument's "Depth of Field" so that some fore ground and some background is also viewable by the eye.

Translating this requirement from the object space to visual space implies that the image vergence must be at the intermediate point of the observer's amplitude of accommodation.

Therefore, the observer focuses his telescope such that the object of interest is observed with a finite (non-zero) vergence approximately half the value of his amplitude of accommodation.

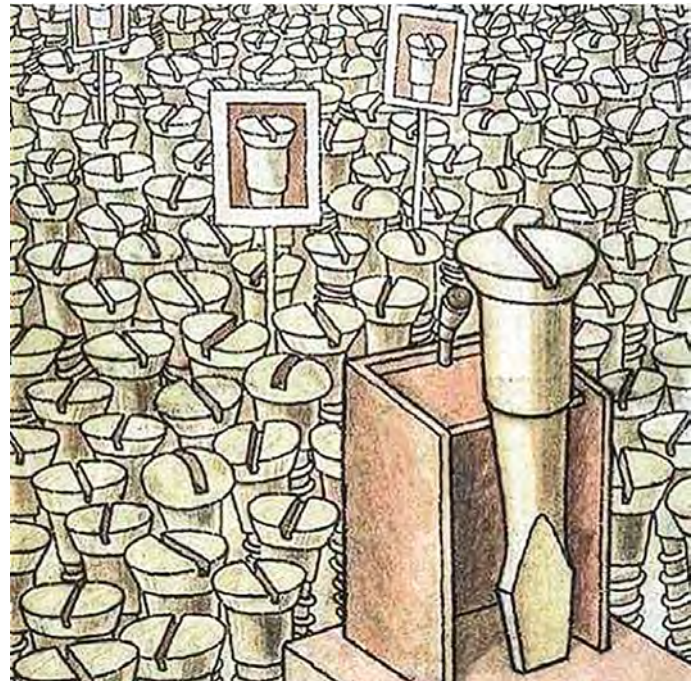


END

Enneagram is a template of our behavioral habits. If you are over criticizing yourself, and if you remember every detail of your past that keeps flashing in your mind, and constantly have regrets about your past, you are most likely a type 1. Knowing that, helps you remove those colored glasses to see the world as it is, instead of thinking what you see is real. Mastering your mind will bring you true happiness. Without a clear mind, you'll be always self limiting, and self degrading.

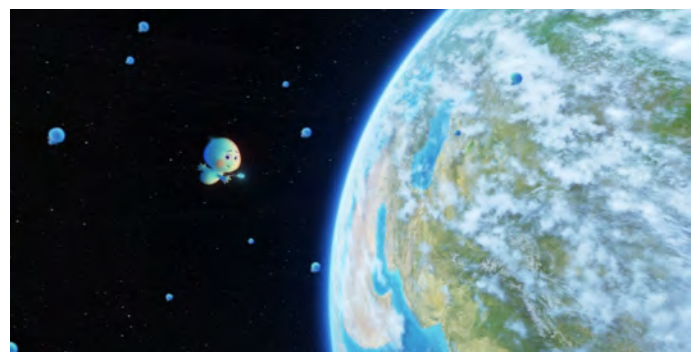
Becoming a peaceful warrior is really the most difficult task in life. In his teachings, Eckhart Tolle always emphasizes on liberation from the mind, and living in the now. But how would you turn your mind switch off? I found Enneagram to be the right tool for it. These are techniques you could learn to free yourself from your inner sadness.

There are two great animated movies that I would like to bring up in our discussion of the self. Pete Doctor has contributed immensely by developing these works of art. They are called the "Soul", and "Inside out". These are concepts learned from Rumi's book: "Masnavi". Western world has always been interested to understand the teachings of this book, but every nation has to have its own interpretation to understand spiritual concepts.



Although so delightfully intended, this is the worse kind of leadership, and that's how it usually is. People blind fully listening to a leader to be screwed for life.

Carlos Castaneda's books are works in English literacy, but he had followed the path a great teacher to bring it to life. This is true about everything you, and I are good at. If you are good at chemistry, you must have had a good teacher who helped you understand it clearly. The "Soul" presents life as that teacher, and it points out that we chose to descend to earth, and after our return, we'll have the earth experience, but those who didn't come here, will not know it. Who was the mentor who encouraged us to come here, is a real mystery. Taking this journey to earth, had prerequisites that we know so little about. All sorts of beings chose to come to earth, from hunchback of Notre-Dame to Elon Musk.



Courtesy, 2015 Pixar Animation

Soul: We were encouraged to come to earth to experience life, but who was our mentor? These are some of the big questions the movie raises. We could compare it with those who have been our life mentors, so why doubt there could have been similar beings that we now can't remember? Another big point the movie raises is we decided who we want to become before coming here.

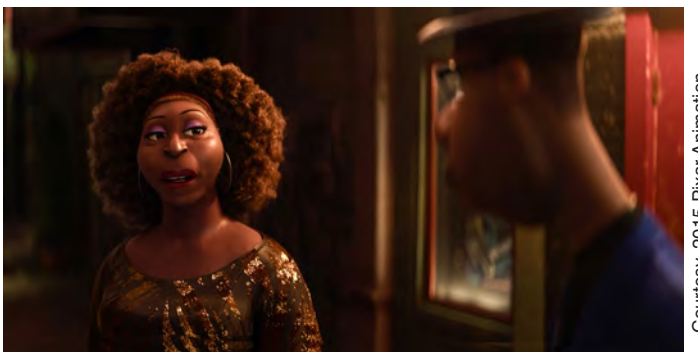


Courtesy, 2015 Pixar Animation

The mystics world is shown to be accessible by spiritual travelers like Moon Wind. He helps a hedge fund manager to realize what he's doing with his life. After this awakening, he throws all his computer monitors off his desk, and yells: "I'm alive!" "I'm alive!" One of the questions the youth has every right to ask is: "How will he now be making a living?"

Mysticism is not about quitting your job, and to go live like a homeless. It is allowing yourself to seek the meaning of life when you are called from within. You'd come back with some answers, and continue your search while living your ordinary life. Knowing those initial answers will help you learn to live life with self worthiness, and to also find you true purpose. Rest assured that in the world hereafter, we'd be placed on a continuing journey in some other form. So we'd better find a worthy purpose that we could carry on.

What's harmful is when we literally take something that has nothing to do with who we are and say: "This is me". One could have wealth, and not consider it as "me". Everybody works, and everyone serves one another. Even God is really busy working: "We would know when the time comes".

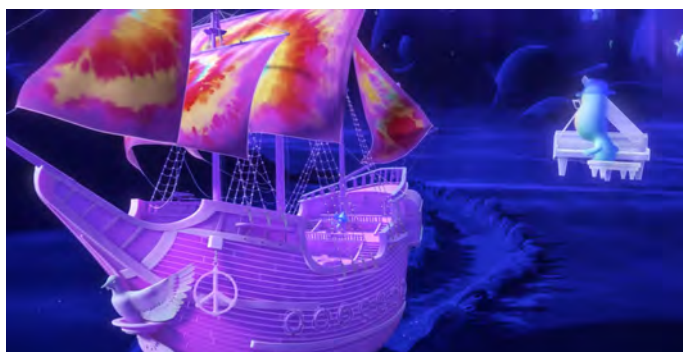
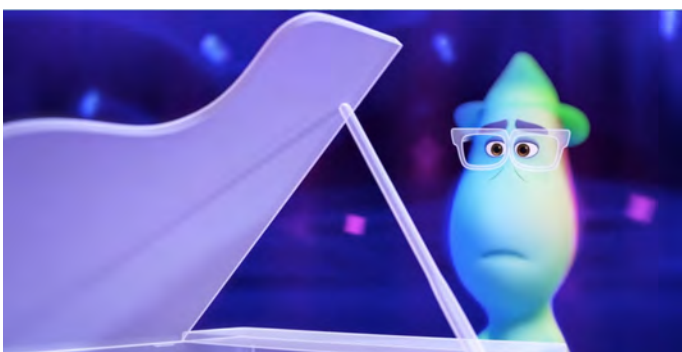
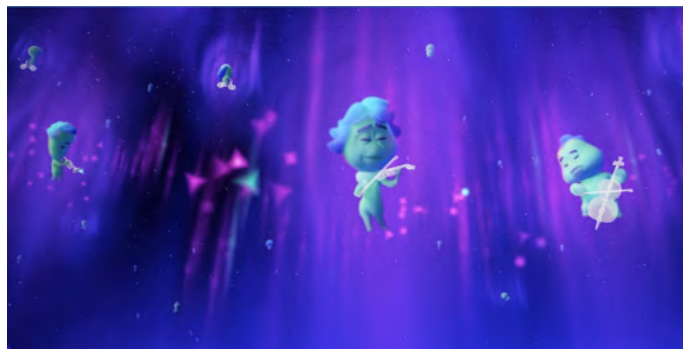


Courtesy, 2015 Pixar Animation

Dorothy: I heard a story about a fish: He swims up to this older fish and says: "I am trying to find this thing they call the ocean". "The ocean?" Says the older fish, "that's were you're in right now." "This?" Says the young fish, "This is water, what I want is the ocean."

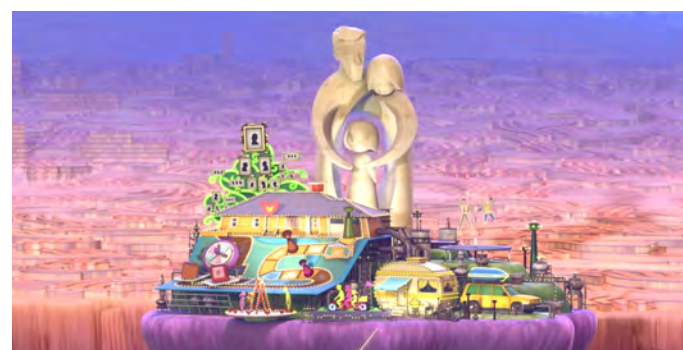
It's interesting when you read the fish, and ocean story in Rumi, it's difficult to understand what it really means. It's a metaphor that would have a different meaning to anyone who is looking for meaning of life.

Let's look at that conversation again; Joe: "I have been waiting for this day my entire life but I thought I would feel different". This is the same line Dustin Hoffman says to his father in "The graduate". The fish and ocean story is addressing their point. One interpretation of this poem is if we don't enjoy the path, we'd miss the ending. We should enjoy life while we are on the path, and not wait until we got there. Think about it: If the only point of being here is to have this life's experience, then we'll have it whether we succeed or not. Whomever sent us here, knew we'll get this experience. Those who struggle harder might be wearing some fancy clothes in hereafter, and hang out with more influential people. In fact, the more failures we have means we've tried more challenging paths, and we'll have more interesting stories to tell.



Courtesy, 2015 Pixar Animation

Let's revisit how Joe is able to enter the mystic "Zone"; It's through his piano. What you love is your means to get to the zone. If you are disconnected from the spiritual zone, then you haven't found what you truly love, and are good at.



Courtesy, 2015 Pixar Animation

Inside out: Family bounds are so weak in America, and this movie by Pete Doctor focuses on family. The best events of our lives are stored as "Core Memories". Without them, good luck climbing out of mind's worse trap called depression.



Courtesy, 2015 Pixar Animation

Joy had to let go of Bing Bong (childhood imaginary friend) in order to rescue Riley, an 11 year old girl from Minnesota.

Inside out focuses on the inner dialogs we keep hearing in our mind. The five characters are: Sadness, Fear, Joy, Anger, and Disgust, but it's really an over simplified version: "Mind dialog 101". The main focus is on joy, and sadness. When Joy makes up with sadness, true happiness is realized. American poet Robert Bly says: "You could always spot an American in the streets of Europe when you find someone smiling". He points out a similar dilemma in trying to make a bridge between men, and their father in America. Jack Nicolson, in "Five easy pieces" takes his father who is half paralyzed, and speech impaired to the beach. He starts telling him about his own failures in life, and begins crying: "Sorry my life didn't turn out the way you had wished". While the father stares at him in silence on his wheelchair, Jack says: "I wish this was a two-way conversation, but my feeling is if you could talk, we wouldn't be having this conversation.

Making peace with the father is a big challenge because what most men have experienced with their dad has been their temperament. We could get by not connecting with the father but you can't go too far with it. As Robert Bly says, jokingly:



Courtesy, 2015 Pixar Animation

The control room starts with just one button, but then expands to a huge consul. In the last issue, I illustrated Rumi's model: The carriage with a driver, a passenger, and horses. What's missing in this simplified model is a holly preacher. Anger is also way too simplified. It's much more complex than dealing with sadness, but it's dealt with the same way.

“You’d hear some men say: I have been divorced 8 times, but I’m fine!” You can’t fix your life until you learn to sympathize with your father; “Up until I was able to connect with my father, I was writing poetry from a glass shell around me”. The solution, he says, is to accept grieve, not blame, but to learn to grieve, he says: “The boy has to go to the father to fix it”. Like sadness in this movie, the father feels inappropriate, and unwanted. So how would it be possible to help Joy win the battle in our minds? You’ll have to come up with your own solutions. Let me give you an example:

Those who have grown up in religious families are stuck with a very common mind dialog called sin. The first step is to get rid of the “sin” label by calling it: “mistake”. In Islam, sin qualifiers are called Sharia (jurisprudence). We have a more restrict version of it in Judaism called Halakha, meaning: “the way to walk or behave”. If you look up the statistics of the highest converts in America to Buddhism (the least difficult to practice), it’s from the Jewish faith. If you have the sin dialog present in your mind, I know a way out: Hold on to your religion at its core value, and broom out all other goodbye-laws you have been taught since childhood. Break a few minor rules just to get warmed up! Trust me, you won’t be thrown in hell for it. In a very short while, you’ll notice a new dialog starts taking place in your mind, and will find yourself in more control. You could always go back to your own self, but this time, you won’t be anguished by the sin dialog because it knows it will be shown out the door. You can’t become a peaceful warrior, until you begin to connect with your faith with full honesty.

According to Enneagram’s 9 personality types, in “Inside Out”, the father is type 2, and the mother is most likely a type 1. So let’s take a look at what types systematically would get married with each other without really knowing why:

Most Common Match If The:

- Woman is Type 1 (Perfectionist) + Man is Type 9 (Peacemaker)
- Woman is Type 2 (Helper) + Man is Type 8 (Leader)
- Woman is Type 3 (Achiever) + Man is Type 1 (Perfectionist)
- Woman is Type 4 (Artist) + Man is Type 9 (Peacemaker)
- Woman is Type 5 (Thinker) + Man is Type 1 (Perfectionist)
- Woman is Type 6 (Loyalist) + Man is Type 8 (Leader) or Type 9
- Woman is Type 7 (Enthusiast) + Man is Type 5 (Thinker) or Type 1
- Woman is Type 8 (Leader) + Man is Type 9 (Peacemaker)
- Woman is Type 9 (Peacemaker) + Man is Type 6 (Loyalist)



Most Common Match If The:

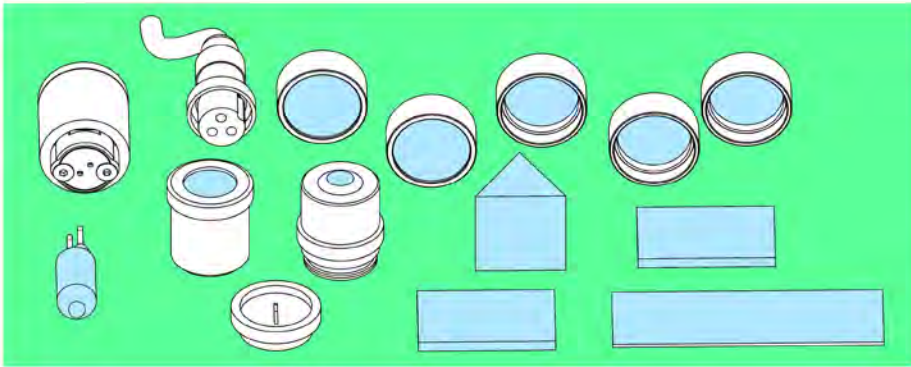
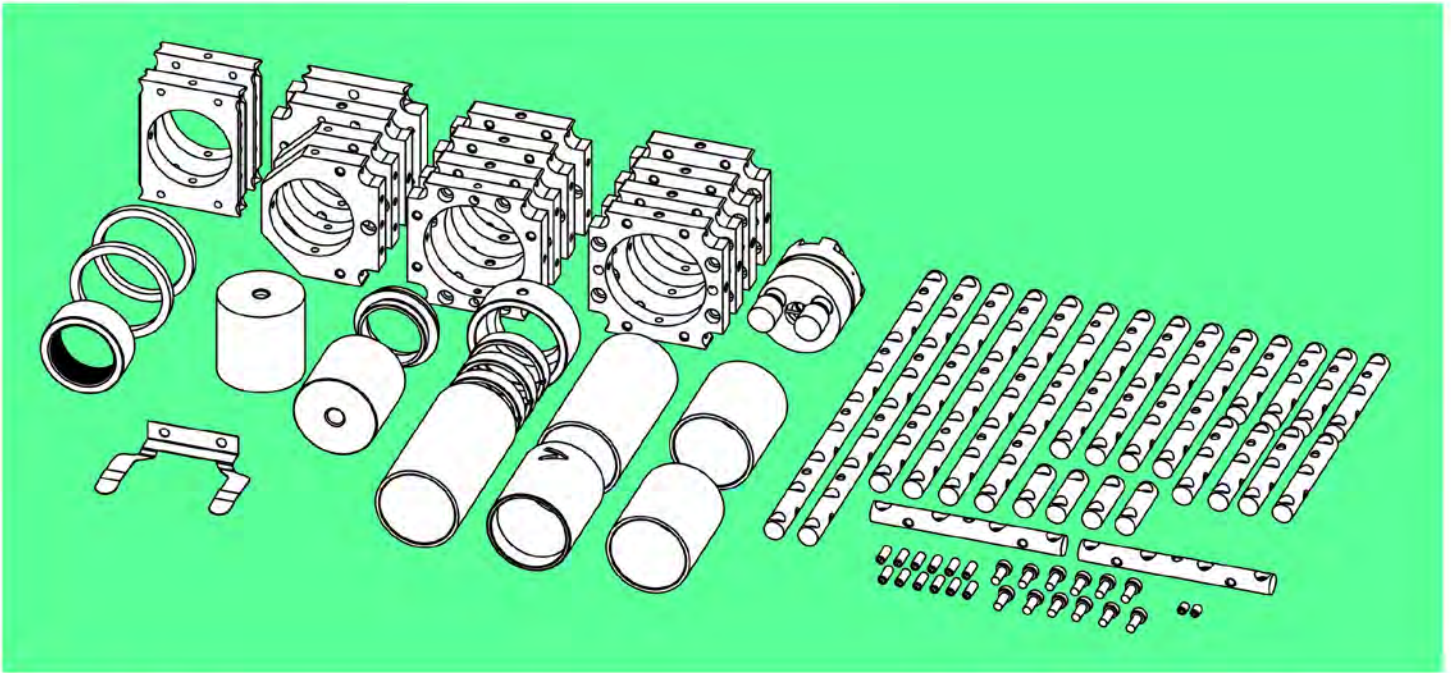
- Man is Type 1 (Perfectionist) + Woman is Type 2 (Helper)
- Man is Type 2 (Helper) + Woman is Type 4 (Artist)
- Man is Type 3 (Achiever) + Woman is Type 9 (Peacemaker)
- Man is Type 4 (Artist) + Woman is Type 2 (Helper)
- Man is Type 5 (Thinker) + Woman is Type 1 (Perfectionist)
- Man is Type 6 (Loyalist) + Woman is Type 2 (Helper)
- Man is Type 7 (Enthusiast) + Woman is Type 1 (Perfectionist)
- Man is Type 8 (Leader) + Woman is Type 2 (Helper)
- Man is Type 9 (Peacemaker) + Woman is Type 4 (Artist)

If you aren’t sure what type you are, test yourself to find out. Here’s is a test example for type 1:
A: Not true, B: Rarely true, C: Sometimes I feel this way, D: It’s usually the case, E: It’s absolutely true about me.

- 1) Most people think I am too serious; I think so too.
- 2) Although a part of me could be passionate but that’s really not my life style.
- 3) I think I have paid a high price for being a perfectionist.
- 4) I like to be happy like the rest of people but I have to work hard for it.
- 5) The world would be a better place if people were more principle-centered & acted from their conscience.
- 6) I’ll be condemned if I deviate from my ideals and high standards.
- 7) I can never be out of control (or else I’ll be led astray by strong subconscious impulses and desires).
- 8) I’ll be severely reprimanded if I make mistakes.
- 9) I’m responsible for making everything right.
- 10) I know I have been given a serious responsibility, and I will accomplish something so extraordinary in my life.
- 11) To be loved I must be perfect.
- 12) The world is imperfect.

If you gave yourself a score of 10 out of 12, you are definitely a type 1. If you aren’t type 1, then find out which type you are by taking other type’s tests. Truity is one place you could take an Enneagram test, and it’s free:

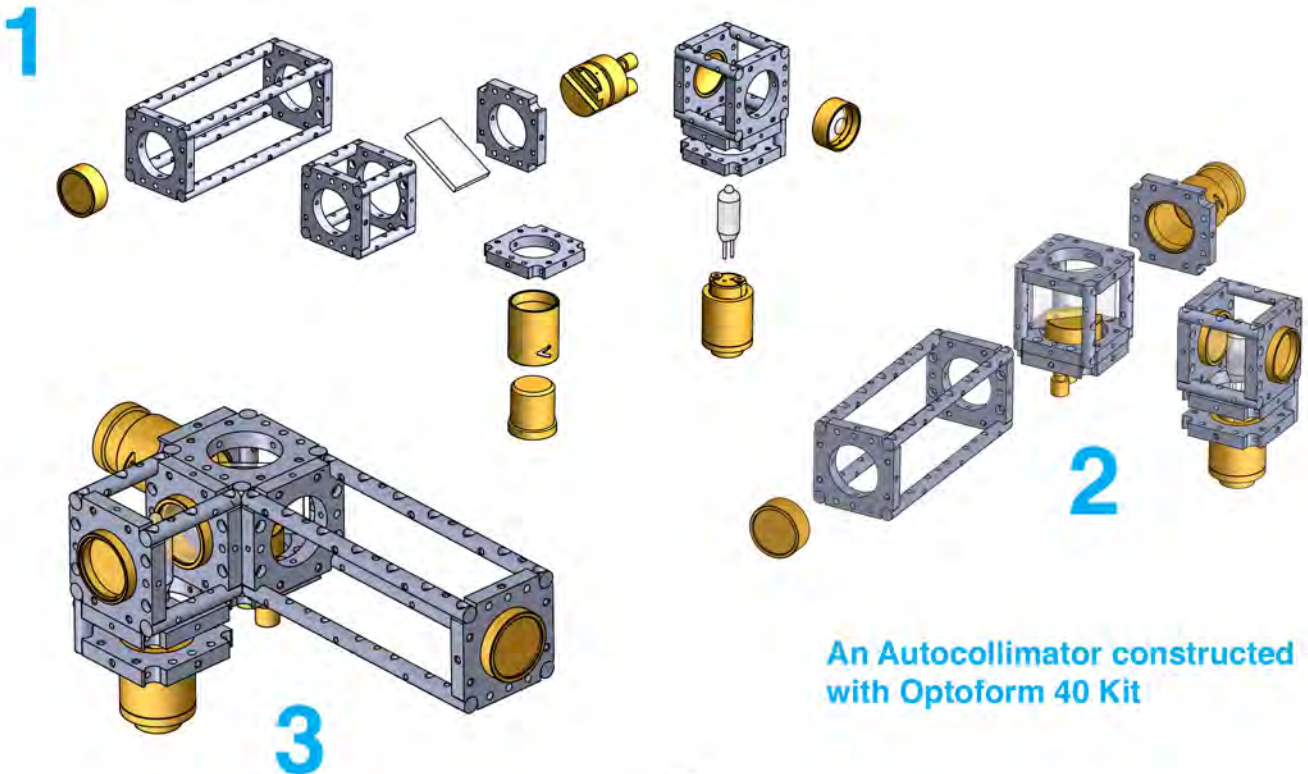
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