# 85 years Development of the optical erector set

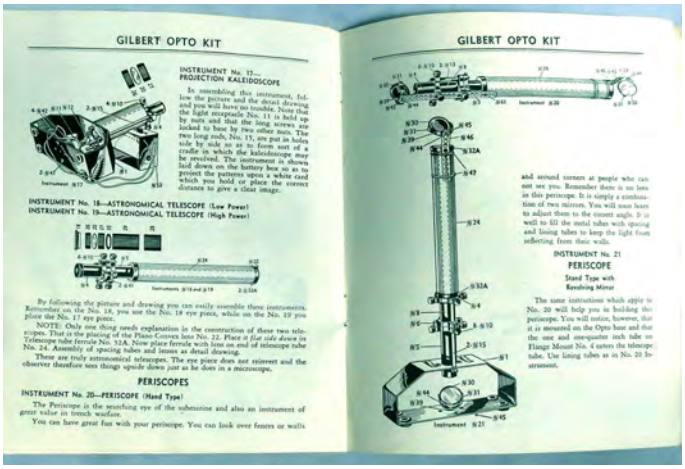
By Ali Afshari

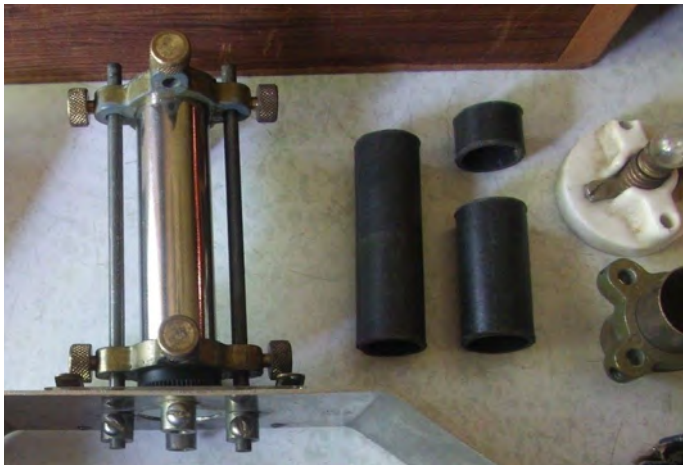
The optical erector set has had the utmost love affair among optical engineers. The fantasy to create a system that would allow building optical instruments that are both playful, and truly functional has been troubling designers, and end users alike. We have a fair collection of these kits at OMiD museum, and I would like to go over their innovative ways in assembling their pieces into optical instruments. In every design process, as the designer moves forward in creating function, he/she is always preoccupied with form. Why is form always so prevalent?

From childhood, our brain learns new design concepts by memorizing their form. For example, in creating icons for Windows or Mac, a microscope has a certain shape, while a telescope has its own universal shape. A spectroscope, or a camera also have their own universal shapes. So when we begin to build it with an optical kit, we would start with that same universal picture in mind. To build a microscope for example, we begin by matching its already learned form in our mind, and try to build it with the pieces present in the set. In post-mounted laboratory setups, form is not important, and a researcher only focuses on function, and the result. This makes doing science way too serious, and we end up writing dull papers children can't read. So here's our first design criteria: If a child can't play with it, it's not an erector set.

With this in mind, lets look at a few examples of Optical Erector Sets. One good example is "Gilbert's Opto Kit" (below), manufactured from 1936 to 1940. It was sold for $2.50, and a child could make 22 different optical instruments with it. A more fascinating and higher quality set is the "Constructments kit" set No.100, (opposite page). Gilbert's optical mounts utilized steel rods and set screws to secure lens plates at any distance from each other, while Constructments utilized long threaded rods, and bolts. The nuts, and bolts method is the less expensive alternative but the drawback is the time





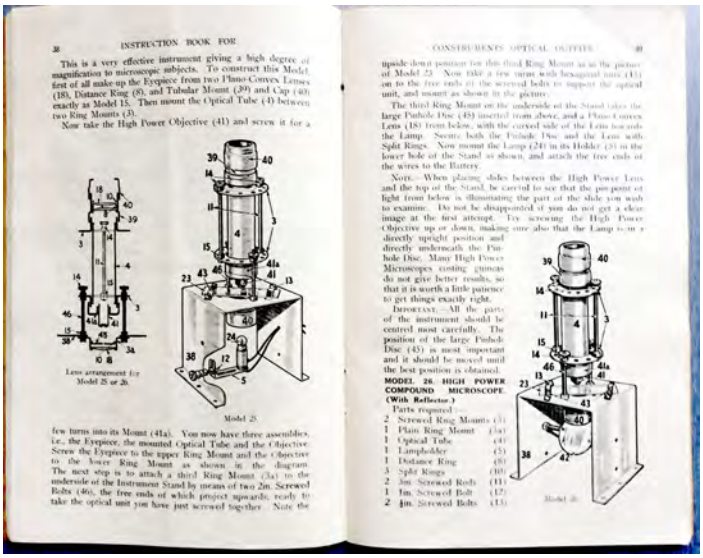



Gilbert's Opto Kit of 1936 in wooden box 25 x 22.5 x 6.5 cm at OMiD museum. Tubes are made of cardboard with outer Aluminium covering. This design resembles the four-rod scheme of Microbech system by Spindler & Hoyer. The engineering detail in the illustrations is amazing. It's like treating a child like an adult to seriously learn how to read blueprints.

it would take to position the bolts along the rods. For a 100 mm rod with a thread pitch of 1mm, the bolt has to be turned 50 times from either end to position it at the center of the rod. This is intentional in Erector-like toys, because it forces a child to think instead of immediately reaching the final assembly. Some parents try to help their child in assembling these kits, and they soon realize it takes more patience than they thought.

Curiosity is stoked the most by how different pieces go together to create form, and how they function together but also by how it is explained in a user's manual. Good illustrations are an important part of a science kit. They teach engineering at an early age, and set a model for the youth to follow when they grow up. What always fascinates me is how beautiful the user's manuals were written for these kits in the past. My technical writing teacher was an old man, and he said to us many times in class: "There are not so many of us left"! I remember telling him that I had written a book about camera design, and Cal State library in Los Angeles had a copy. After the next class session, he greeted me with joy, and said: "Ali, I read your book, and I thought it was wonderful! Why don't you explain your illustrations? Focus on explaining your illustrations". Ever since then, I try to write less, and continue using more illustrations.

Ever since plastics entered toy business, children's educational kits became easier to put together, and less thought provoking. When you teach mechanics, there are just no replacement to nuts and bolts. The next example in our inventory of optical sets is "kit No.1" made by American Optical (next Page). This kit is not as playful as the previous examples. It is more for verification of concepts from a text book, and it is more beautiful than useful. Its optical rails are so fragile that lenses might fall off in field use. The only "instrument-Like" device you could build with it is an already made periscope that (thanks God) it's made of cardboard. With cardboard, one might be encouraged to build other devices with it.

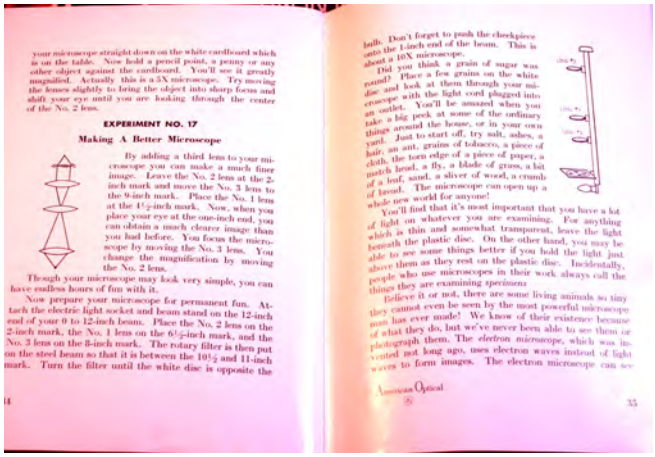





Construments Ltd London, set No.100 of 1930 in brown fabric clad box. A larger, briefcase size was avilable with more number of parts, and a smaller size called Set No. 20 was also available. Note "The White House" label. Could this be the optical kit president Roosvelt's children played with?! This design resembles Optoform circular mounts.

The next one I would like to discuss is a quite heavy kit (5Kg) made by NTL (bottom of this page). This kit has been designed to allow the end user to build a professional optical lab with a 1 meter optical rail. If I was a physicist, and wished to buy my son an optics lab kit, I would have bought him this set. It doesn't have X-Y stages that are required for higher level experiments, but it does have rotary stages suitable for polarimetry. A physics teacher at a high school would show students what to do with the parts in the kit. There are three light sources that would connect to standard lab power supplies, and a Moon, and Earth model to show lunar eclipse. There is also a good selection of filters, and image masks to perhaps perform some Fourier optics.




American Optical Kit No.1 has mounted lenses, color filter wheel, a light source, and lens carriers to secure them on a two-piece, extendable optical rail. The illustrated manual has fair number of illustrations, but similar to an optics chapter from a physics text book. There is a cardboard housing to consruct a periscope.

NTL optical lab kit consists of nicely finished extruded optical rail, and carriers. lenses, light sources, and filters are held in plastic lens mounts that are then inserted onto 100x100 mm lens boards. The lens boards have a friction tab on their base that allow them to be mounted on lens carriers. This makes a fair quality optical rail system.

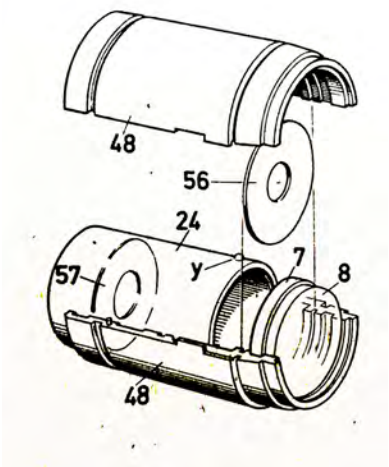
Now here is what proves me wrong in my philosophy about plastics entering the toy market. This is a fantastic kit (below) that is at its best in use of plastics. I hope I am not so fond of this kit because I like cameras, but no, it also comes with this very serious manual that gives any kid the true feeling of being an optical engineer. I was only 18 years of age when I arrived in US, and I saw this kit in the RadioShack catalog, and immediately fell in love with it. Unfortunately, it disappeared from their next catalog, and I waited 30 some years to buy one from eBay. It has precision injection molded parts to build a single lens reflex camera, and even has a neck strap! The bottom right image shows the manual illustration to install the mirror cage into the body. It shows how the shutter assembly, the mirror housing, and the viewfinder optics are layed out inside the camera.

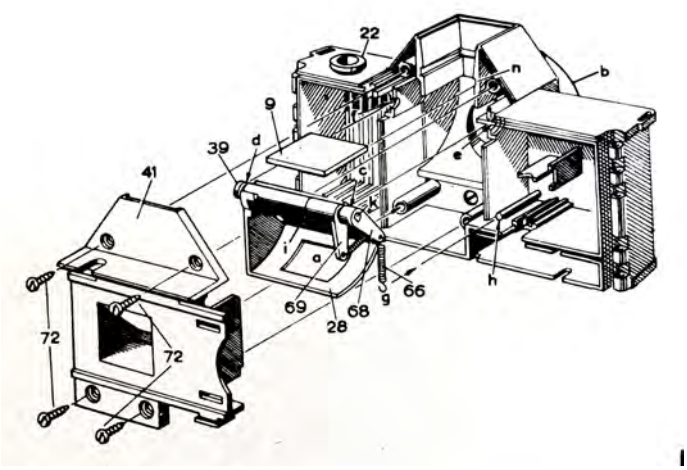
There is a set of injection molded plastic lenses that are nicely laid on a red tray. These lenses can be placed inside lens barrels that are cut in half (below-left), so the lenses are placed in pre intended slots, and the two halves of the lens housing are mated together to make a sealed lens assembly. I think microscope designers at Zeiss, Leica, Nikon, and Olympus must have played with this kit when they were a kid, because most of their microscope illumination barrels are built the same way. I can not say enough about this set because it teaches not only optics, but it teaches the mechanics of motion with its mirror flip up, and down mechanism, and shutter design. It shows how a film transport mechanism works, how diaphragm blades are assembled inside a lens, and a bit of photography.

Building a microscope is at the center of this next optical kit which we are going to discuss shown at bottom of next page. It's a German made product named "Optik Montage". This is also a kit that proves me wrong again about use of plastics in toys, but I still insist there is no replacement for nuts, and bolts in teaching optomechanics. There is a good emphasis on creating form, and function in this highly versatile kit that fascinates any user. There is also good use of color in the injection molded parts that makes working with it a pleasure. There is a 3D viewer with two stereo slides that makes it look like it was bought from the store. The microscope is quite well designed, and putting it together, can teach a child how a self holding three dimensional instrument can be built, and what is essential in its alignment. The user's manual is well written, and highly illustrated.

The next kit I am going to discuss is no stranger to anyone (page 11), but I saw it for the first time at a camera show in Orange County, California. An old couple had inherited two wooden boxes filled with optomechanics, and they had put it for sale on their table at the fair. It was love at first sight. I didn't have money at the time to buy it, and almost a





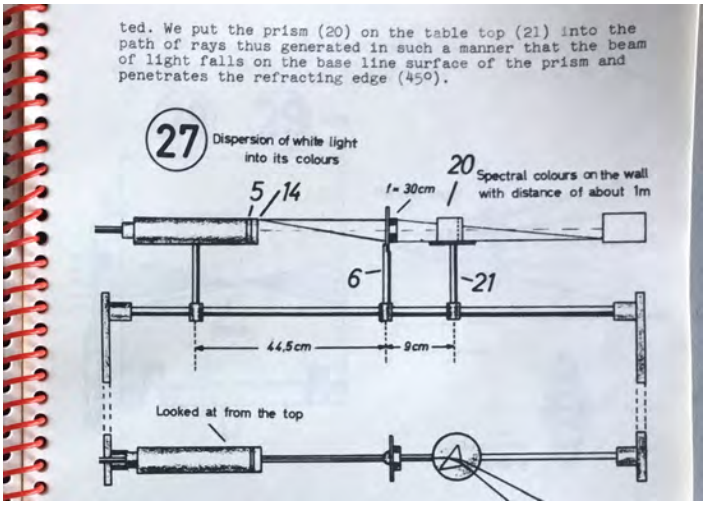

"Optical Lab Kit" was distributed in 1970's by Radioshack for $29.95. This is a fantastic optical kit with beautifully illustrated user's manual. A 35 mm SLR camera could be built complete with a film advance mechanism, two sets of lenses (normal, and telephoto) would allow the user to focus the image on a focusing screen before taking a picture.

year passed, and no one else bought it. This time, I only had $180 cash in my pocket, and they agreed to sell it. I took it home, and it was two weeks of non-stop fun to study each and every piece, and how they went together! I had no user's manual so I had to figure it out on my own. A year later, I saw its ad in Laser Focus magazine, and I called them to send me a catalog. I learned they were two Microbench sets made by Spindler & Hoyer in Germany, and their actual cost was $10,000. One kit was labeled: "Optics", and other: "Mechanics".

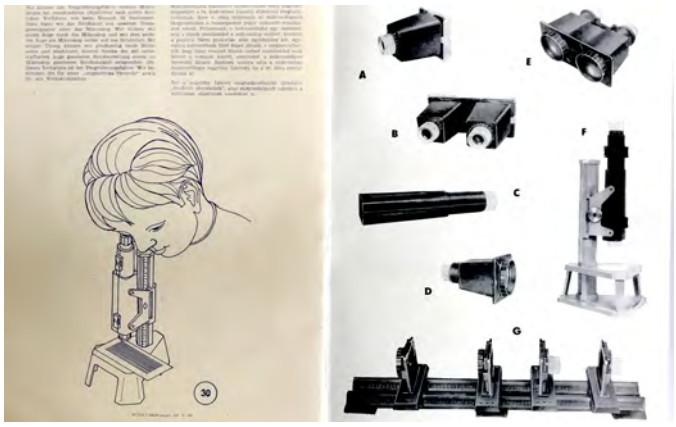
Microbench is truly a masterpiece in design, and precision. I am still an admirer, and a true fan of Microbench. It utilizes the 4-rod system, in which the optical axis is the same as its mechanical axis of symmetry. A larger size mount called Macrobench (Patent number US3945600A) was invented first in 1973 by Hartmut and sold by Klinger. Microbench's patent application was filed later in 1976 (German Patent 2636657), invented by Detlef Mallwitz, and later a plastic version (US Patent 5035333A) was filed in 1983 by Klinger. The first Klinger catalog that introduced Microbench was printed in 1977 (opposite page, bottom-left), and it was a well illustrated 16 page catalog. Their next catalog was 66 pages (blue), and showed a larger range of accessories for Microbench as well as covering the Macrobench system. It next appeared in Physitech catalog (bottom-center). Later, as many companies normally do, and it's not done intentionally to piss off the already well established distributors, Spindler & Hoyer opened its own US office in Milford, MA.

A new catalog was put out for both the Microbench, and X-95 optical rails, and accessories. Microbench had a huge range of accessories including detectors, a wide range of 25 mm mounted optics, optoelectronics components, spectrum discharge lamps, and motorized stages. Microbench was well sized for building a veriety of optical instruments (40x40x10 mm in Anodized Aluminum). A second catalog was put out for Spindler & Hoyers's huge line of optical components. The nicest part of Microbench system was its wide range of 25 and 30 mm mounted optics with focal lengths, and lens shapes engraved on them. A yet smaller sized mount called Nanobench was later introduced for even smaller sized tasks.

The "Circular Microbench" (page 13) was invented by me back in 1994, and it's a silly story how it came all about: Being a Microbench fan, I realized there wasn't a good user's manual for it. So I contacted Linos to convince them to commission

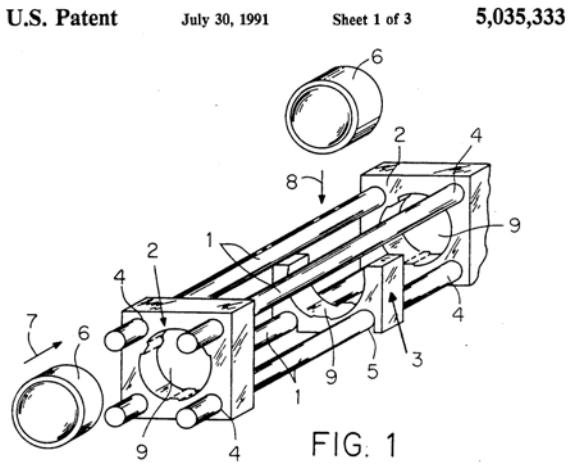


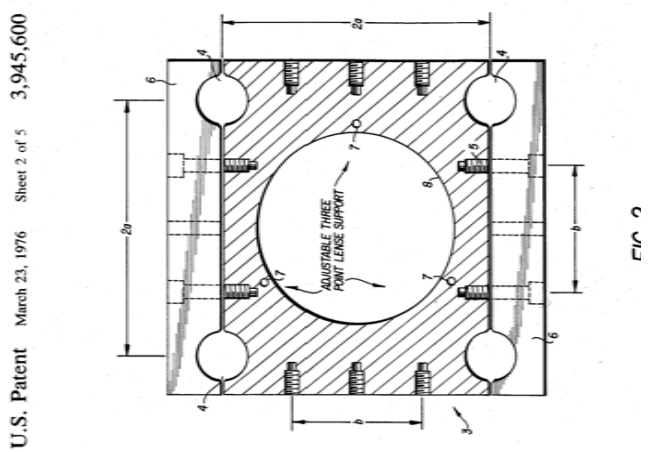

Neva Optics kit is a high quality laboratory set in wooden box with well illustrated user's manual (right). It comes with collimated light source, various frame masks, Equilateral prism, four post mounted lenses, and even candles!



"Optical Montage" is a colorful injection molded Erector set to create optical instruments. The parts fit into one another nicely to make a microscope, 3D slide viewer, telescope, etc. It has a nice illustrated manual that would encourge the user to build the experiments. An optical rail with carriers also allows lab-like experiments to be performed.

me to write a user's manual. Peter Andreas was so much in favor of it after seeing my work but his bosses in Germany said no. This was the attitude of most German companies at the time: The "If it's not invented by us, we are not interested in it" philosophy. I think all I was asking for was recognition, and perhaps two Microbench kits. A few years later, I invented my own version of Microbench so I could write a good user's manual for it! This is a tweak of Edison's line: "I look for what user's manual people need, and I then try to invent something so I could write it!" Optoform was cheaper to produce, and it used Allen screws. This was a major headache when using corner connectors in Microbench system. My design allowed mixing different mount sizes from 25 mm to 150 mm in diameter, and it utilized a 3-point lens mounting scheme which was superior to their four set screws coming from each side of the square shape. Optoform was manufactured and sold by AF Optical since 1994. I wrote an elaborate user's manual for it, and saw how expensive it was to produce.




Microbench (above-right patent drawing), and Macrobecnch (lower left drawing) began a sensation in optomechanical prototyping using off-the-shelf components. Nanobench (right) was also introduced later for smaller sized prototyping. Three mount sizes: 25, 40, and 150 mm square that could be mixed together to build almost any optical instrument.

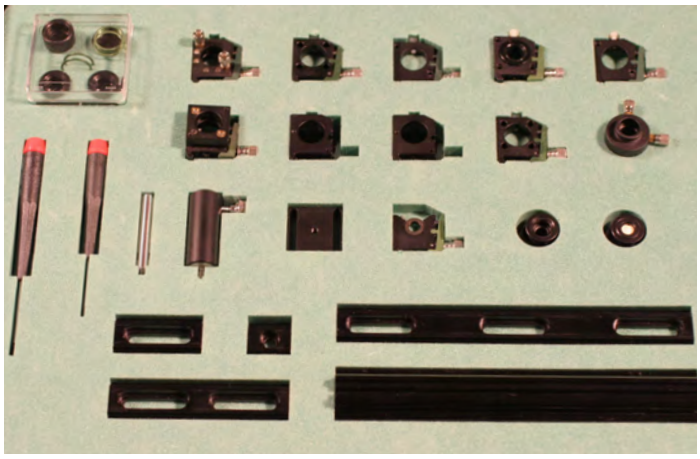

25 years of Microbench catalogs from 1977 to 2002 in OMiD archives. Their 1992 "OPTO-MECHANICS" catalog was one of the most well written, beautifully illustrated manuals ever put out for optical engineers. It was a hidden treasure whose worth was unknown. It was the perfect opportunity for a marketing power house (Thorlabs) to make it popular.

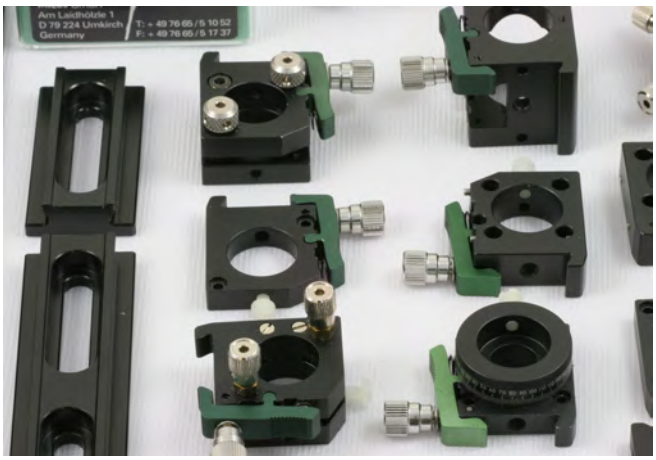
With over 25 years of marketing, Microbench was still not well received in US, and now there was the new Optoform system to challenge it. Thorlabs, a marketing power house, saw its potential, and started copying Microbench, whose patent had long expired. I remember my friend, Peter Andreas, president of Linos' first reaction to it was: "They can't compete with us. We have been doing this for so many years". It took less than a year for Thorlab's "Cage System" to be laying around in most labs in US. I remember a year later someone leaned inside the linos booth, asking Peter Andreas: "Excuse me, are you Thorlabs compatible?!" It was a sad story for Microbench. Thorlabs hired a design team, and they began adding new components: The first was an easy to use Z-stage that utilized a flexure design. It was such a good idea that Linos started copying it a year later. I saw in Microbench's later ads: "The original Cage system".

Thorlabs even infringed on one of the claims in my Optoform patent. The threaded bores at end of rods were my idea. I mentioned this to Alex Cable at their booth in Photonics West, and his reaction was very friendly. He said: "Why don't you explain this in a letter, and email it to me please". I went back to my office (AF Optical Inc. at the time), and wrote it up, but before emailing it, I said why not first email it to my Patent Lawyer Paul Ware. He immediately called me back to change my mind. He said: "Do you have a million dollars? They will take you to court, and don't even think about challenging them!"

Newport, and Melles Griott were both interested in acquiring Optoform from AF Optical but were not willing to give reasonable royalties, until in 2011, Edmund optics seized the opportunity. With the efforts of Linda Smith at Ceres, an M&A agreement was signed between Edmund, and AF Optical, and their new "Cage System" entered Edmund's catalog. Microbench is currently being produced, and sold through Qoptiq catalog. I have many new ideas for Optoform, and I am introducing an improved version. Edmund's contract prevented me from pursuing it for 5 years, and that obligation has long elapsed.

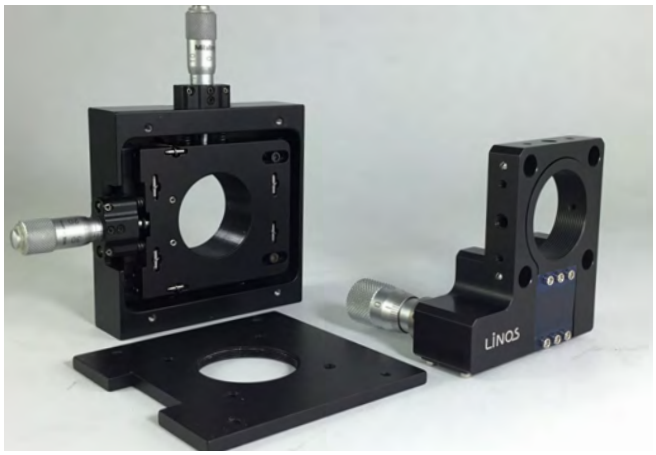
Microbench, Optoform, and Thorlabs' Cage system play an important role in today's Optical prototyping. Many companies have great interest in creating their own concepts. Micos Germany, lead by Lucius Amelung, produced two products





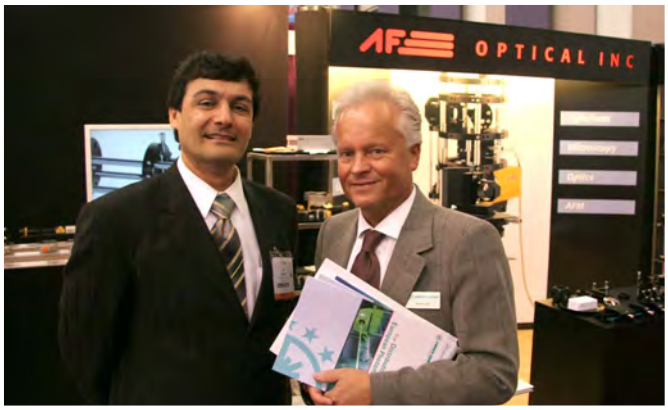
The "Moskito" optical set was created by Micos Germany. It was nanobench sized optical railmount system, and most of its mriror mounts, and accessories were compatible with Nanobench. This system used extruded form to create cubes, and lens carriers that snapped in place like X-95 system rail, and they could each be secured by a thumb screw.


Microbench offered beautifully engraved 25 mm mounted optics. Thorlabs followed their own 1" threaded mounts.



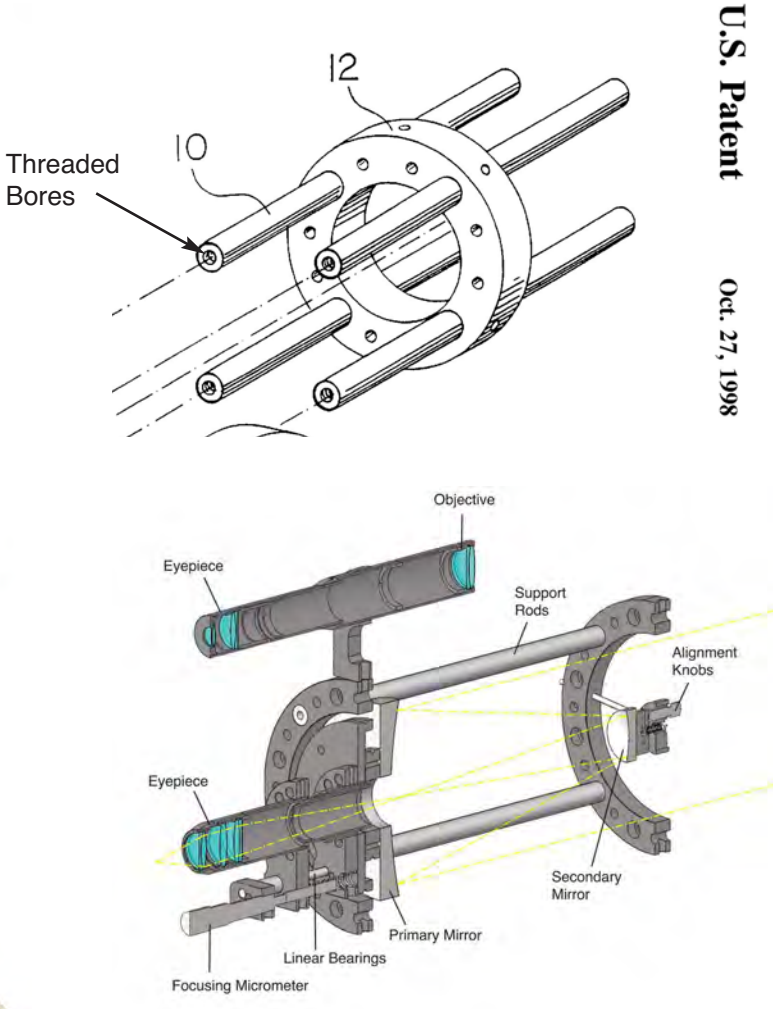

Thorlab's first innovation after copying Microbench was the X-Y and Z stage, later copied by Linos (right).

that were mainly a rail based system but allowed 3D setups. The Moskito was a Nanobench size mount (previous page), and their Campus mount was a bit larger (65X65 mm), and it was also rail based. Owis had created a similar system. OptoSigma has recently introduced a 3-rod system, which I think is clever. The idea is why use 4 rods if you don't need them? The result is a less crowded system that has easier access to optics. Many ideas seem smart in beginning but fade away from the market because it is not a complete solution to customer's needs. Many ideas seem silly in the begining but grow strong later. The A-Line system by Newport is a good example. With monorail, table top setups can be taken off to free table space, and then brought back in place without having to lose their original layout. One could think of the rod as the shadow of beam path itself. Newport claims the original alignment can also be maintained, and to prove the point, an inerferometer was set up for students to play with at CLEO.



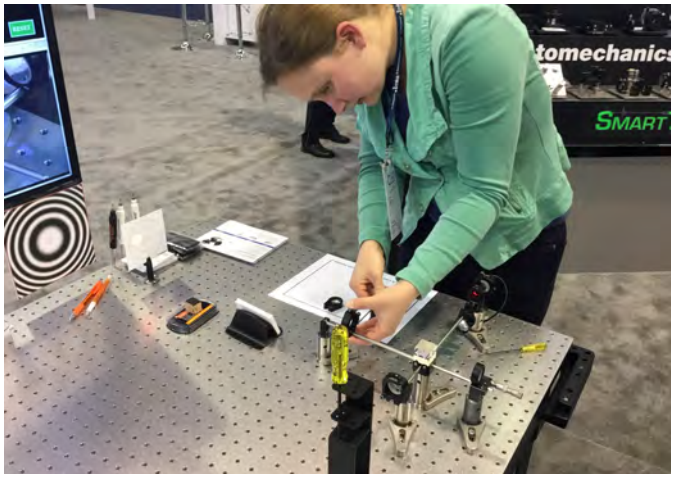


With Armin Luft of Laser 2000, at AF Optical booth, PW 2007. With Dan Denison sales manager of OptoSigma (right) at CLEO 2017. Their new 3-Rod rail system is a great idea that gives easy access to optics.



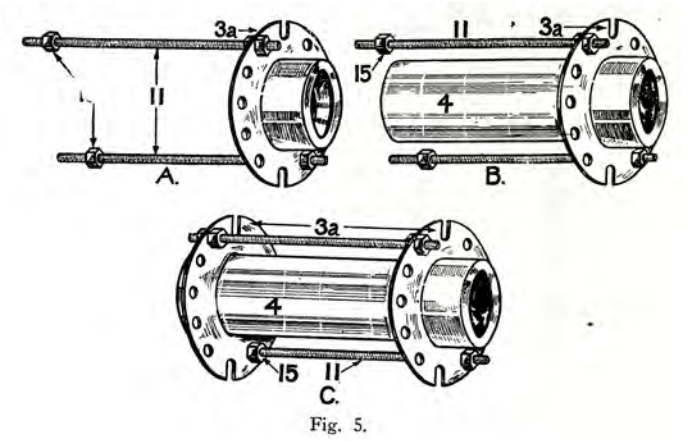

Optoform was invented by me in 1994 (Patent No. 5,828,502). The name Optoform refers to a cage system that handles both form, and funtion. To reach this goal, over six mounting plates from 25 to 150 mm in diameter were designed for the system, resulting in the largest number of components ever created for an Optical Erector Set.

To summarize, while presenting the Gilbert, and Construment kits in the beginning of this article, I humbly realized that my Optoform line that I invented in 1994, and Spindler Hoyer's Microbench invented in 1960's, as well as Newport's new monorail are all similar to prior art, while we made our fortune claiming them as our own. Their inventors created a thought provoking toy for children but we arranged it exclusively for adults. We did that by taking away the illustrative user's manual from them, but we are really not talking about children here. It's our own inner child that has been forgotten some years ago because somehow, somewhere, we stopped ourselves from being curious any more.

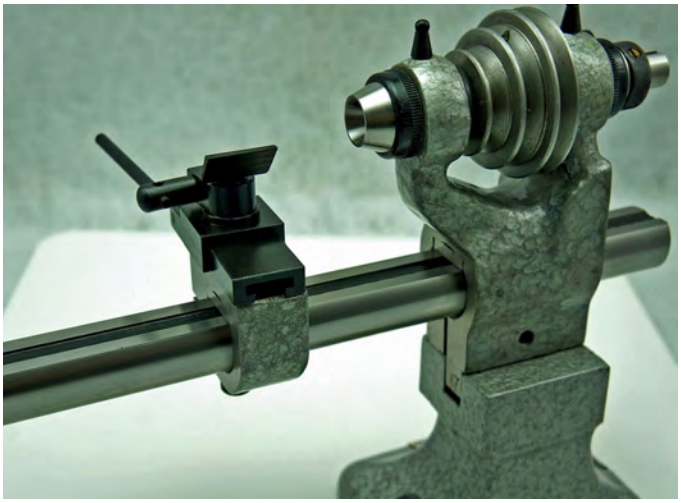


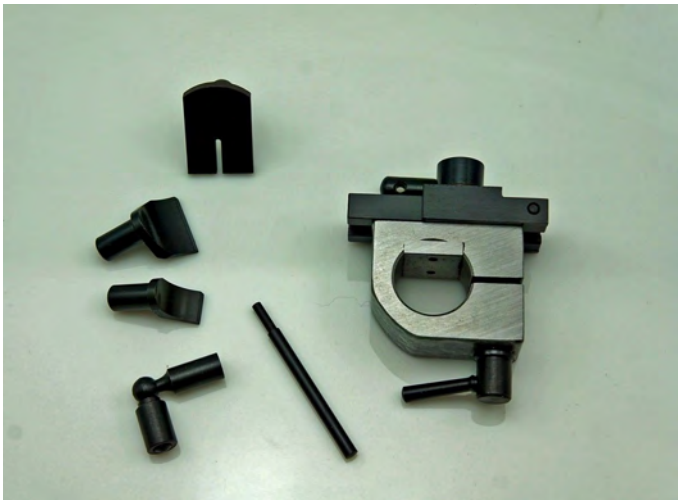

A-Line setup in Newport booth at CLEO 2017. The first time I saw it, I thought it was a joke. Now I think it's a clever idea for table top setups.


With Thorlabs design team at CLEO 2017. Thorlabs continued adding new accessories to their cage system, and now has its own distinguished system.




Gilbert's Opto Kit (left) resembles Microbench design, while Construments mounts (right) resemble round Optoform mounts. New invention or copy? Inventors come up with new ideas without knowing much about prior art.





Traditionall watchmaking lathe bed (still manufactured by French, Bergeon) resembles the new A-Line product by Newport. Newport's innovation was to use a set screw to both align, and secure the quick-release mounts.