Optomechanix

Emco Precision Lathes:

Unimat 3
Compact 5
Compact 8
Super 11

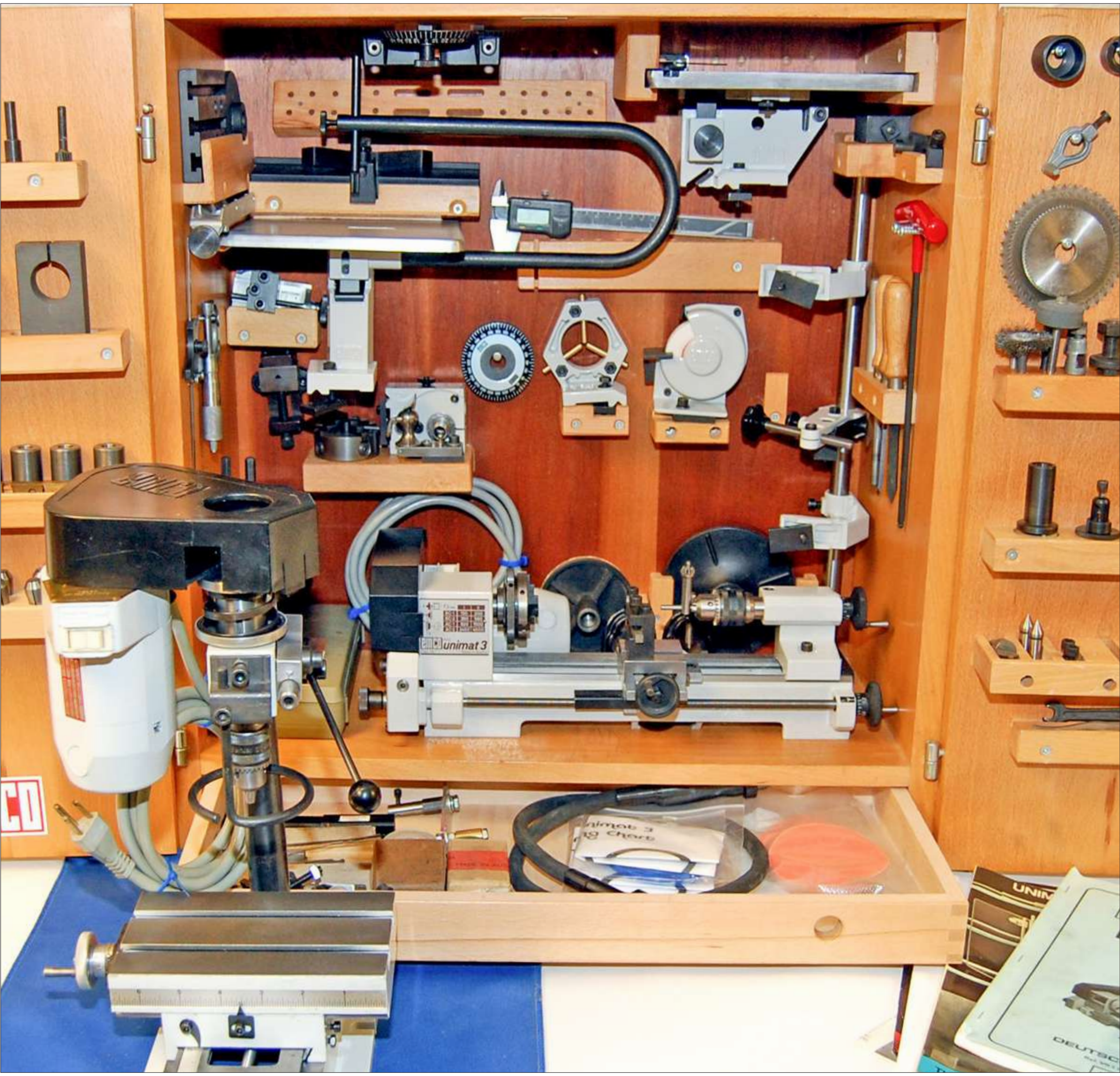
Emco's CNC machines

The Art of Spindler & Hoyer

Trustee from the toolroom

The Machines That Made Us: A Tribute to EMCO Maier and the Craft They Preserved

July-Sep 2026



Technical journal of OMiD, Opto-Mechanical Institute of Design

The precision hobbyist's machine. The legendary Unimat 3 on its optional X-Y milling table is a versatile table top machining center with numerous accessories for dividing, gear cutting, milling, drilling, and fly cutting operations. Over half a million Unimats 3's was sold world wide for their versatility, precision, and affordability.

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Emily Griffith 1967-1947

This issue Dedicated to:

Emily Griffith (1867-1947) was not a politician or an industrialist. She was a schoolteacher who believed that education should be available to everyone — regardless of age, background, or circumstance. In 1915, she shared her dream of an opportunity school with a Denver Post features writer. The idea caught. She persuaded the Post and the city's trolley car lines to promote it, and in May 1916, the Denver Board of Education gave her the condemned Longfellow School building at 13th and Welton Streets. Opportunity School opened on September 9, 1916. By 1954, it served 10,000 students annually and claimed more than 400,000 alumni.

I was one of them. I arrived as a self-taught machinist with two years of experience on a Unimat — a tabletop machine. Emily Griffith taught me to work with American-made industrial machines: larger, heavier, far more powerful. Our instructors were working machinists who brought the factory floor into the classroom, and sometimes brought us to the factory floor itself. They took us to the annual trade shows held in Denver, and it was at one of those shows that I saw EMCO CNC machines for the first time. That moment quietly changed the direction of everything that followed. The school that shaped me no longer offers what it once did. Funding from Denver Public Schools declined steadily over the decades. Tuition was introduced in 1991. Courses in shoe repair, audio/visual electronics, and precision machining were closed in the mid-1990s to make room for English as a second language and healthcare programs. The original building was demolished for a hotel. I looked up their current syllabus — I found a welding class. The machine shop is gone. The same quiet disappearance took National Camera, the best Camera technicain school where I also studied.

These institutions did not close because what they taught lost its value. They closed because not enough people fought to keep them. That is worth remembering.

I have great memories from this entrance door. I attended Emily Griffith for two semesters to learn machining training. It was the foundation to learn how to work with precision machines, some CNC training, and measurement tools.

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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: Emco Unimat 3 cabinet with its full range of accessories

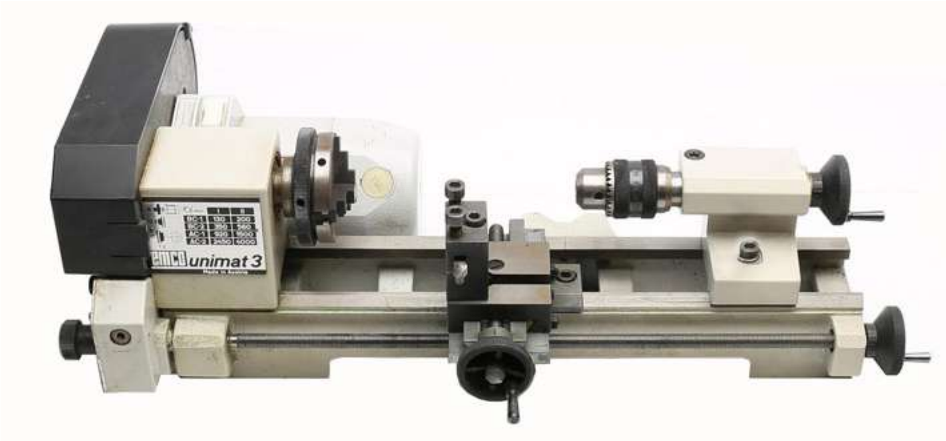
Front back: Emco Unimat 3 on its rare milling base attachement for stand alone milling, and drilling.

In This Issue ...

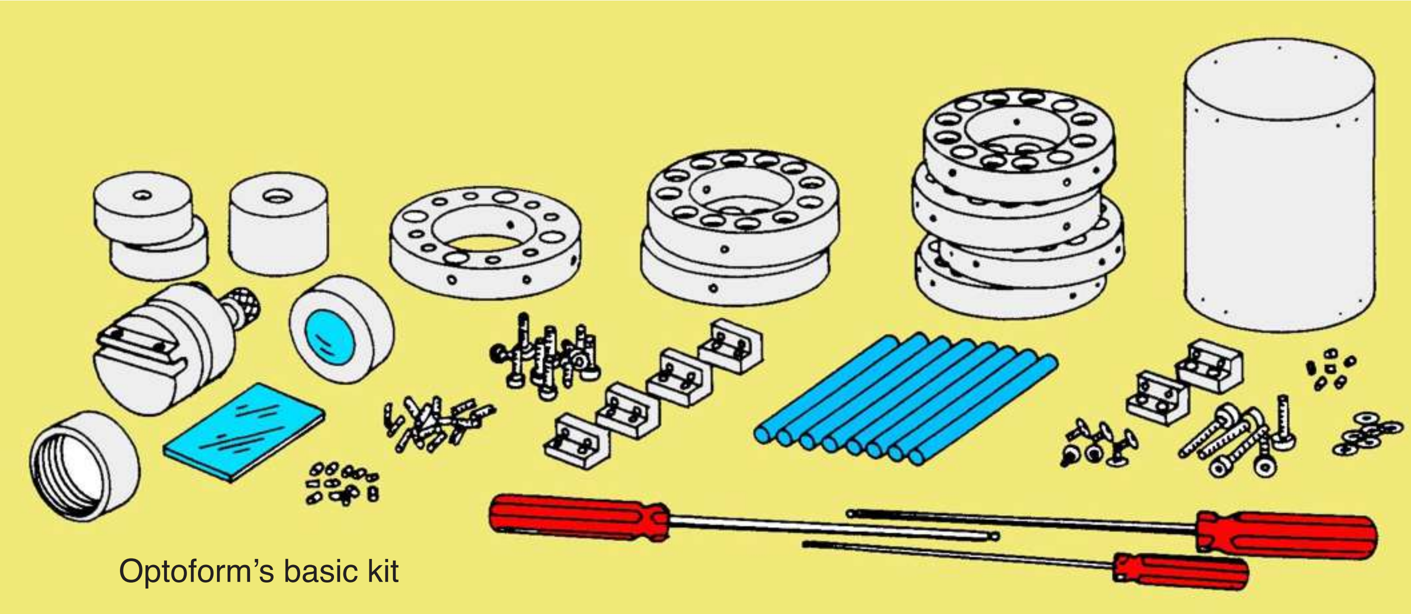
There is a certain kind of love that machinists understand — a love that cannot be explained to someone who has never felt the resistance of aluminum giving way to a properly ground cutter, or the satisfaction of a part dropping off the chuck exactly to dimension. I have felt that love since 1982, and for most of my life as an inventor and precision engineer, that love has had a single address: Hallein, Austria. That is where Emco Maier makes its machines. And it is where my story begins.

This issue of Optomechanix is a personal tribute. Over more than four decades, I have owned and operated a progression of Emco machines — from a humble Unimat 3 sitting on a workbench to a live-tooling CNC turning center that completed a finished Optoform component in under four minutes from raw bar stock. Each machine was a chapter in the story of Optoform. Together, they tell the story of what it means to build something from nothing, with precision tools, a clear vision, and the stubborn Austrian engineering quality to back it up.

Ali Afshari
Editor in chief
Optomechanix



This is a complete machine shop for the micro machining enthusiasts who are still a fan of Unimat 3 all over the world. The accessories shown are the optional milling machine in front of the lathe sitting inside the cabinet. There is the steady rest that first catches the eye, next to the grinder wheel, and dividing plates, thread cutting attachment, cut off saw, collets, gear cutting discs, jig saw attachment, circular saw attachment, flexible shaft, user manuals, etc.



Optoform's basic kit

$3,000, One Machine, and a World-Class Idea

In 1993, I started AF Optical Inc. with three thousand dollars. Not three hundred thousand. Not thirty thousand. Three thousand dollars — enough to cover a business license, some raw aluminum stock, a few cutting tools, and the rent on a small workshop. By any conventional measure, it was not enough to start a manufacturing company. Certainly not enough to develop a product line that would eventually attract the attention of engineers at JPL, university optical laboratories, and research institutions around the world.

And yet, that is precisely what happened. The reason it was possible comes down to one decision made at the very beginning: instead of investing in expensive custom machining services or a large inventory of pre-made parts, I invested in a machine. A small, precise, Austrian-made machine that could produce professional-quality components in my own shop, on my own schedule, one at a time.

That machine was an EMCO. "Optoform was not built with investment capital. It was built with Austrian steel, Austrian precision, and the conviction that a sole inventor with the right tool could compete with anyone."

Unanodized Optoform pieces that I produced using Emco CNC Mill 50. Throughout this issue, I will show you how I made them for 10 years.

I want to offer optical engineers a success story — and an honest one. Optoform achieved world attention. It was shown at Photonics West. It was used in laboratories that could have afforded any competitor's product. But it was also built by one person, in a small shop, on machines that any serious hobbyist or independent researcher could afford. The path from idea to world recognition does not require a factory. It requires the right approach, and the right tool.

Prototype First, Produce Later

Before the machines themselves, I want to share the most important lesson I learned — the hard way — over thirty years of building Optoform.

When I invented Optoform in 1993, the system began as a prototype. I showed it at trade shows. I demonstrated it to optical engineers. The reaction was immediate and genuinely encouraging — people understood the concept, they could see the value, and they wanted to buy it. That validation was intoxicating. And it led me to make a mistake that I caution every independent inventor and researcher to avoid.

I built a large product line. Dozens of components, dozens of configurations, a comprehensive catalog. And then I had to produce them — practically by hand, on my CNC mill, one at a time. Delivery dates were difficult to meet. Inventory was expensive to maintain. The broader the product line, the more capital was tied up in parts that might sit on a shelf for months before a customer needed exactly that configuration.

"The lesson is simple but painful to learn: the machine that validates your idea is not the same machine that mass-produces it. Know which stage you are in."

The EMCO machines described in this article are, first and foremost, tools for the inventor's phase — the phase of prototyping, validating, showing, and proving. A sole inventor with an EMCO bench lathe and a modest milling attachment can produce prototype-quality optical mounts, instrument housings, and mechanical components that are indistinguishable from professionally machined parts. That prototype can go to a trade show. It can be shown to a potential customer or research collaborator. It can validate the concept without a penny of inventory investment. Only after that validation — after real customers have expressed real intent to purchase — should production scale up. This is the framework. Now to the machines themselves.

AF 110 camera 1981, built entirely with Unimat 3
When Dr. Ogura saw it, he said out loud: “Auto Focus!”

Part One: The Manual Machines

EMCO Maier of Hallein, Austria has been making precision machine tools since 1947. Long before they became known for their CNC training machines, they built a family of manual lathes that grew systematically with the machinist's ambitions — from the tabletop Unimat 3 to the toolroom-capable Maximat Super 11. Each machine in the family shared a common philosophy: Austrian precision, elegant industrial design, honest construction, and a refusal to make two machines where one well-designed machine would do.

Every machine in the EMCO manual family accepts an optional milling and drilling head attachment. With this accessory mounted on the lathe bed and driven by its own motor, the machine becomes a small vertical mill — no second machine required, no larger footprint, no additional X-Y table. It is an idea of characteristic Austrian cleverness, and it is one reason these machines are so well suited to the inventor working alone in a small workshop. All four machines accept the optional milling/drilling head attachment. All manufactured in Hallein, Austria by EMCO Maier Ges.m.b.H.

1. The Unimat 3 — The Machine That Proved Everything Was Possible (left).

The EMCO Unimat 3 (introduced 1976): 46mm center height, 200mm between centers, eight spindle speeds from 130 to 4,000 rpm. The size of a watchmaker's lathe. The precision of a toolroom.

The Unimat 3 was introduced in 1976 as the successor to the legendary Unimat SL — itself descended from the original Unimat DB of the 1950s, which had been sold worldwide in hundreds of thousands and had introduced a generation of engineers and hobbyists to the idea of tabletop precision machining. The Unimat 3 refined everything the SL had established. The headstock was now solid rather than tiltable. Eight spindle speeds ranged from 130 to 4,000 rpm, covering everything from heavy facing cuts to high-speed finishing of small-diameter brass and aluminum. Spindle runout was rated at 0.0005 inches — half a thousandth — on a machine you could carry under one arm.

With its optional milling and drilling attachment, the Unimat 3 became a complete small machining center in one footprint. The same spindle that drove the lathe drove the milling head. The same precision that defined the lathe defined the mill. It was not a compromise — it was an engineering decision that understood exactly what a small-workshop machinist actually needed.

The Unimat 3 with its optional milling and drilling head: one machine, two capabilities, one footprint. A distinctly Austrian answer to the small workshop's fundamental constraint.

For me, the Unimat 3 was not a hobbyist's toy. In 1982, I used one to build a complete SLR camera from scratch — not a kit, not a replica, but an original design. The film advance mechanism, the shutter housing, the lens mount — every aluminum and brass component turned and milled on a machine the size of a typewriter. People are still surprised when I tell them. But the Unimat 3 was simply that good, and I was simply that determined.

"The inventor does not wait for a factory. The inventor uses what is available — and makes it extraordinary."

2. The Compact 5 — The Step Between the Workbench and the Workshop

The EMCO Compact 5: 65mm center height, 350mm between centers, 50–3,200 rpm. A genuine precision bench lathe produced from 1981 to 1992 — and later offered in CNC form as the Compact 5PC.

Between the Unimat 3 and the Compact 8 sits the Compact 5 — a machine that is sometimes overlooked in historical surveys of EMCO's lineup but should not be. Introduced in 1981, the Compact 5 offered a 5-inch swing and nearly 14 inches between centers, with a 500-watt drive motor and spindle speeds from 50 to 3,200 rpm. These are not toy numbers. The Compact 5 was a serious precision bench lathe.

What made the Compact 5 particularly interesting was its evolution: EMCO later offered it in CNC form as the Compact 5PC, one of the earliest affordable desktop CNC lathes available to small workshops and educational institutions. This demonstrated something important about EMCO's thinking — they understood that the same fundamental machine architecture that served the manual machinist could, with appropriate control electronics, serve the CNC machinist. The manual and CNC worlds shared the same DNA. This insight would define EMCO's strategy for the next four decades.
Like all members of the manual family, the Compact 5 accepted the milling and drilling head attachment — the same elegant solution, scaled appropriately for the larger machine. For an inventor prototyping optical mounts and instrument components in the 5-inch class, the Compact 5 with its milling attachment was a complete solution in one compact package.

3. The Compact 8 — The Machine That Launched Optoform

The EMCO Compact 8: approximately 8" swing, ground ways, precision leadscrews. One of the finest small bench lathes ever made — and one of the most widely imitated. The machine on which the first Optoform components were produced.

When I invented Optoform in 1993 and incorporated AF Optical Inc. with my initial $3,000, I needed a machine more capable than the Unimat 3. The answer was the EMCO Compact 8 — a full-sized bench lathe

Emco Compact 5, Courtesy, Emco Maier

of considerable precision and rigidity, universally regarded as one of the finest small lathes ever produced. The evidence for this assessment is not merely anecdotal: the Compact 8 was so thoroughly correct in its design that it was copied extensively by manufacturers around the world, particularly in China. When your design is copied on an industrial scale, it is the highest possible endorsement.

What distinguished the Compact 8 was not its specifications alone but the quality of their execution. The ways were ground. The leadscrews were precision-cut. The headstock was rigid. There was no chatter where there should be none. Finish was predictable. Dimensions were repeatable. For a new product line that would be shown at trade shows and demonstrated to professional optical engineers, these qualities were not optional — they were the minimum standard.

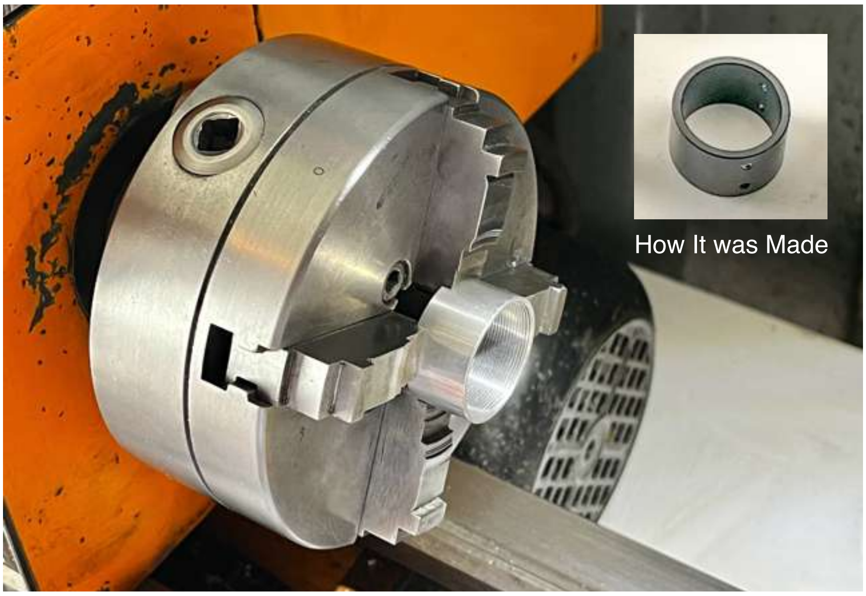
With the Compact 8 and its milling attachment, I machined the first Optoform components. The system was shown at trade shows. Engineers held the parts in their hands. They were smooth, dimensionally correct, and indistinguishable from professionally machined components — because they were professionally machined components, just by a very small professional operation. That is the point. The machine does not know how large your company is. It only knows whether you are asking it to produce good work. Ask correctly, and it answers.

My own Compact 8, still my favorite lathe

How I hand built Optoform parts with Compact 8

Numerous chucks from C5 & C8 that are adapted for use on Compact 8.

Soft jaws can be machined to hold specific diameters like above/below.



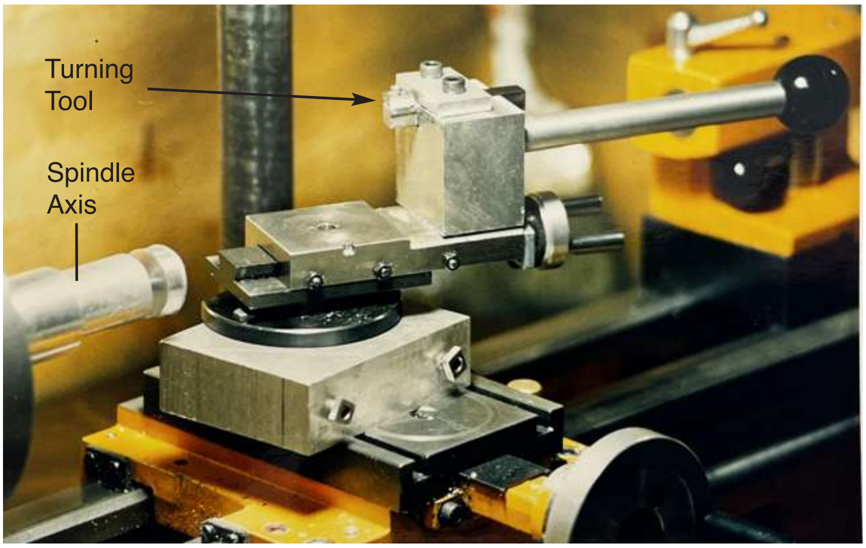
How It was Made

I will show how you could produce complex shapes utilizing a midsized machine like Compact 8. This machine can maintain 10 Micron (0.01 mm) cutting tolerances.

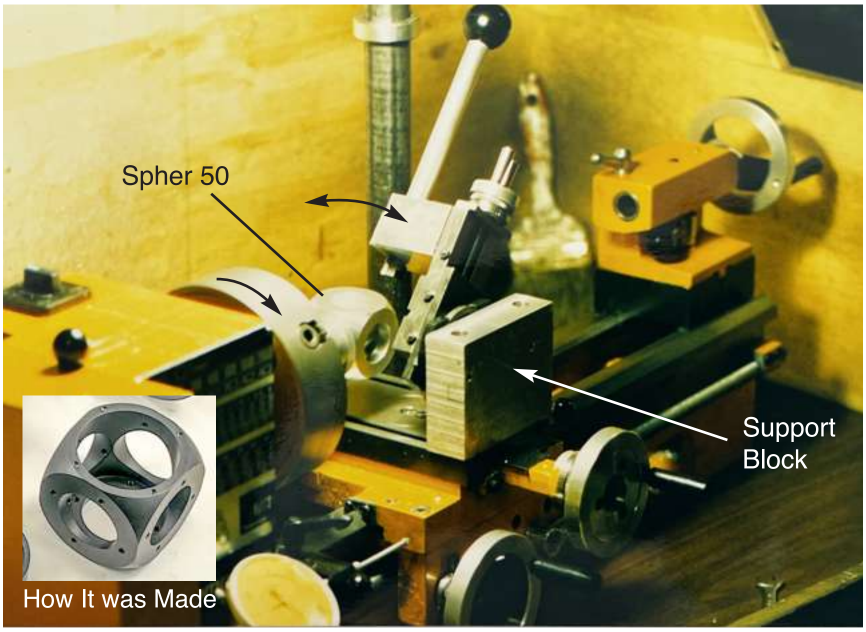
Engineering is all about making mistakes, but its your job to know how to correct them. If you have fear of making a mistake, you'll never reach your full creativity. So when you learn machining, you could keep your mistakes to yourself, and never be embaressed about them. I always criticize myself when I undercut a part, but that's fine, I'll make it again, and again until I get it right.

Through making your own parts, you'll begin appreciating what a responsibility you are putting on someone else's shoulder when you give them a drawing to machine it. In any case, let's learn a few methods to machine precision parts. When you are working with an electric drill, your hand could drill a hole anywhere, at any angle. But when you are setting a machine to do it, both the drilling spindle, and the workpiece have to be rigidly clamped down. Otherwise, the cutting tool will destroy your part. The first time you are going to encounter this is when you are counter-sinking a predrilled hole. If the countersink bit is not precisely centered, or not rigidly in place, it would rattle, and give you the ugliest countersunk hole you have ever seen. In a lathe it's all about concentricity. This is facilitated by the main bed that guides both the headstock, and tail stock always remain perfectly aligned.

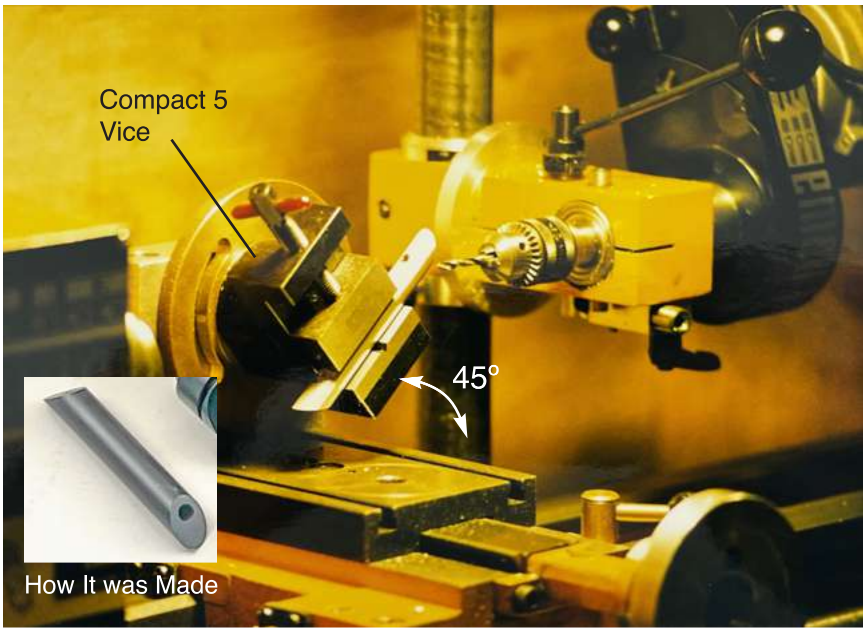
If you have seen the movie “The good, the bad, and the ugly”, there is a scene that the ugly character goes to a gun shop to get himself a gun. He disassembles many guns, and checks alignment, and custom builds himself a revolver. That's how you should examine your lathe. Secure a coned-tip tool to the main chuck, then approach it with a dead center on your tail stock, and see if the two cones precisely line up. In Compact 8, there is a horizontal adjustment for that. When you are using a cut-off blade, always check its cutting tip alignment with the dead center on the tailstock.



This fixture was built to machine Optoform's 50 mm spheres.



This setup was for drilling the oblique rods for 100 mm Minioptic mounts.



These basic skills plus learning the sound of a normal cut, and how it should sound like helps you to get the perfect finish, or a clean cut.

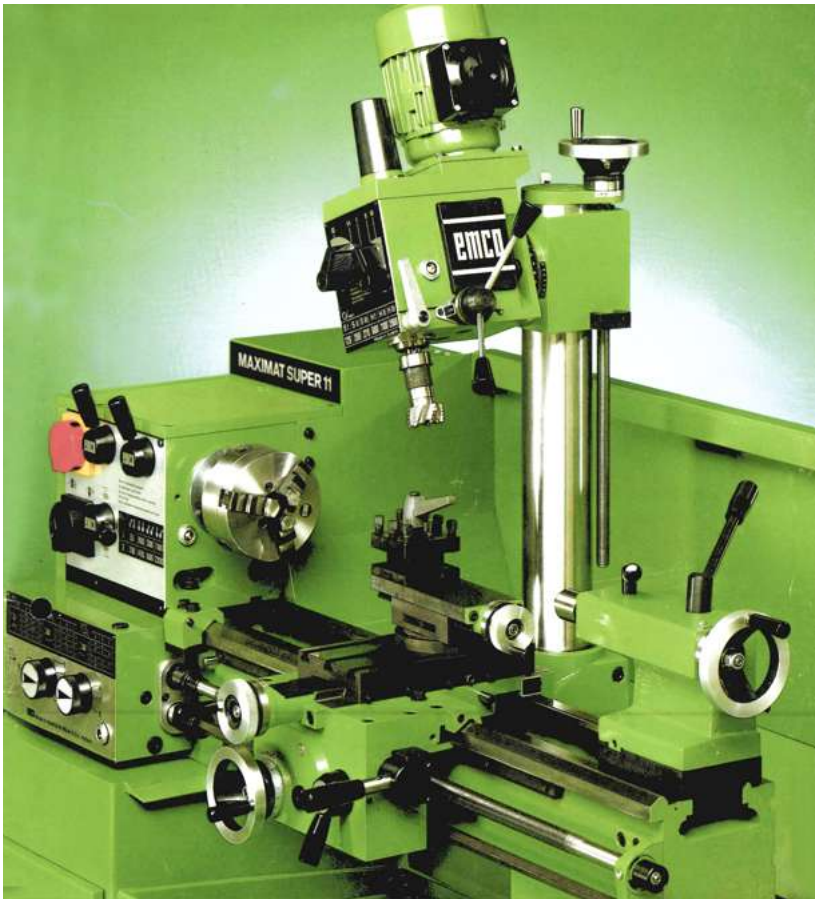
Knowledge plus experience takes fear out of creativity

Most people don't dare to try things because they are scared of failure. Because I had very limited budget for prototyping, I tried to accomplish more with what I had. I think I am the only one who has turned a 2" sphere with my compact 8. Also, the oblique rods that are used in JPL setup were a real challenge to make. It still made them using my compact 8, and it's drilling attachment.

When you learn how to do things, it gives you freedom of action to do more. We have a lot more film makers today than before because film making was made possible at your own desktop. In any case, many of these machines were discontinued, but there are newer machines by EMCO that replaced them.

Specification	Unimat 3	Compact 5	Compact 8	Super 11	Emcomat 14D (current production)
Center height	46mm	65mm	100mm	140mm	140mm
Between centers	200mm	350mm	480mm	650mm	650mm
Swing over bed	80mm	130mm	200mm	280mm	~280mm
Spindle bore	—	—	—	26mm	40mm
Max spindle speed	4,000 rpm	3,200 rpm	2,500 rpm	2,200 rpm	4,000 rpm
Drive power	—	0.5kW	—	2.5kW	7.5kW
Milling attachment	Optional	Optional	Optional	Optional	Not offered
Status	Discontinued	Discontinued	Discontinued	Discontinued	Current production
Best suited for	Watchmaking-scale parts	Small instrument components	Optics lab parts	Full toolroom work	Industrial toolroom, EMCO's smallest current manual lathe

Emco's next generation D14 replaced their very popular Super 11



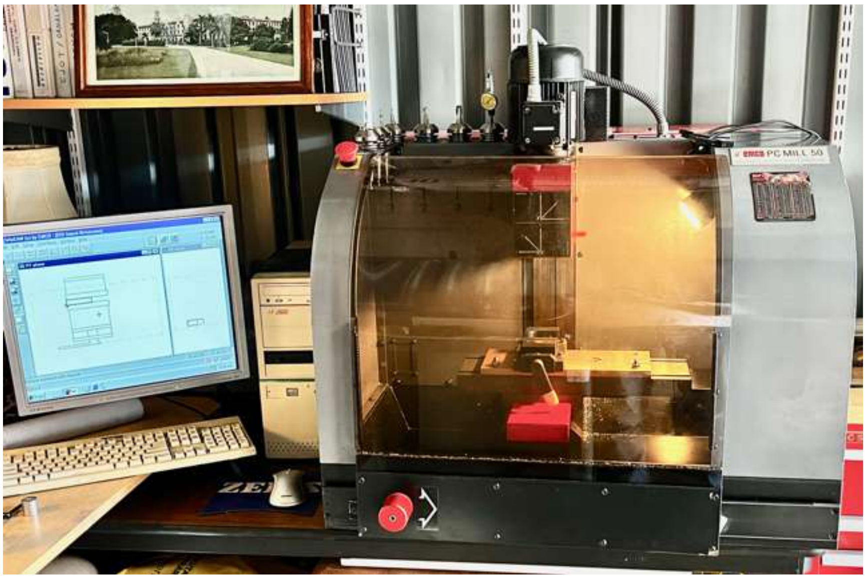
4. The Maximat Super 11 — The Top of the Manual Line

The EMCO Maximat Super 11: 280mm swing over bed, 650mm between centers, 5.5" center height, 2.5kW spindle motor. The 2nd to largest of the EMCO manual family — a machine that bridges the precision bench lathe and the professional toolroom.

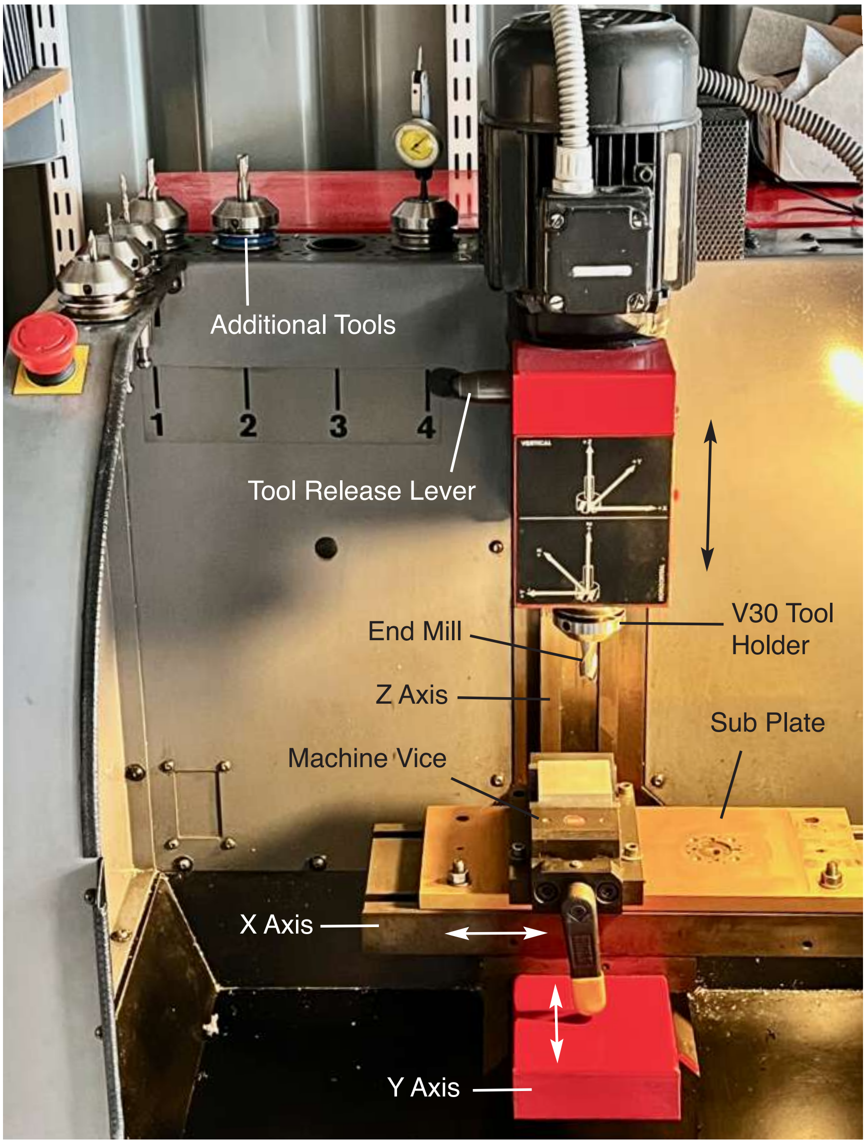
At the top of EMCO's manual lathe family (smaller than their Maximat 13) stood the Maximat Super 11 — a machine of an entirely different scale. With 11 inches of swing over the bed, 25.6 inches between centers, a 5.5-inch center height, and a 32 mm spindle through bore, the Super 11 was no longer a bench machine in the conventional sense. It was a floor-standing or cabinet-mounted precision lathe that belonged in a professional toolroom — and performed accordingly.

The Super 11 accepted the full range of EMCO accessories, including the milling and drilling head that was standard across the manual family. In Super 11 configuration, this attachment was capable of genuine milling work on substantial parts — far beyond what the smaller machines could attempt. An inventor producing larger optomechanical housings, telescope focuser mechanisms, or instrument bases would find the Super 11 a capable and reliable partner. It was the right machine for our larger 150 mm dia. Macroptic mounts.

What I find remarkable about the entire EMCO manual family — from Unimat 3 to Super 11 — is the coherence of the design philosophy across four machines spanning nearly an order of magnitude in capability. Each machine is distinctly itself, appropriately sized and specified for its intended work. But they all feel like products of the same values: precision without extravagance, elegance without ostentation, quality without compromise. You can see it in the castings, feel it in the handwheels, hear it in the cuts.



My first Emco machine was this CNC Mill 50. I bought it direct from Emco Maier. I didn't have good credit but they were nice enough to ship it to me. It was an affordable machine, and I made payments on it every month. They had great technical support. Steve Loockabagh was their tech support, engineer in US, and he is now in upper management at EMCO.



Part Two: The CNC Machines

The CNC machines in EMCO's training line represent the next step in the inventor's journey — not before the prototype is validated, but after. EMCO's CNC training line divides cleanly into two families: turning machines (the PC Turn series) and milling machines (the PC Mill and Concept Mill series). All of these machines run EMCO's WinNC software, which emulates the major industrial CNC controllers — Fanuc, Siemens Sinumerik, Heidenhain — on a standard PC. A machinist trained on an EMCO CNC machine is trained on the same control language used in factories worldwide.

PC Turn 50, 55, and 60

The PC Turn 50 is the entry point of EMCO's CNC turning line, a desktop-scale CNC lathe connecting to a standard PC via serial RS-422 interface. Its 4-station turret handles outside diameter, facing, boring, and threading without the complexity of a larger system. It is an excellent bridge between the manual lathe and more capable machines.

The PC Turn 55 is a significant step forward in design philosophy. Where the PC Turn 50 is a desktop lathe with CNC control, the PC Turn 55 is built on an industrial slant-bed architecture, the same fundamental geometry used in production turning centers costing ten or twenty times as much. Its 6-station turret and 0.0005mm step resolution place it firmly in serious small-batch production territory, with maximum workpiece dimensions of ø60 x 215mm covering the majority of optical instrument components.

The PC Turn 60 extends that slant-bed architecture to a larger workpiece envelope, with Ethernet connectivity and full compatibility with EMCO's CAMConcept integrated CAD/CAM system. For the product line that has grown beyond what the PC Turn 55 can comfortably accommodate, the PC Turn 60 provides additional capacity without a move to full industrial equipment.

PC Mill 50 — The Machine That Built Optoform

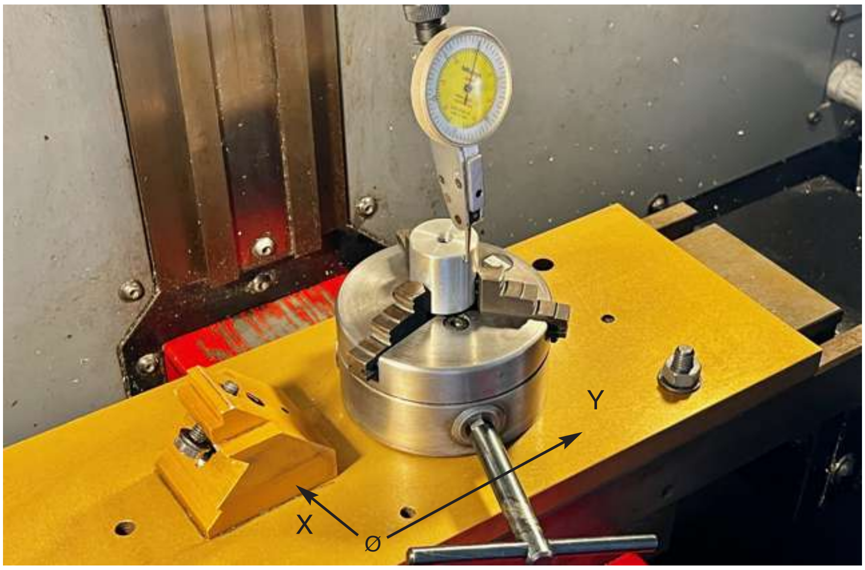
For the first ten years of Optoform's commercial life, the machine at the center of my shop was an EMCO PC Mill 50, and then PC Mill 55 that offered more Y travel. With Mill 50 I could hardly machine Optoform 100 mounts, but later the Concept mill offered 140 mm travel in the Y direction which was nice. They were PC programmed, but self controlled for having their own CPU, and control boards. They were a vertical machining center, compact, precise, and built to the same exacting standards that defined EMCO's entire product line. When I bought the PC Mill 50, I was producing 90% of the entire Optoform line on that single machine. Every base plate, every mounting ring, every adapter and bracket that went to engineers at JPL, to university optical labs, to industrial researchers worldwide, was touched by the PC Mill 50.

The machine connected to a standard PC via RS-422 serial interface and ran Wincam software, the graphical CAD/CAM environment I have always preferred for its intuitive interface and direct machine control. A part designed in Wincam could be on the machine and cutting within minutes. For a sole inventor managing design, programming, and production simultaneously, that workflow efficiency was the difference between a viable business and an impossible one. Wincam software was so easy to use. It generated the code in G-code that you could open and modify for more efficient tool paths. Those who are familiar with general software programing, editing G code was similar to assembly language programing. High level languages produce a huge number of lines, but with G-code, you could program it with far more efficiency. This made the machine work faster that using high level software.

PC Mill 55 and the Concept Mill 55 with Automatic Tool Changer (ATC)

The Concept Mill 55 shares its fundamental mechanical architecture with the Concept Mill 50, the same bed, spindle, and travel dimensions, but incorporates an upgraded interface card for improved reliability with newer PC hardware. For the inventor already familiar with the PC Mill 50, the step to the Concept Mill 55 is evolutionary rather than revolutionary.
The Concept Mill 55 represents the culmination of EMCO's milling machine development in the training category, and with the automatic tool changer option, it crosses firmly into production-capable

Emco PC Mill 50, as well as its other models utilize V30 tool holders with ESX 25 collets that could hold any drill/end mill/reamer size from 1 mm up to 16 mm in diameter. I also bought tap holders from Emco. These machines could tap but you'd have to calculate the feed rate and the spindle's RPM to avoid breakage. Tap holders allow vertical displacement of the tap to compensate for errors in programing.



Sub plate installed on Concept Mill 55, and aligned usinge a dial indicator.

Centering the X-Y coordinates of a circular part using a dial indicator

An interchangeable sub plate specially made for Optoform 50 mounts

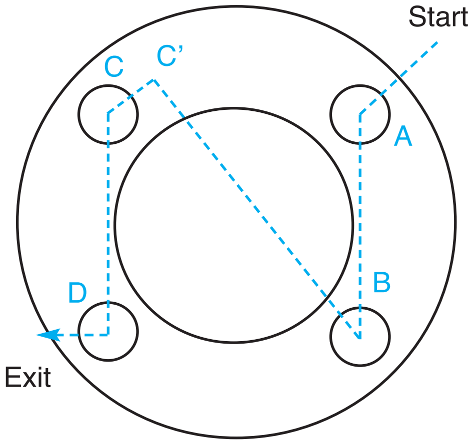
territory. This is the machine that sits in my shop today. It is fully enclosed, coolant-compatible, and chip-contained in a way the older PC Mill 50 or 55 with less travel/lower RPM cannot match. The ATC carousel allows a program to call up different tools automatically, enabling complex multi-operation parts to run without an operator standing at the machine changing cutters by hand, exactly the kind of work Optoform required.

I will now cover a little bit the manufacturing techniques I used to produce such a wide range of parts in the small machines. The main factor that slows down machining process is setup time. I solved that by producing about 25-30 sub plates to be able to switch between jobs very quickly. There was a first a steel plate that permanently stayed with the machine. Then a smaller Aluminium sub plates that I eventually anodized them in gold to extend their life. On each plate, there was X-Y-Z coordinates that I could update as machine vice position inside Wincam software.

The steel plate on machine bed had three cone tipped dowel pins that located each sub pate to a repeatable position. Then I utilized a dial indicator to zero position each sub plate more accurately. To get more accuracy out of these machines, I added an extra path C' to the tool to always start from the upper right side of where it was to be drilling (bottom drawing). This takes care of mechanical backlash on the machine. As you got to know the software, you'd find the way to set the backlash but mechanically speaking, I always used this scheme to achieve 0.01 mm accuracy on hole location.

"I saw how producing a small number of parts with multiple smaller/slower machines would have an advantage over having a single rapid operating machine that obviously cost a lot more."

Optoform followed the manufacturing accuracy of Microbench. These are tight tolerance location, and hole diameters that were produced by using reamers. I was always impressed by the near mirror finish of Microbench bores, and of course, their mirror finished hardened rods. The bore finish of Thorlab's cage plates are not as accurate. Also, Thorlabs' rods are made by single point turning 1/4" stainless steel rods on a swiss machine to reduce them to 6 mm. Optoform, as well as



Drill path to make 4 precisione holes

Microbench rods are centerless ground hardened to rockwell 65.

To achieve bore location accuracy in the Concept Mill 55, you could always add an extra path C' (above) whenever your path is ABCD. This would eliminate any back-lash that might exist in its ball screws. It used to be that Spindler & Hoyer wouldn't reveal their bore tolerances, but it's no longer a secret. The reamed holes are 6.02 mm, and the rods are 5.995 mm, leaving nearly 10 microns clearance

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(**#00005 drilling (removal), ISO format **)
N0045 G97 S2500
N0050 G0 Z3
N0055 X163.435 Y43.435      ← A
N0060 Z0.5
N0065 G1 Z-4.5
N0070 G0 Z5
(**#00005 End **)

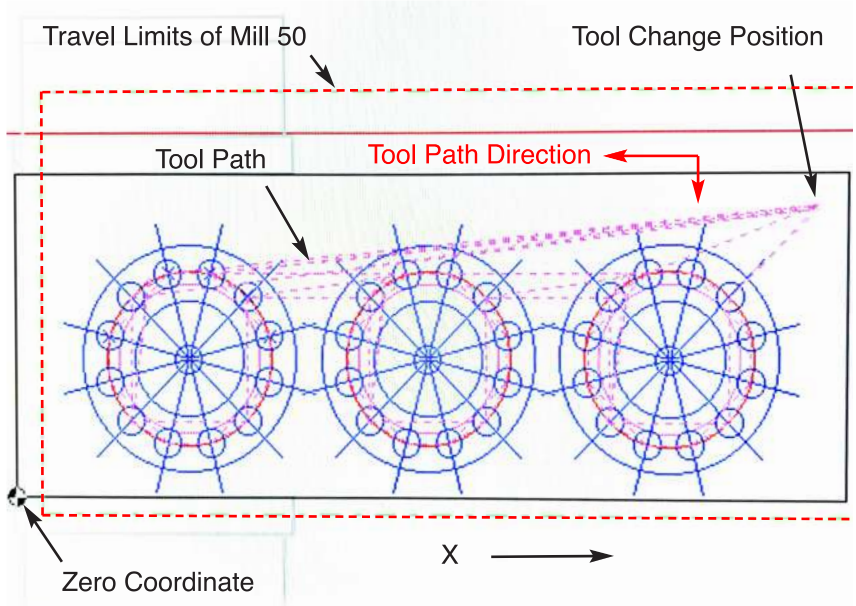
(**#00005 drilling (removal), ISO format **)
N0075 G97 S2500
N0085 X163.435 Y16.565      ← B
N0090 Z0.5
N0095 G1 Z-4.5
N0100 G0 Z5
(**#00005 End **)

(**#00005 drilling (removal), ISO format **)
N0105 G97 S2500
N0115 X136.565 Y16.565      ← C
N0120 Z0.5
N0125 G1 Z-4.5
(**#00005 End **)
N0135 G0 Z5
N0140 G0 X140.091 Y48.513   ← C'

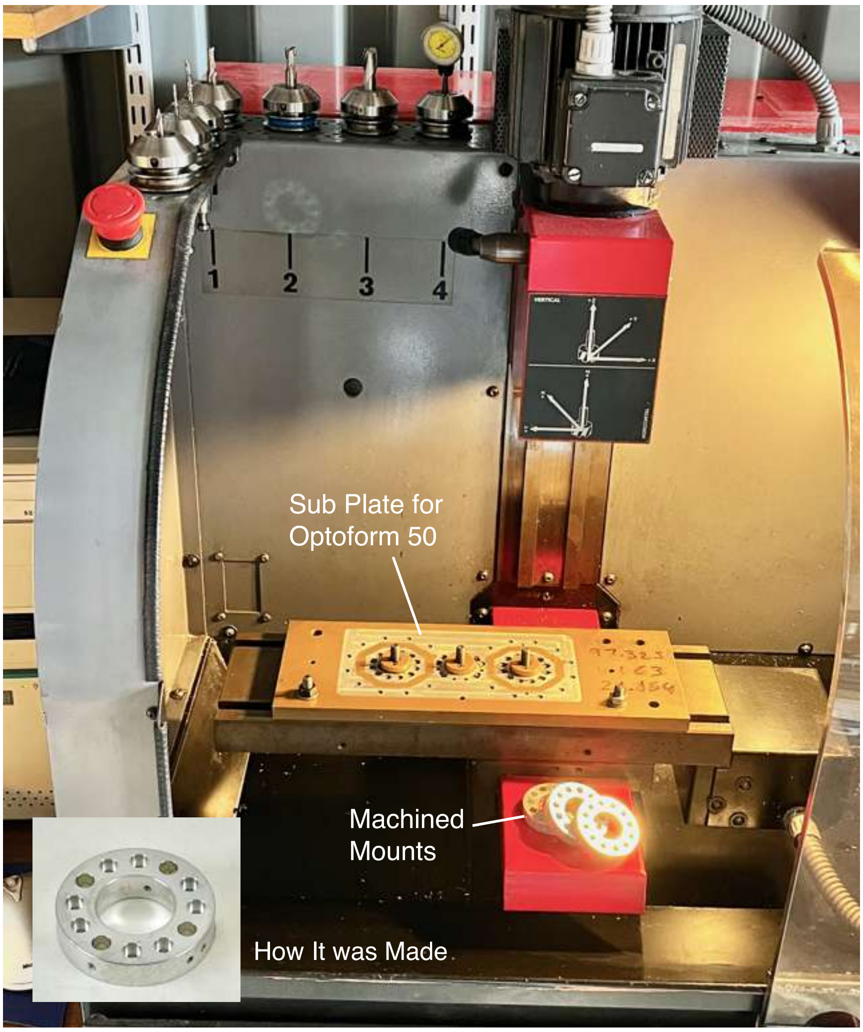
(**#00005 drilling (removal), ISO format **)
N0145 G97 S2500
N0155 X136.565 Y43.435      ← D
N0160 Z0.5
N0165 G1 Z-4.5
N0170 G0 Z3
(**#00005 End **)
```

Line numbers

Achieving 0.01 mm accuracy with Concept Mill 55



The tool path shown on Emco's Wincam's graphic interface before the CNC cycle begins to avoid crashes.

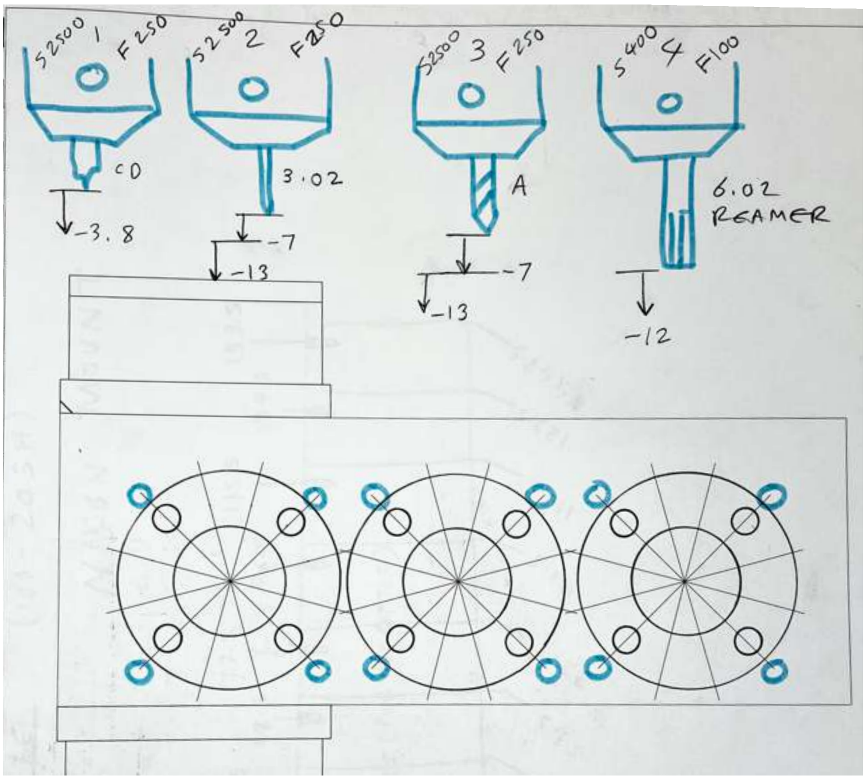


Program lines for center drilling the bore pattern in Microptic mounts (left, above). There is nothing difficult about editing G-code: M3 = Spindle on, M5 = Spindle off, G0 = Fast feed rate, G1 = feed rate specified by F, and S (spindle speed) on top of program. (**) = Coment line. G97, X, Y, and Z are coordinates in mm. Before every comand these are just line #.

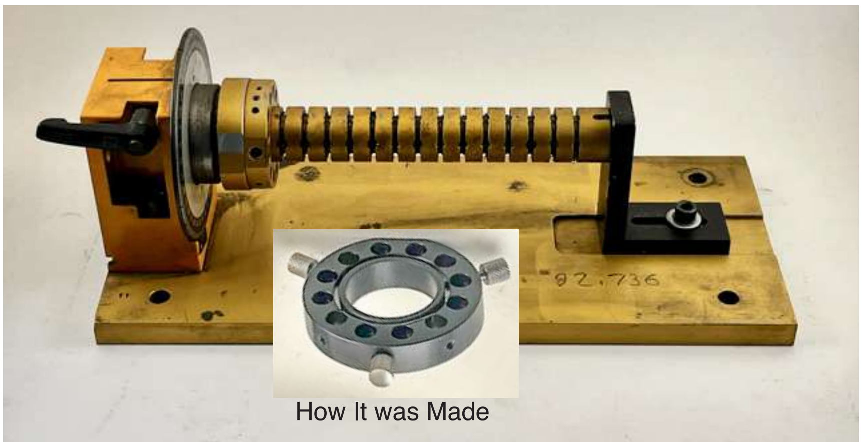
around the rod to slide freely. The bore locations should favor no orientation, like if a mounting plate slides along the rods to touch against another plate, it should not bind. With larger mounts you can't do that. So the bores are made oval, so when the set screw is tightened, there are only three points securing the rod.

As time went on, and I was overseeing the production, we acquired more PC Mill machines. While I was watching them work simultaneously, I saw how producing a small number of parts with multiple smaller/slower machines would have an advantage over having a single rapid operating machine that obviously cost a lot more. The setup time slowed them down. The simple truth was Optoform was intended to be produced with live tooling machines, and I was stuck at phase one because those machines cost over $65K plus the cost of live tooling, etc.

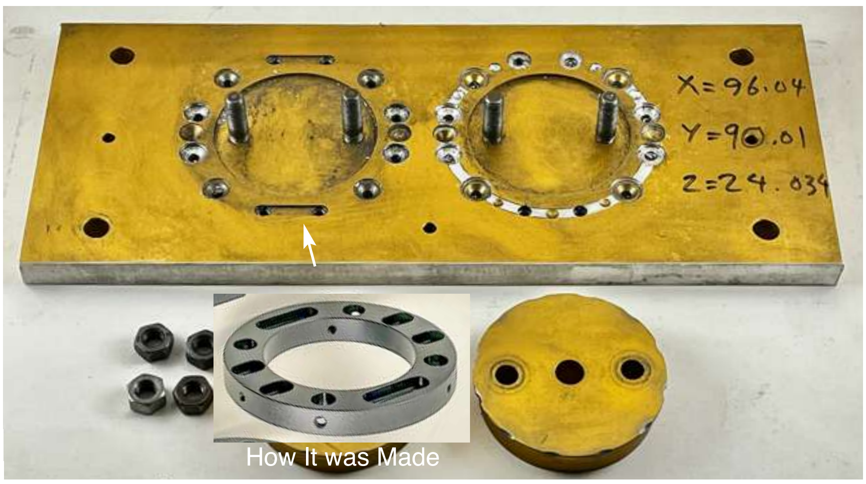
What saved me eventually was getting contracts. From the experience I had gained working at JPL, and years of pro-



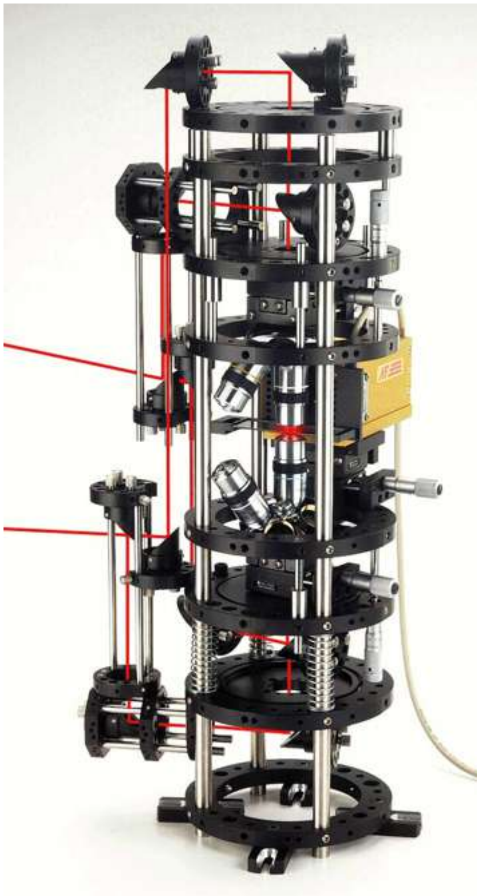
Print out of Wincam's CAD drawing of 3 Optoform mounts, along with the right sequence of tools to machine its 3 mm, and 6 mm bores.



14 Optoform mounts were stacked using 6 mm rods to align them, then slid along this 25 mm dia. horizontal fixture to drill and tap their side holes.



Special sub plate made for securing 100 mm diameter Minioptic mounts.

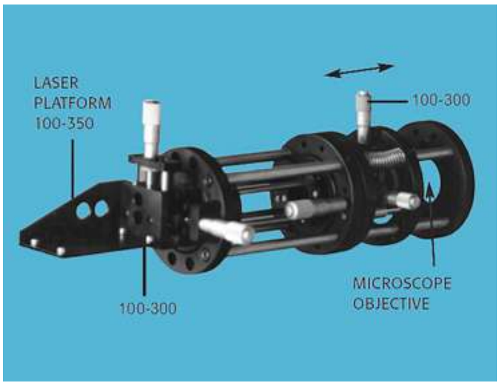


UCSD built this complex setup using 150 mm Macroptic mounts to setup their 3rd harmonic generation microscope. Two objective turrets from below, and above focused to a sample.

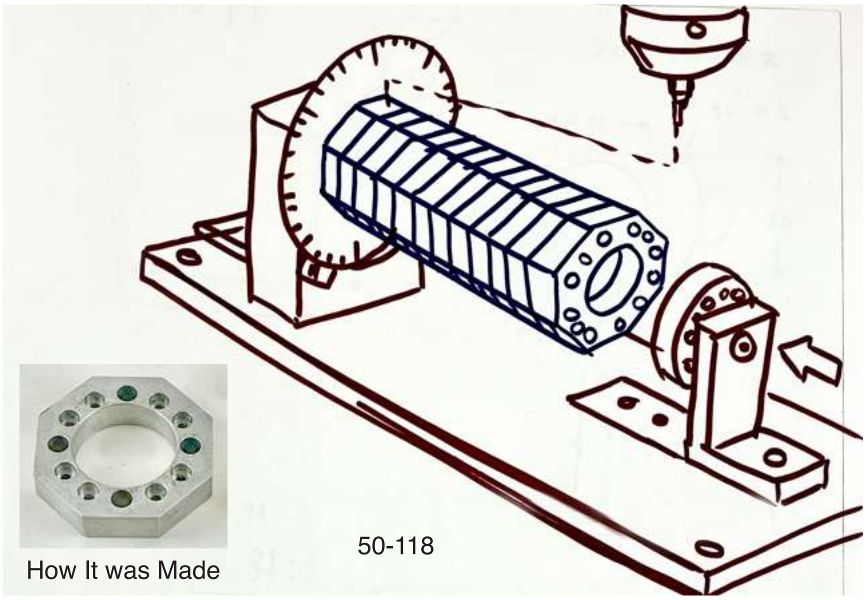
ducing Optoform, I finally hit the million dollar a year revenue, and with that budget, I was able to acquire a live tooling machine. The advantage of live tooling was obvious: It cut short three operations into a single machine cycle (see page 25).

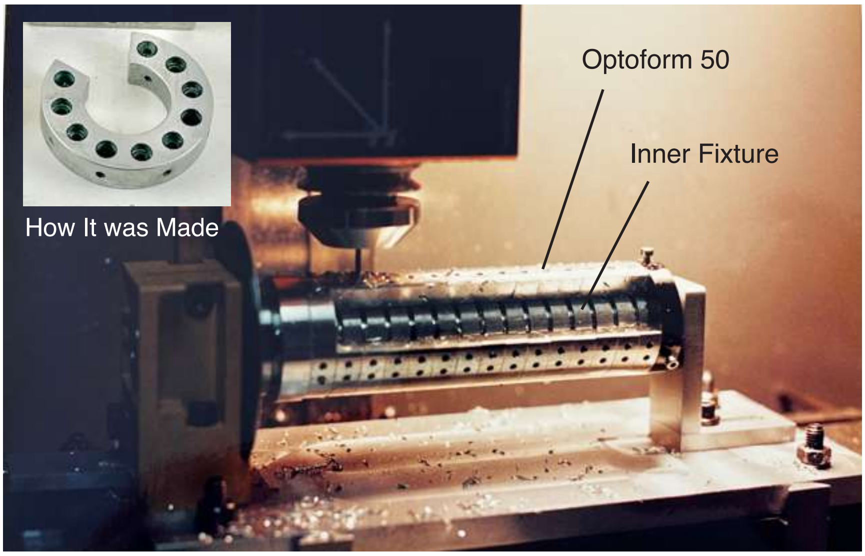
Previously, I had to machine circular discs for 25 mm, and 30 mm O.D. mounts, then place them 3 at a time on Mill 50 sub plate, and switch its 5 tools by hand, then pull them out, debur the bores, then pass two 6 mm rods through its bores to stack 14 of them together, push them along the horizontal fixture I had made on another sub plate, align the new fixture, then keep running the side bores using 3 tools. Then pulled them off the horizontal fixture, and deburred its tapped holes from inside the mounts, and throw them into a tumbler.

Custom parts for Optoform like this eye surgery system was ideal for Emco Mill 50 and Emco PC Turn 55 machines. Making these parts will not take machine time from a large machine.

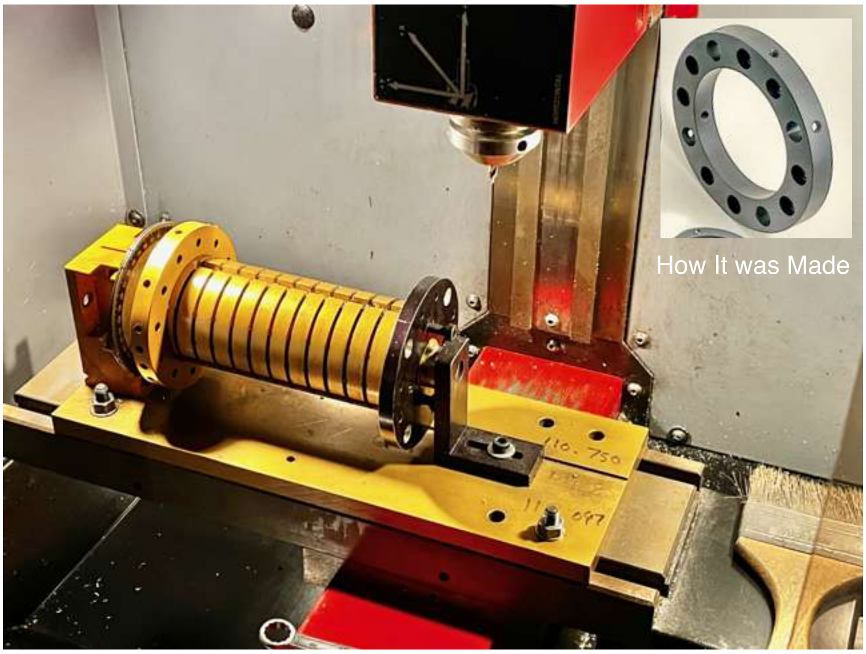


This self-holding instrument was ordered by Stanford University. It projected a beam from a solid-state laser to a detector inside a vacuum chamber. Minoptic 100 mounts served as the carrier, and the fact that it could be easily attached to the circular window of their vacuum chamber.

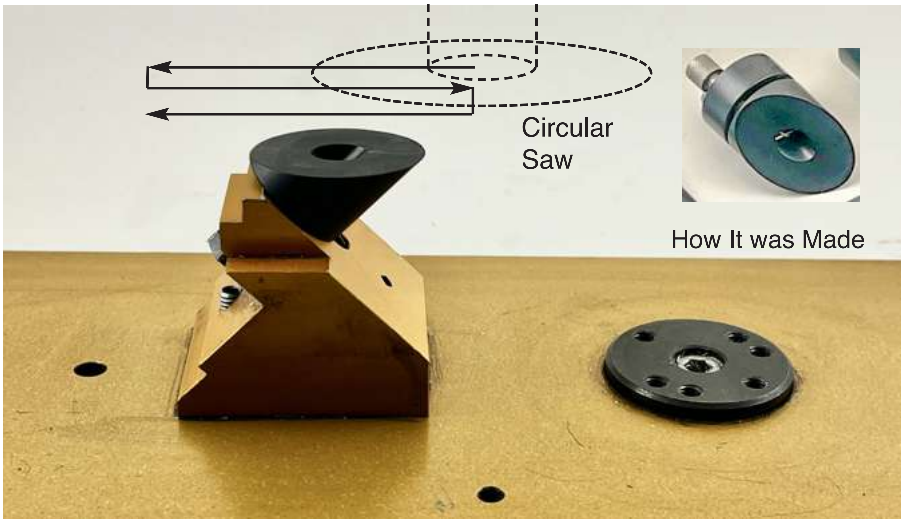




Very top, hand drawn procedure to manufacture hexagonal mounts by stacking 14 of them at a time. Below, sub plate to produce 100 mm mounts.



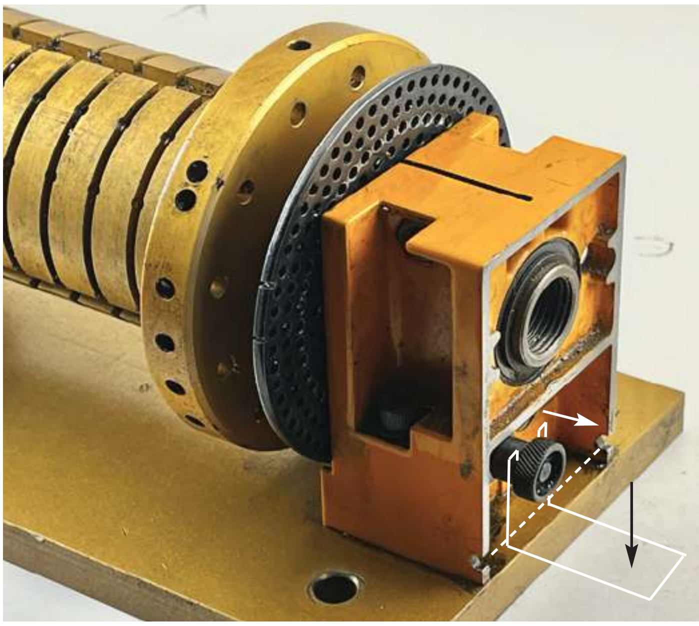
Emco's Compact 5 chuck was used for milling the faces of cylindrical parts.



Special fixture to make 45 deg. mirror mounts using Unimat's circular saw.

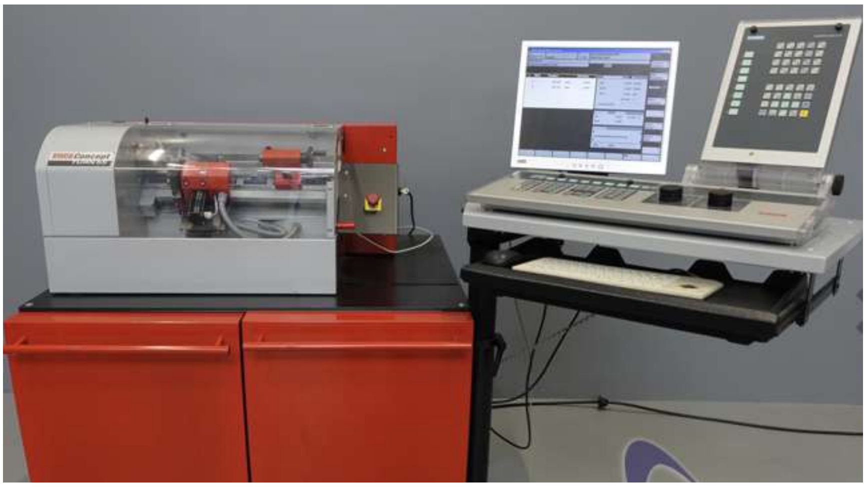
Tumbling the parts was to achieve consistent satin finish before anodizing. When Edmund took over Optoform's production, their supplier didn't tumble the parts, so they came out shiny, and that's not good for optics. In any case, various methods are shown in these pages that show how each part was made using specifically designed sub plates to produce those parts. With live tooling CNC lathe, all these operations were reduced to a 4 minute machine cycle that kept going without much supervision.

In CNC mill, what you also have is the Y-axis, to drill holes not only aligned with the optical center of the mount but also shifted to the side. This is shown in case of 50-118, or the octagonal mount. This mount could not be produced without a Y-axis live tooling machine (50-118). That would bring up te price to $100 K. So, as a manufacturer, the cost of each mount can be calculated by the monthly payments towards the cost of the machine. This is why those machines must be running around the clock. You know by now why each Microbench mounts costs $40 each. Optoform's circular design cut down its cost to $30 each.



Dividing head for Compact 5 was utilized in building all side hole fixtures. I added a L-Shaped lever to pull back the lock pin by a simple push on the lever to advance the fixture to the next drilling angle.

Unimat's dividing head also helped making many of Optoform's pieces. This is a compact, and versatile dividing head (compatible with Emco chucks with 14 mm thread) that can be utilized to fabricate small parts.



Concept Turnl 60 with faster feed rate, and more powerful motor with slant bed similar to production machines.

Concept Turn 55 handled well in putting out Optoform 50 sized parts

The automatic turret of Concept Turn 55 can carry 8 tools. Automatic turret is specially necessary for CNC lathes for high tolerance machining.

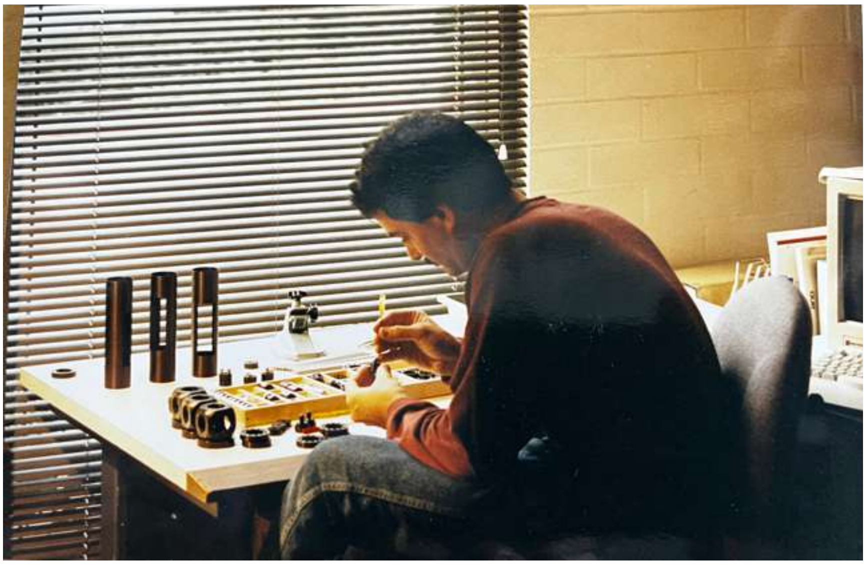
Model	Status	Notes
PC Mill 50	Discontinued	Author's original machine; superseded by Concept Mill line
PC Mill 55	Discontinued	Interface-upgraded successor to Mill 50, also retired
Concept Mill 55	Current production	8 tool stations, 0.75kW spindle, 190x140x260mm travel — still EMCO's smallest training VMC today
Concept Mill 105	Current production	10 stations, 1.1kW, larger 200x150x250mm travel
Concept Mill 260	Current production	20 stations, 7kW, largest of the Concept Mill family

Model	Status	Notes
PC Turn 50	Discontinued	Entry-level desktop CNC lathe, retired
PC Turn 55	Discontinued	Slant-bed successor, also retired
PC Turn 60	Discontinued	Top of the PC Turn family, retired
Concept Turn 60	Current production	60mm turning dia., 215mm length, 4,200 rpm, 1.1kW — closest current peer to the old PC Turn 55
Concept Turn 105	Current production	75mm turning dia., 4,000 rpm, 1.9kW
Concept Turn 260	Current production	25.5mm bar dia., 6,300 rpm, 5.5kW, 6 live stations
Concept Turn 460	Current production	45mm bar dia., 6,300 rpm, 13kW, largest of the Concept Turn family

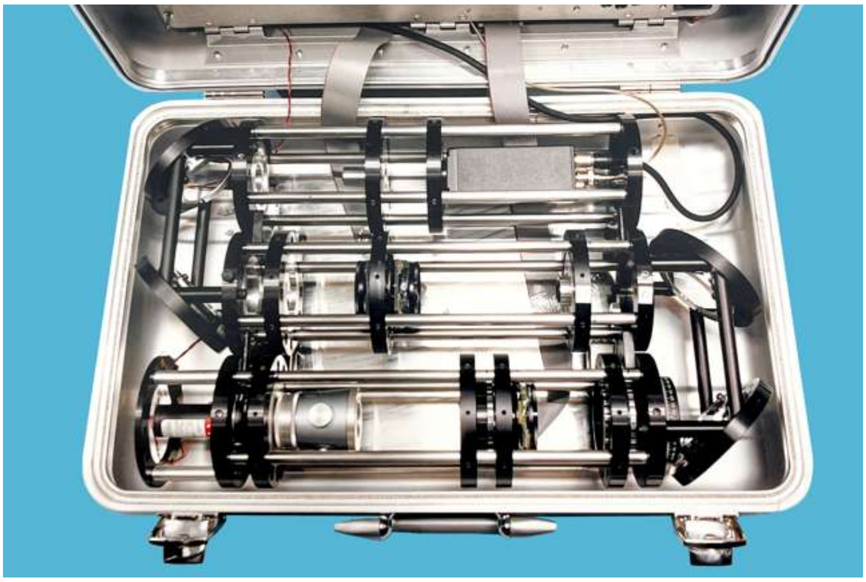
Above, Emcoturn E45 is the next generation of Emcoturn 360, and 365 machines. Back in the days, we were using Emcoturn 360, and absolutely loved it.

Discontinued EMCO machines are sometimes sold on eBay. Emco no longer supports those machines, specially when the RS-488 cards go bad, and there are no replacements for them. My 30-year-old Emco Mill 50 was so well built. It runs on Windows 98 with Wincam software, and still keeps running.

Opening of my first office my in Irvine, California in 1993



Assembling my first order: An eye surgery system mounted on a slitlamp



NASA's Jet Propulsion Laboratory ordered this pattern recognition system built entirely with Optoform 100 mounts. The self holding nature of Optoform allowed it to be fit inside an attractive Aluminum case.

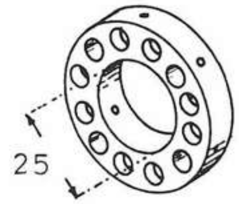
What My Marketing Teacher Taught Me

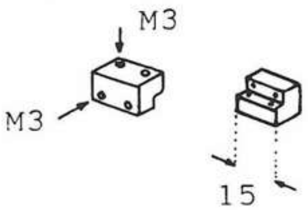
My marketing teacher was Joseph Cossman, a self-made American entrepreneur who taught many students his strategies for promoting and selling their products. He emphasized testing a product before anything else, so I did exactly that at trade shows. He gave great insight on how to run a trade show booth, and I followed about ninety percent of it. The ten percent I did not follow cost me a few million dollars.

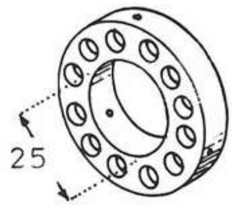
The problem was that I was so passionate about Optoform that I ignored other opportunities that came my way while attending trade shows. Joe's own example was the shrunken head: He had a booth selling Michelangelo replica paintings, and the booth next to his was selling shrunken heads. He asked himself who would pay $2.99 for a shrunken head when they could have a beautiful Michelangelo replica for ninety-nine cents. The show started, and there was a big crowd in front of his booth, except the crowd was actually an overflow from the shrunken head booth next door. Right after the show, he went and secured the exclusive rights to the product, and made his million dollars selling shrunken heads.

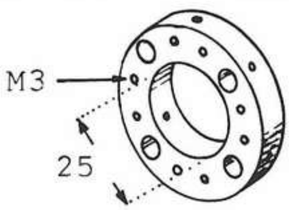
I learned that lesson the hard way, holding so tightly to my own product that I ignored opportunities standing right next to me. It is really not entirely an inventor's fault. If you have spent years developing, patenting, and producing your own product, you understand the pull of that singular focus. The other side of what Joe taught was the value of meeting great people through marketing efforts. He said it was the greatest influence toward world peace. I cannot emphasize enough the value of business friendships. They took me to Germany, to Singapore, to places I would never have visited otherwise, and when those same people came to the United States, I made sure to treat them the same way.

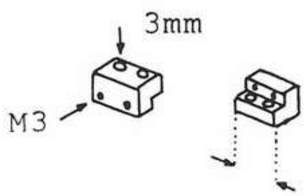
Joe also emphasized the importance of a good relationship with your bank. I remember times when I had so much money in my account that the bank would not let me transfer it to another branch. I also had hard times, and a

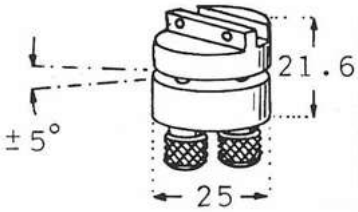


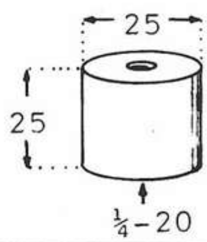


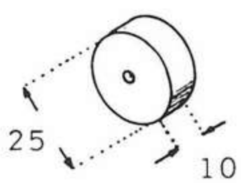




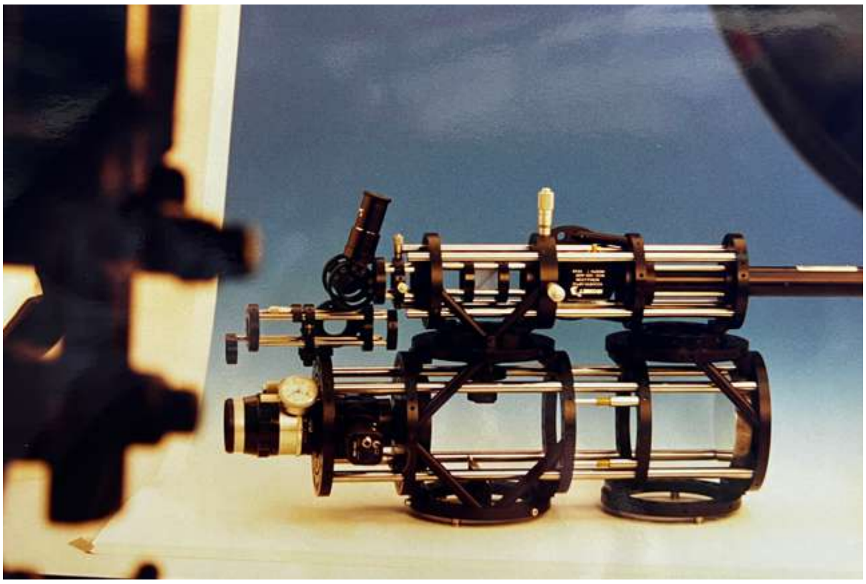








At Chester Maharaj's studio, we began photographing Optoform for ads.



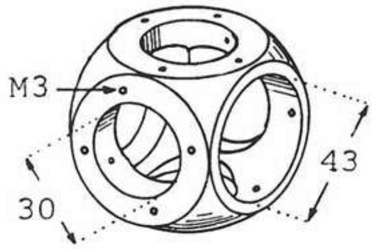
This Optoform photo took half a day to make using dry ice to create smoke. Back in those days, to show the laser path, you had to have smoke!

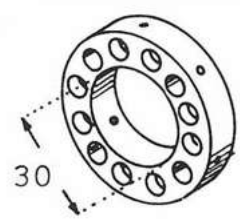
That picture was enlarged to a poster, and used as background at my shows

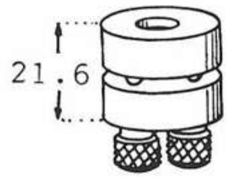
One of our early stands at World of Photonics show in Munich, Germany.

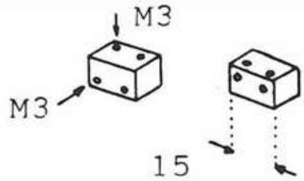
Photonics West was our main show, held every year in San Fransisco.

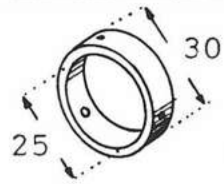
Barry Johnson who owned Optical Etc., became our first distributor in the East Coast.

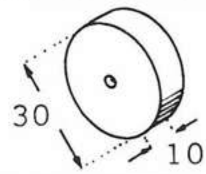


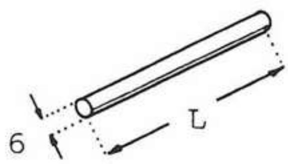


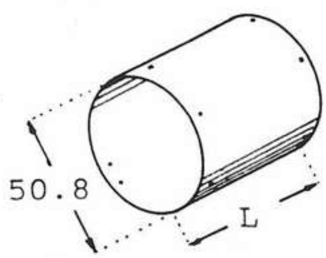










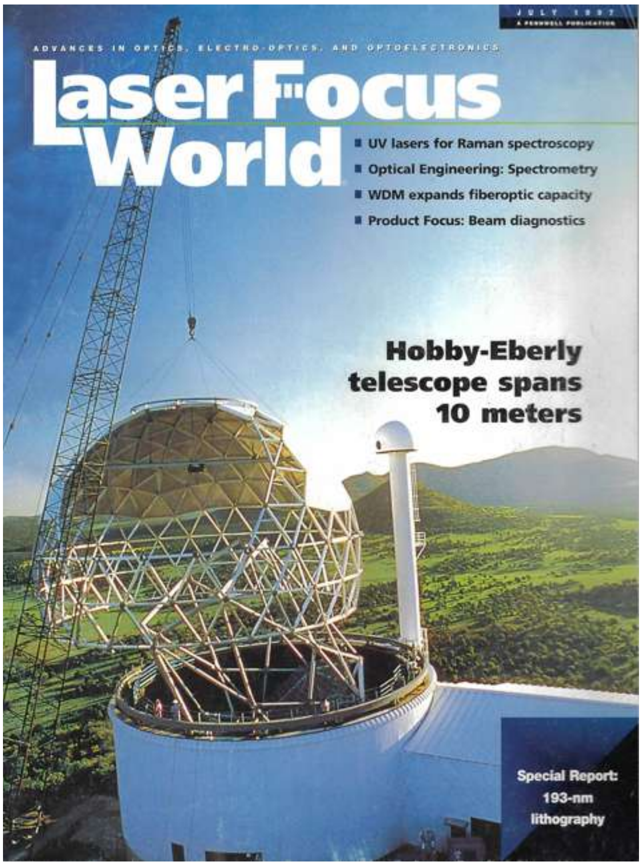


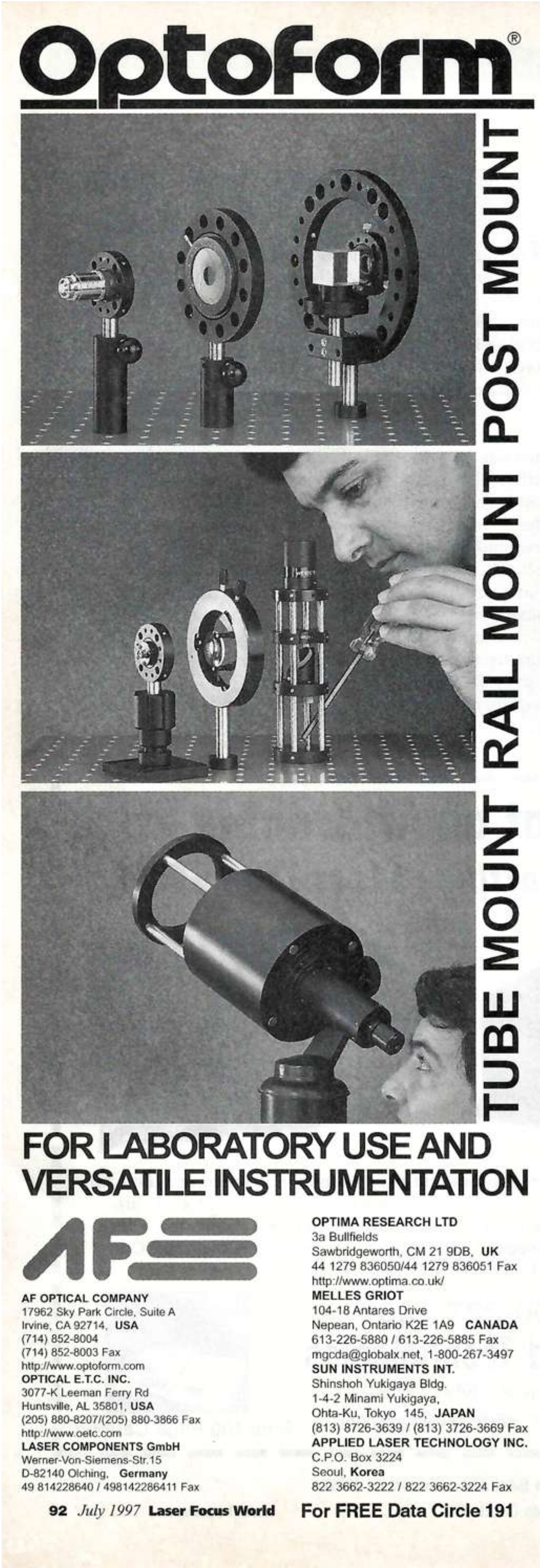
worker at my bank kept refunding the fees on my bounced checks. What comes with promoting your own product is a new way of seeing the world. Every time I travel with my wife, I notice details in museums in Russia or Munich that a typical tourist would walk past without a second look. That habit of attention is something marketing your own invention teaches you, whether you intend it or not.

The Catalog, the Merger, and the Cost of Losing Control

Eventually I became saturated with the business and marketing side of Optoform, to the point that I considered handing it to someone who could put more capital behind it and make it more widely available. Ironically, this decision came right after I had printed a large catalog and bought the EMCO 360 with live tooling. Producing that catalog actually cut into sales for six months, because we stopped manufacturing and focused entirely on getting the catalog right.

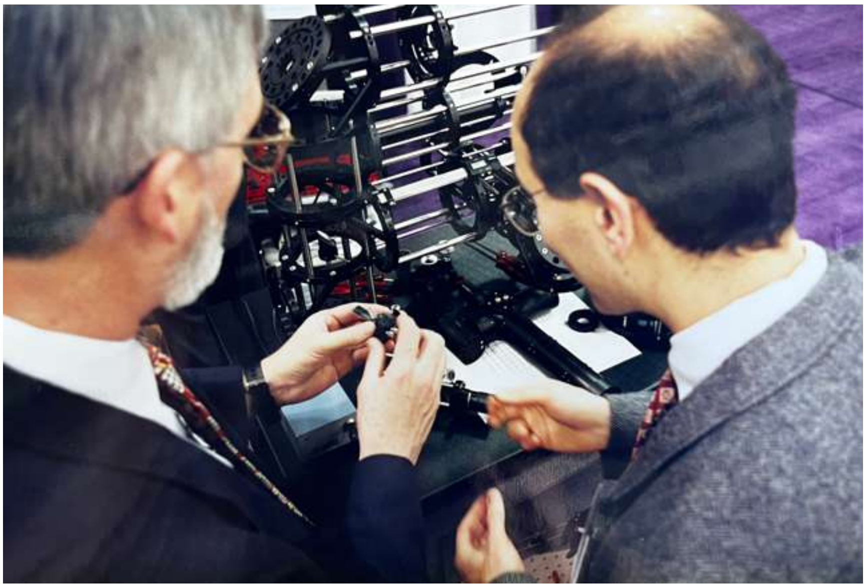
Lucius Amelung, CEO of Micos in Germany, once told me that his company had hired a professional photographer and spent twenty-five thousand euros on their own catalog, and it still turned out with far less information in it than mine. When I told him we had simply stopped manufacturing and sales for six months to focus on it, he could not believe it. That is something only possible when you run a small company and can make that trade-off yourself.



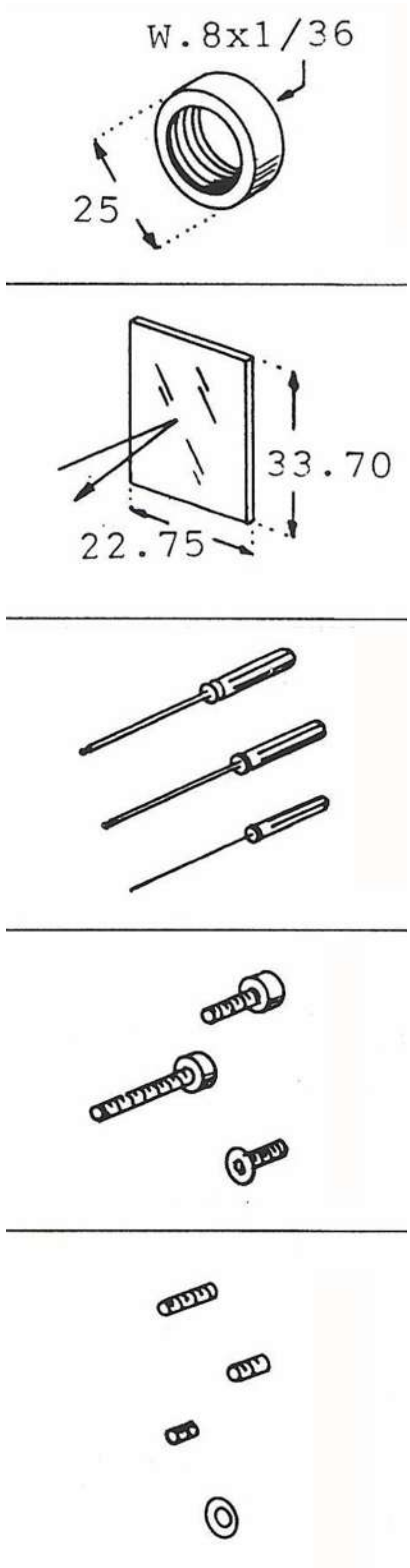


Optoform Ad, July 1997, Laser Focus World. We also ran full page ads that cost $4,500 but I soon learned frequency was more important than than our ad size.

With Coung Dang, Sun Instruments became our distributor in Japan.



Laser Components became our distributor in Germany, and Optima Research became our distributor for UK, also Melles Griott was our distibutor in Canada.



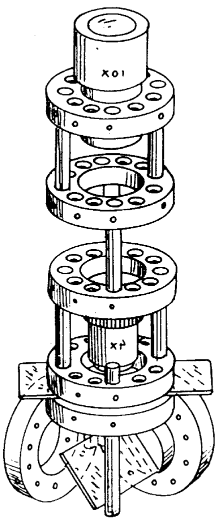
Drawings from our first catalog showing some dimensional data on the basic parts. Believe it or not, these were drawn by hand, and labeled with a typewriter. The labels were typed, then cut out with scissors, and glued in place using tweezers. With these simple components, so many optical instruments could be constructed. The mounting possibilities were intended to be like LEGO blocks.

Eventually, in 2013, we signed an M&A agreement with Edmund Optics, turning the product over to them for manufacturing and marketing. While transferring the product, I spent a week in Tucson, Arizona, with their design and manufacturing staff to walk through the technical details. They showed little interest in the underlying design philosophy and wanted mainly to review the tolerancing of the parts.

After they took over, they began changing the design. Despite a verbal commitment to manufacture the whole system, they kept only the 50mm mounts and set aside the rest. The circular mounts had originally been made 49.25mm in diameter specifically so they would be tube compatible, using a specially ordered 2.5 mm-long M3 set screw to secure the rods. Edmund's team asked why not simply use a standard 3 mm-long screw and make the mounts an even 50mm instead. It seemed like a minor simplification, but it broke the tube compatibility that had been engineered into the design from the start.

That is what happens when you lose control of your own product. Looking back, I still believe it was such a great design. Our five-year non-compete agreement ended in 2018, and we still carry a good inventory today, especially of the larger mounts that Edmund chose not to continue.

"What I learned from Optoform I was to never over-expand your product line to the point where you cannot deliver on time."

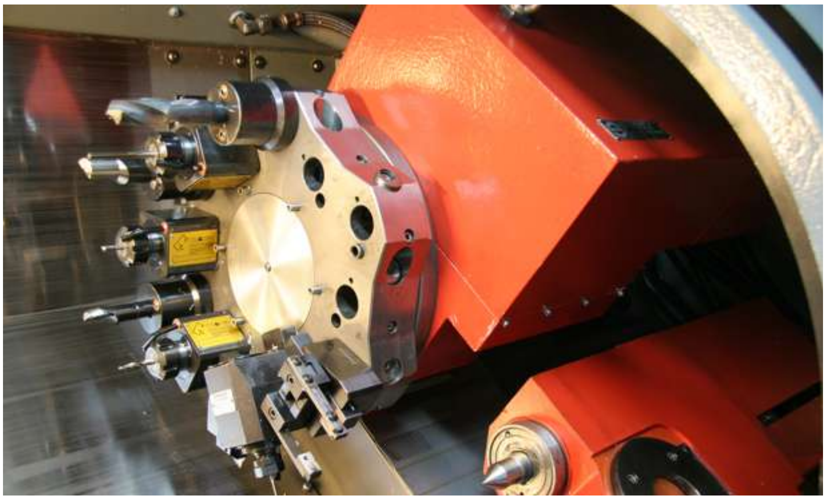


A Transmission Microscope

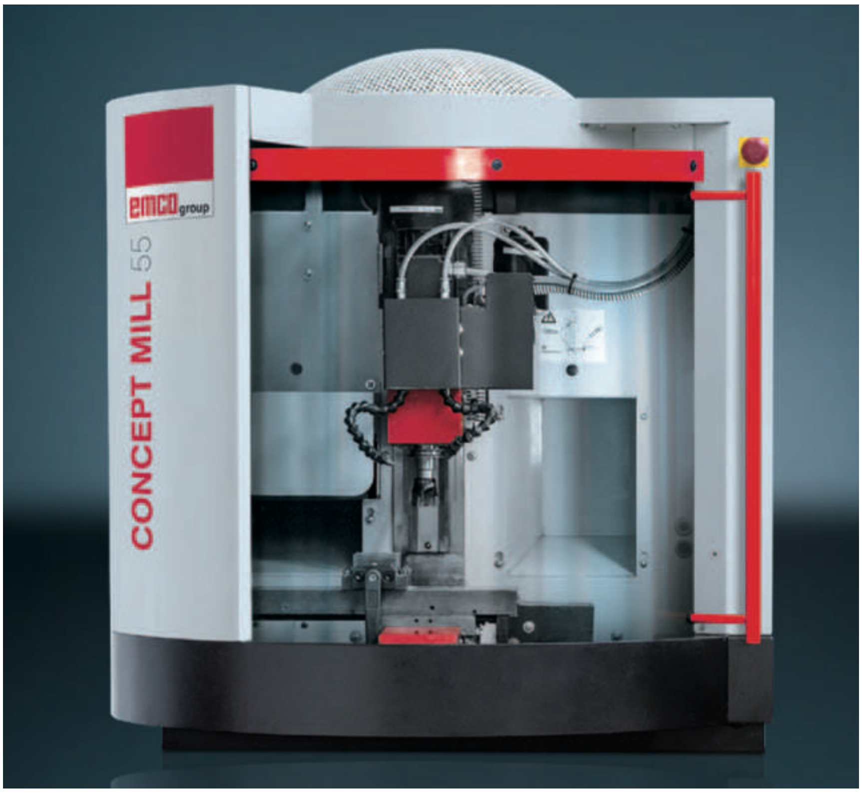
Mounting possibilities with the basic kit

WIth the basic kit you saw on page 4, you could construct all the following instruments.

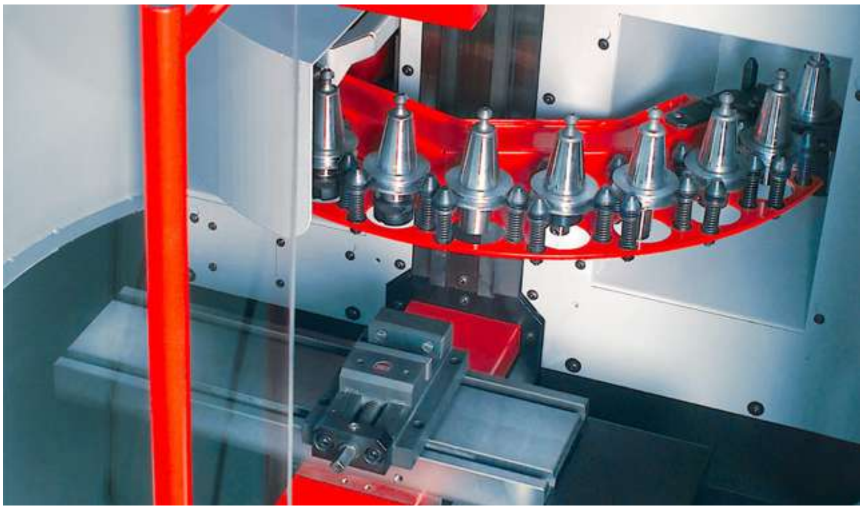
Emco 360 put out once Optoform mount complete every 4 minuts.



Close up of some of the live tooling we used in manufacturing Optoform. To start with, this machine drilled a 1” drill right into the 2” bar with no problems.

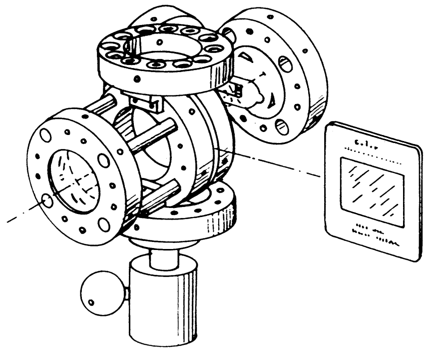


Emco’s Concept Mill 55 has an 8-station tool changer for fully automatic machining, plus updated software that runs on Windows 10.

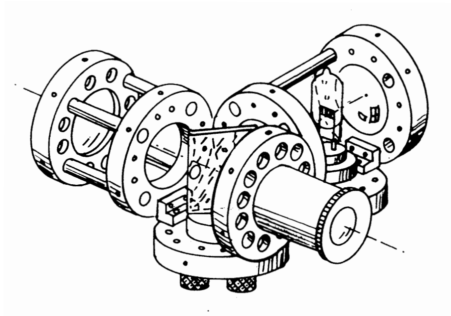


The 8-station tool changer in Concept Mill 55 offers full machining cycle.

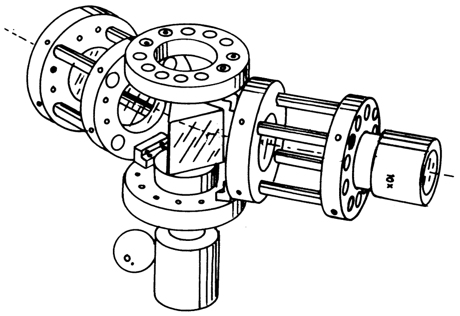
Concept Mill 55 has more powerful 3,500 RPM motor, and higher feed rate



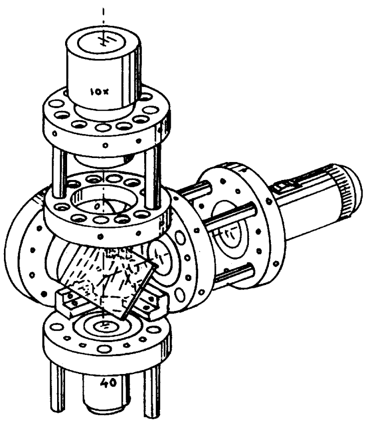
A Slide Projector



An Autocollimator

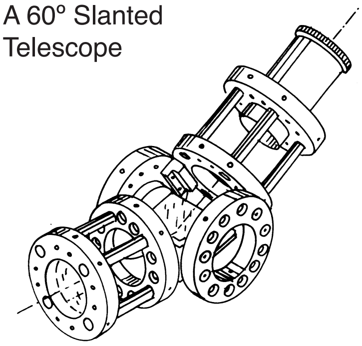


A Spectroscope

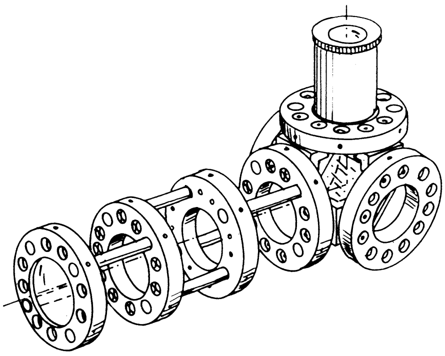


A Metalurgical Microscope

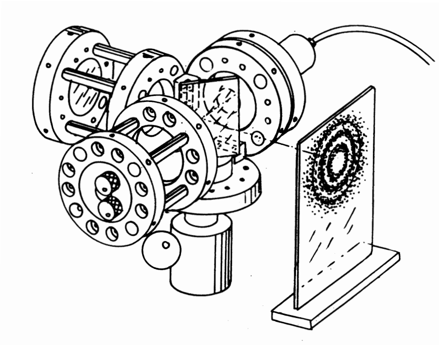
A 60º Slanted Telescope

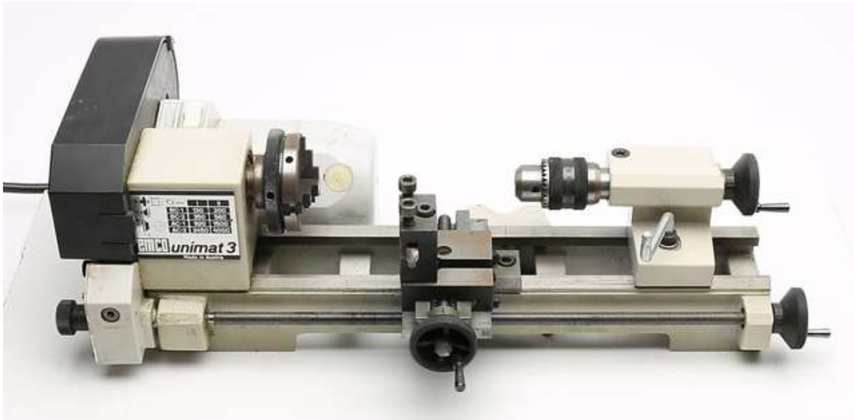


A 90º angled Telescope

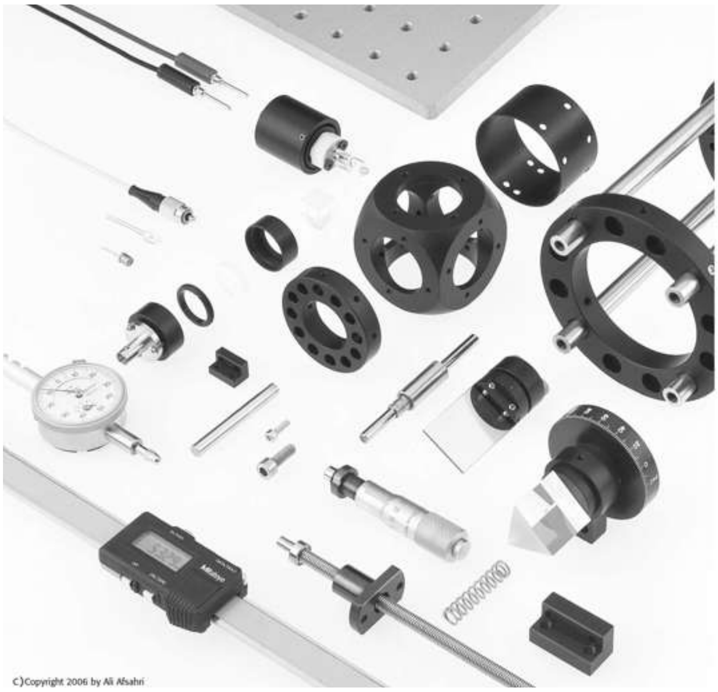


An Interferometer





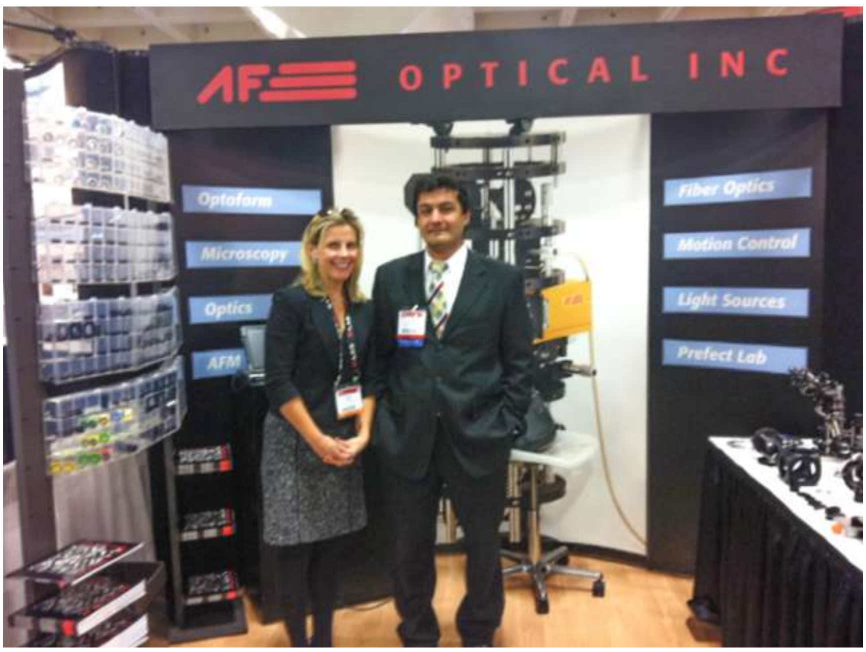
For me it all began with buying this small lathe, and it led me to the world of creativity, manufacturing, and marketing, and meeting some great people.



Optoform catalog: You had to look at the logo off of the reflective back of front cover to see “Optoform’ logo the right way.

I understand exactly why I offered such a large number of mounts in the first place: It was meant to prove the wide range of the system's prototyping capability. But my distributors were frustrated when a two-week back order sometimes stretched to a month. With Optoform II, I will not make that mistake. We will mass produce a smaller number of parts and keep stock of them before offering the system again.

For the new Optoform II, the manufacturing scheme will be different, and considerably less expensive to offer. I hope the industry and educational institutions will find real use for its lower price, and that it plays a meaningful role in education and in research and development labs worldwide.



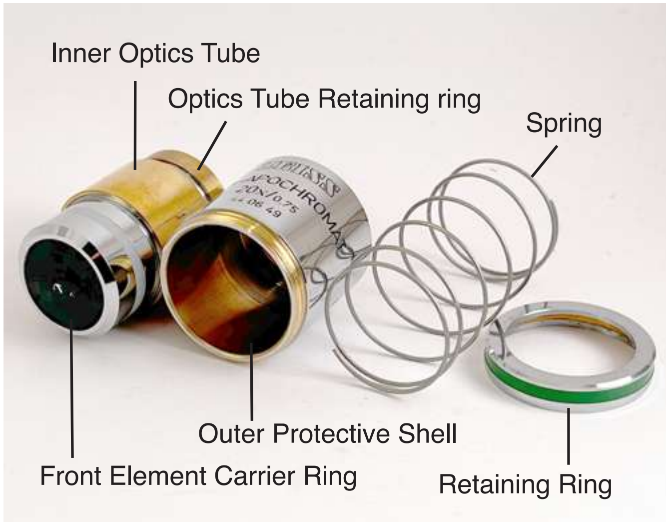
With Linda Smith who arranged the M&A contract with Edmund Optics

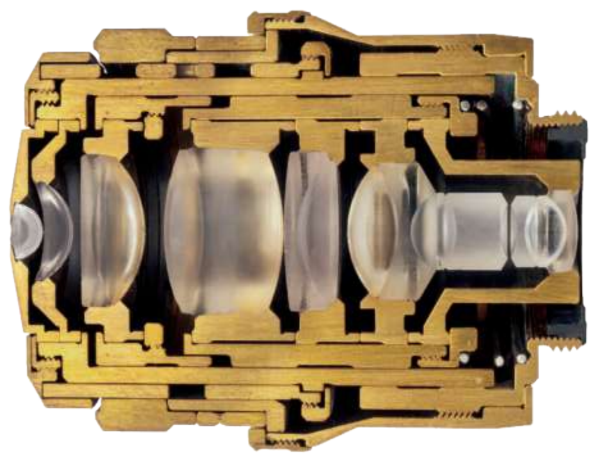
Zeiss Objectives

Microscope objective lenses are the most difficult part of the system to design and to fabricate. This is the optics that is focused very close to the sample to project its very image at a distant in a similar manner to a slide projector. That image is then focused to the eye or a CMOS sensor for viewing or image capturing.

This is the least disassembled, and studied part of the microscope because of its delicate nature, and dust proof construction. It is also because so expensive to explore, such as this $$4,000 Plan-Apochromat 20X objective lens by Carl Zeiss. So, I said why not disassemble this lens to make it less scary to look at. I actually took off the rear lens cell of this objective, and torched it’s housing to extract its triplet lens to study it. To any Zeiss expert, I probably rrrruined it, but I doubt that. All I am saying is show some courage to understand things.

Using a micro-torch, that you could purchase from any electronics store, you’d first heat up a front ring that seals its mechanics, and after its removal, the rest of its disassembly is quite easy. Just remember the direction, and order of its inner elements, and if there are any washers in between. Use derlyn rods to push elements in and out.





Just see the number of elements in this 100x design. Exactly how is Zeiss securing its rear elements?

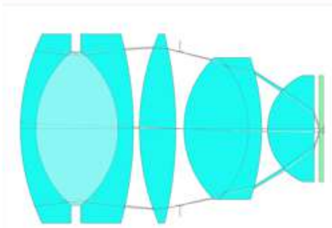
Zeiss 20X Plan-Apochromat objective disassembled to show its inner elements. Each lens is centered/epoxied inside precisely machined brass cells, 19 mm in their outer diameter. The lens cells are then stacked inside a tightly toleranced barrel to achieve their critical coaxial alignment. If necessary, extremely thin washers are added to insure proper spacing. The precision of these lens cells, and their flawless cementing is impressive to anyone experienced in the field.

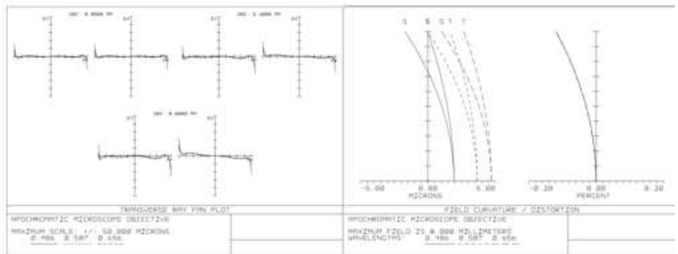
One notable lens group in its design is this really big fat element sandwiched between two meniscus elements on the back. Zemax rendering of a similar design is shown below. This rear end triplet plays an important role in image sharpness across the field of view. The art of producing these small elements, and stacking them into such compact space is worth handling, and learning from for all micromechanics enthusiasts.

Apochromatic microscope objective

Eff. Focal Length	: 3.61
Total Track	: 12.78
Image Space F/#	: 0.47
Working F/#	: 0.53
Parax. Ima. Hgt.	: 0.17
Max. Field (HFOV)	: 8.00 mm
Wavelength Range	: Visible
Number of Elements: 6	

Source : Laikin, *Lens Design*





Just because an objective says Zeiss on it doesn't mean it's as great performer as the rest. There are 15 categories of Zeiss objectives. The front row is the Plan achromat series, the most affordable zeiss objectives moderately priced under $500. The rear row is Plan Neofluar series, in the $1000 price range. The Plan-Achromats discussed earlier are in the $3,500 range. From industrial design perspective, all Zeis lenses whether they are for cinematography, or microscope, you just want to buy them for how they look. Their Contax rangefinder cameras weren't so attractive compared to Leica, but ever since then, Zeiss has really turned around to produce some of the most attractive optomechanical designs.

A-Plan: Good entry level product

LD A-Plan: For inverted microscopy

ACHROPLAN: Good color rendition for microphotography

W ACHROPLAN: Water objectives for immersion

FLUAR: For detectig very weak fluorescence signals

ULTRAFLUAR: For UV light microscopy Transmission for 240 nm to IR

EC Plan-NEOFLUAR
For enhanced contrast and high resolving power

LD Plan-NEUFLUAR
For extra long working distance microscopy

PLAN APOCHROMAT
For live cell imaging, with high numerical aperture

W Pan-APOCHROMAT
For electro physiology for visible to near IR

C-APOCHROMAT
For 3D microscopy, confocal and ASM

LD C-APOCHROMAT
For multi photon microscopy long W.D.

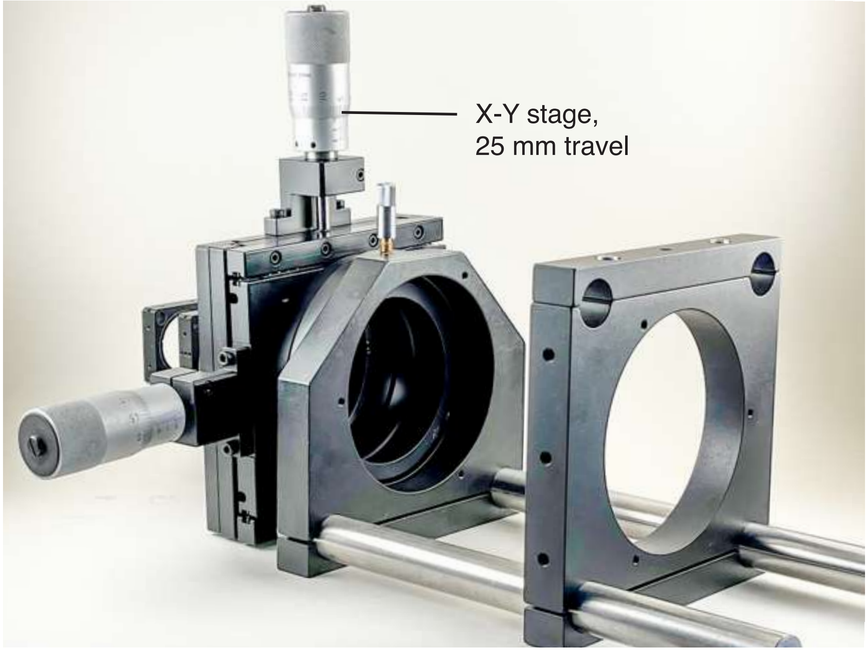
LCI Plan NEOFLUAR
For live cell imaging without cover glass

LD LCI Plan-APOCHROMAT
Ulta long working distance to see through thick specimens

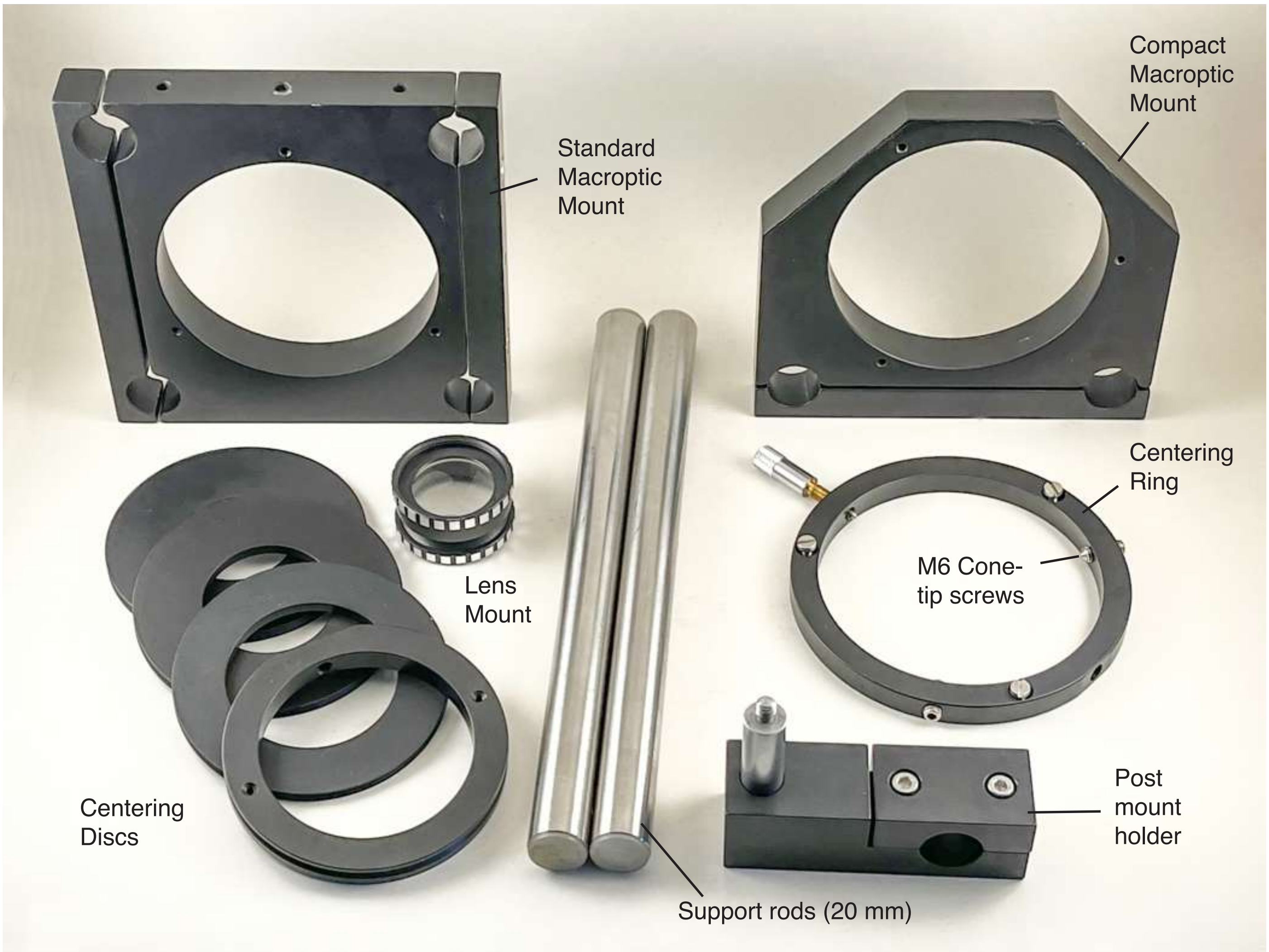
α Plan-FLUAR 100X
Excellent transmission properties for 340 nm

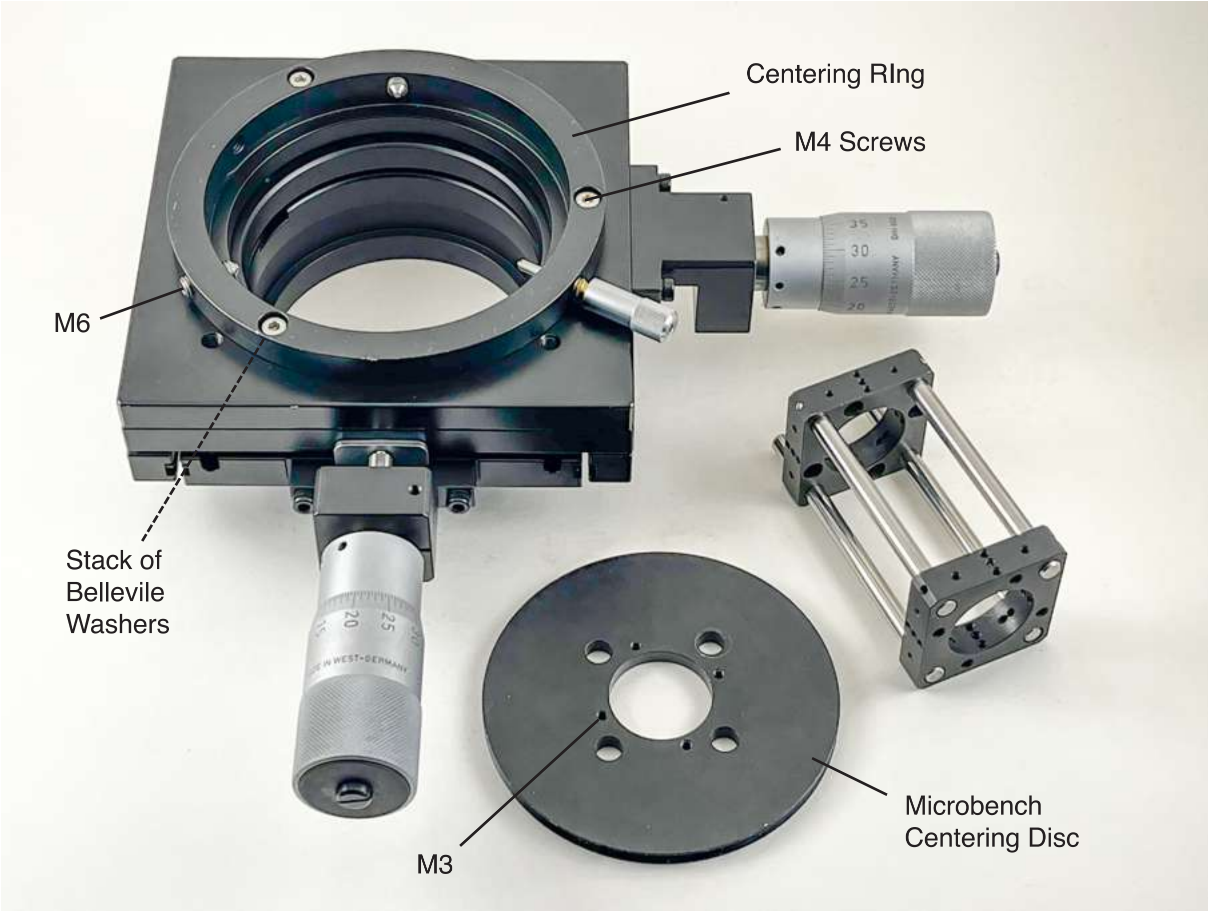
The Art of Spindler & Hoyer **Part 2**

In this series of articles, I am searching for the finest examples of industrial design in the history of optical instrumentation. By covering Spindler & Hoyer, I hope to preserve what the industry has largely forgotten. In the previous issue, I covered the classic V-rail, the X-95 optical rail system, and introduced Microbench. In this issue, I turn to Macrobench.



Macrobench was a scaled-up version of Microbench — mounts measuring 150 × 150 mm, 20 mm thick, carried on hollow 20 mm support rods. Those hollow rods were an elegant detail: they could be sand-filled to damp vibration without adding rigid mass. Optics were secured through a centering ring with three cone-tipped M6 screws spaced 120° apart, one of which was a precision spring plunger adjustable with a 3 mm ball driver (below). Centering rings attached via three M4 screws and accepted Belleville washers for tilt adjustment. The system was designed for large structures — microscopes, telescopes, substantial research instruments. Macrobench was never a strong seller and was eventually discontinued. Patent 3,945,600 (opposite page), filed by Klinger in 1976 in the US, Sweden, and France, and assigned to S&H Göttingen, remains its formal record.





Two sides of the X-Y stage show its centering disc on its back while having a centering ring on its front. All the accessories for Macrobench offered the same V-Grove at its outer circumference.

United States Patent [19]

Mallwitz et al.

[11] **3,945,600**

[45] **Mar. 23, 1976**

[54] **MULTI-DIMENSIONAL APPARATUS FOR MOUNTING LABORATORY AND EXPERIMENTING EQUIPMENT AND/OR FOR ADDITIONALLY MOUNTING OPTICAL ELEMENTS**

[75] Inventors: **Detlef Mallwitz,** Holtensen; **Hartmut Klingner; Wolfgang Kubbetat,** both of Gottingen, all of Germany

[73] Assignee: **Spindler & Hoyer KG Werk fur Feinmechanik und Optik,** Gottingen, Germany

[22] Filed: **Apr. 9, 1973**

[21] Appl. No.: **349,434**

[52] **U.S. Cl.** **248/466;** 403/171; 403/177

[51] **Int. Cl.²** **F16M 13/00**

[58] **Field of Search** 248/466; 211/177; 46/29, 46/31; 403/171, 172, 177

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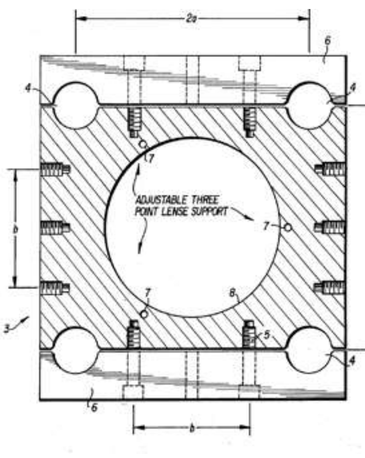
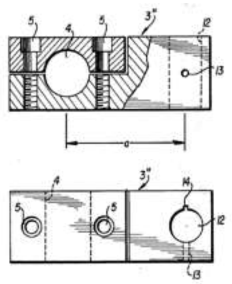
Primary Examiner—William H. Schultz
Attorney, Agent, or Firm—Roland I. Griffin

[57] **ABSTRACT**

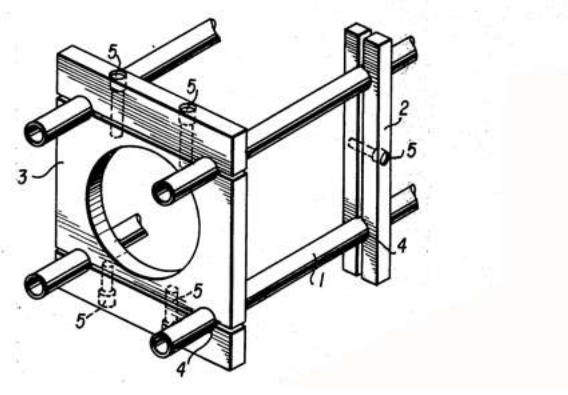
A set of connecting elements and mounting elements are provided with split openings and clamping means arranged selected distances apart and at selected orientations so that these elements may be attached to rods to form a multidimensional frame for mounting laboratory and experimenting equipment. Adjustable mounting devices are provided with three point supports centrally arranged on the mounting elements adjacent to apertures therein so that optical elements and other such devices may be supported on the mounting elements and so that the axes of such devices may be tipped or displaced as required for a particular situation.

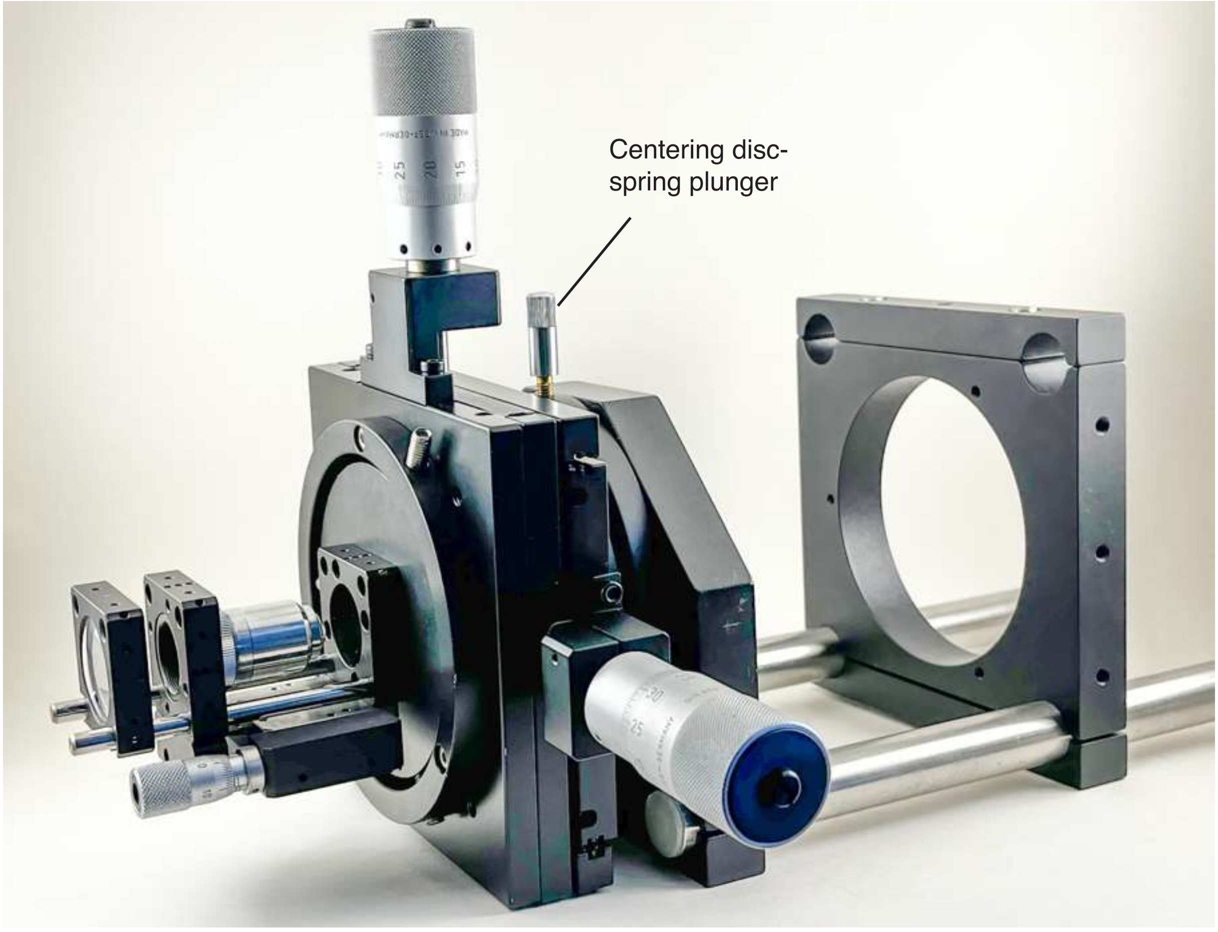
11 Claims, 11 Drawing Figures



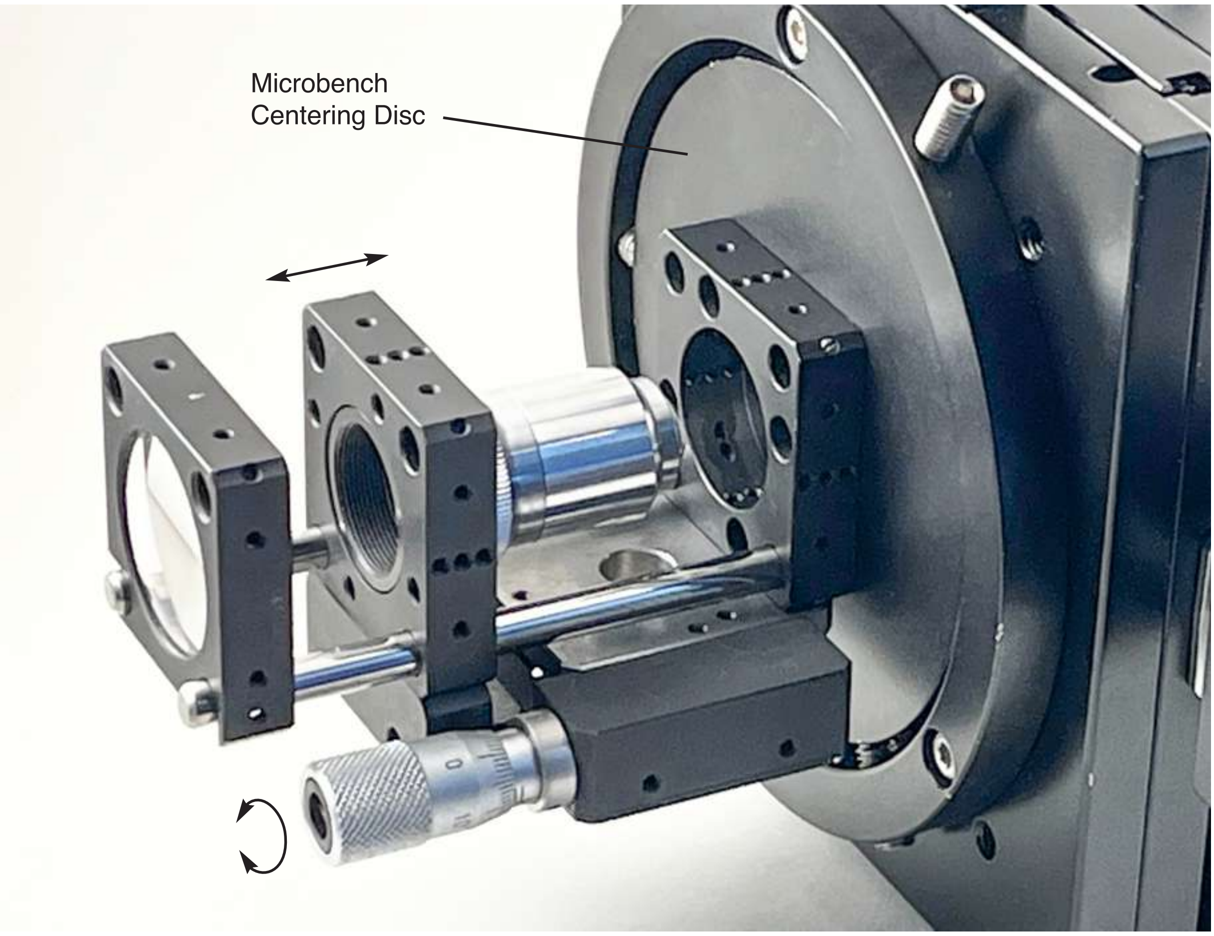


Macrobench patent drawing reveals its post mount accessory (opposite page).

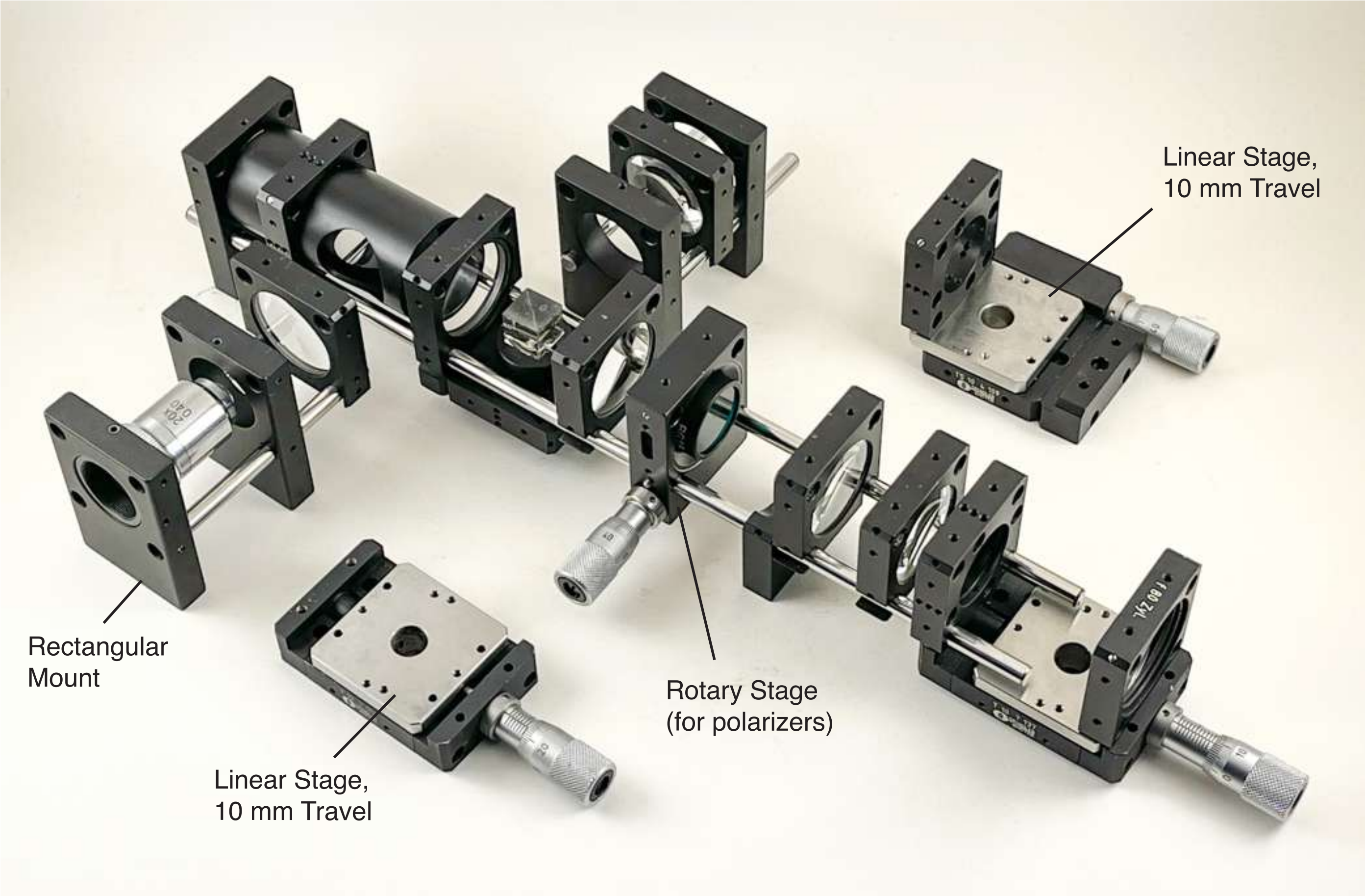




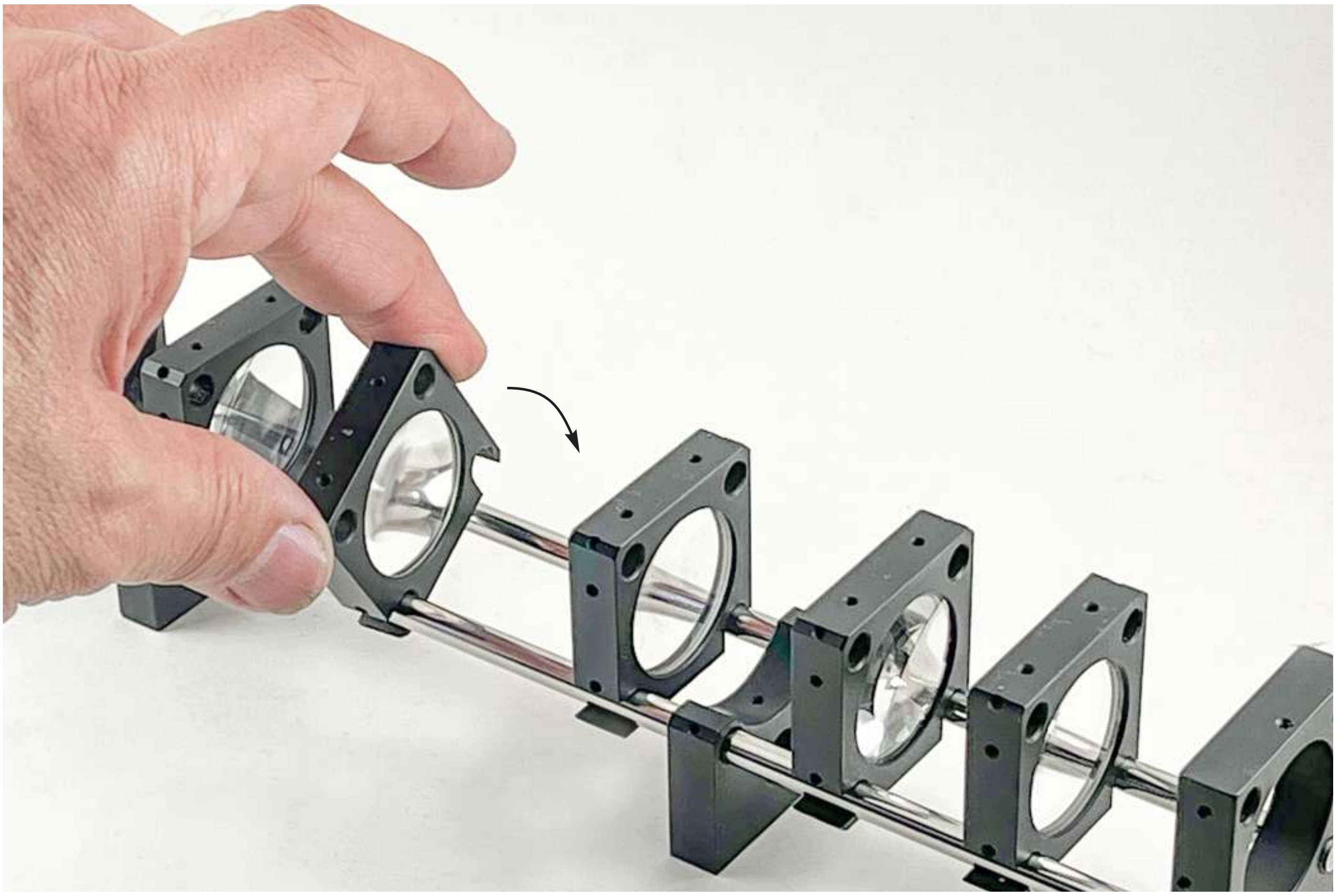
Utilizing the Microbench centering disc, the sub assembly could be rotated, centered, and tilted.



Close up for Microbench assembly reveals a short lived translation stage. Not many customers knew how to utilize them.



Above, Spindler & Hoyer stages offered linear, and rotary stages integrated into their rod system. The rectangular mounts positioned the optical axis at 40 mm above the optical table, providing clearance for micrometers. Below, this quick lens insertion technique is unique to the Microbench system. No other system has it. It is such a slick design to work with.



Trustee from the toolroom

By Ali Afshari

There is a small book I want every optical engineer and precision machinist to read. It is called Trustee from the Toolroom, the last novel written by Nevil Shute — an aeronautical engineer who designed aircraft before he became one of England's most beloved novelists. He died in January 1960, and the book was published that same year. It was his farewell.

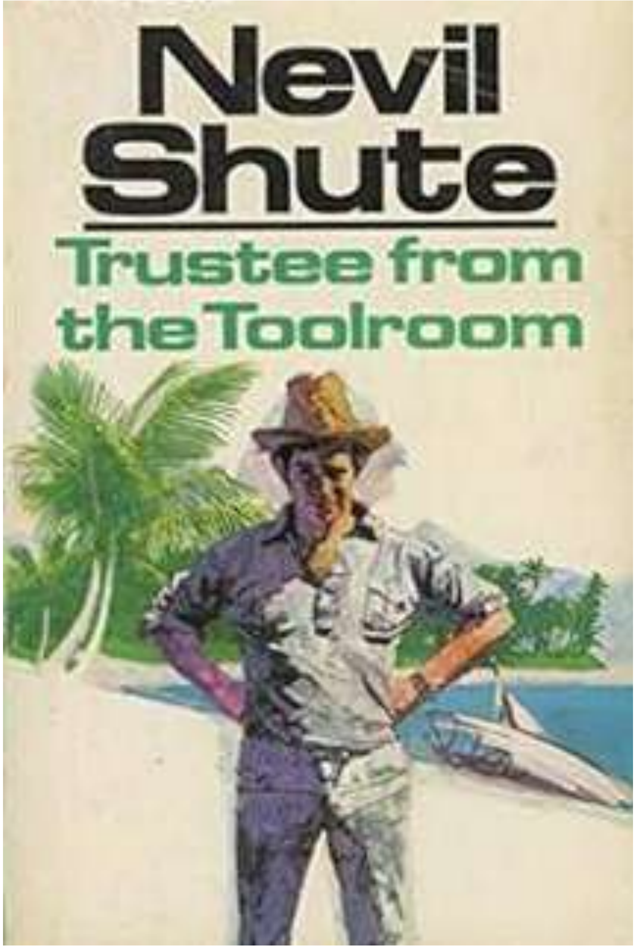
The hero is not a general, a financier, or a famous scientist. He is Keith Stewart — a modest man who writes detailed articles about miniature precision engineering for a small magazine called the Miniature Mechanic. He lives simply. He asks for nothing. But when circumstances force him to travel halfway around the world on an impossible errand, strangers in every port — machinists, engineers, sailors — recognize his name from his articles and rush to help him. His knowledge, shared freely over years of writing, has built an invisible network of trust that spans the globe. That network saves him.

You are holding the real-life Miniature Mechanic. Optomechanix exists for exactly the same reason Keith Stewart wrote — to share what is known, freely, with anyone who wants to learn. The parallel is not accidental. It is the point. Shute's deeper message is this: the true wealth of a craftsman is not his tools or his income. It is the knowledge he has shared — the apprentice he taught, the article that helped a young engineer understand something for the first time. That inheritance endures long after the craftsman is gone.

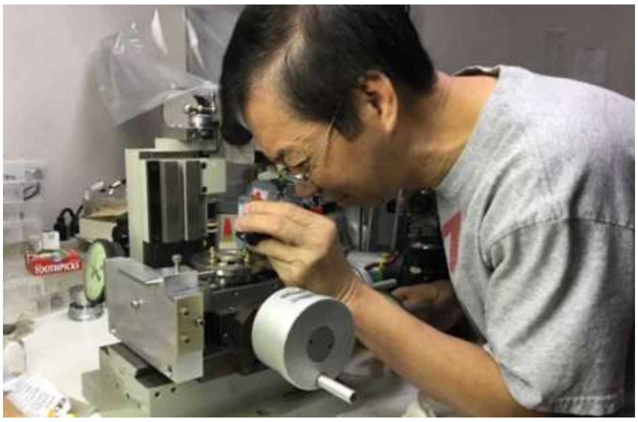
I think often of the Swiss watchmakers of the eighteenth and nineteenth centuries, working under magnification by candlelight in small Jura villages, developing the escapements and gear trains that made portable timekeeping possible. Most were paid little. Few are remembered by name. And yet everything they understood found its way forward — into the optical engineers of the twentieth century, into the CNC machines that cut precision components today to tolerances that would have astonished them. They asked for nothing. They left us everything.

There is a quote, often attributed to Mark Twain though its true origin is uncertain, that belongs here: forgiveness is the fragrance the violet sheds on the heel that has crushed it. The precision mechanics who built these instruments, who ground these lenses, who wrote these tolerances down in notebooks no one preserved — they asked for no acknowledgment. They gave us the fragrance of their knowledge anyway. They were true artists, and most of the world never knew their names.

I shared my own story in these pages because I wanted the young generation to see that with enough determination, it is possible to build something real. But I also shared the failures — the overextended product line, the backorders, the inventory that cost money I did not always have — because an engineer who hears only the success story learns nothing useful. An engineer who hears both has a map.



"The precision mechanics who brought these mechanical wonders to life asked for nothing. They gave our lives the fragrance of knowledge."



Robert Frost wrote that he took the road less traveled, and that made all the difference. Starting your own business is very similar to starting to climb a mountain. Some people, still at the bottom, ask those returning from the summit how it was up there. They keep asking. They collect descriptions. And many of them, eventually, decide they already know what the summit is like — so why make the effort? The knowledge works against them. They never leave the base. What those returning climbers cannot tell you is what you will see from the top. You must go your own path. You must make the climb yourself. And when you get there, you may come across something no one mentioned — a shrunken head, as my marketing teacher Joe Cossman would say.

Cossman had a booth selling Michelangelo replica paintings while the booth next door sold shrunken heads, and the crowd was at the shrunken head booth. He secured the exclusive rights immediately (see page 20). The lesson is not about shrunken heads. It is about keeping your eyes open at the summit, when you finally get there. Cossman also said this: if you have patented your idea, found ways to fund it, successfully produced it, and loaded the truck with the goods to sell — you have still traveled only ten percent of the road. That line should stop every engineer cold. The other ninety percent is marketing, relationships, distribution, persistence, and the willingness to keep going long after the excitement of invention has faded.

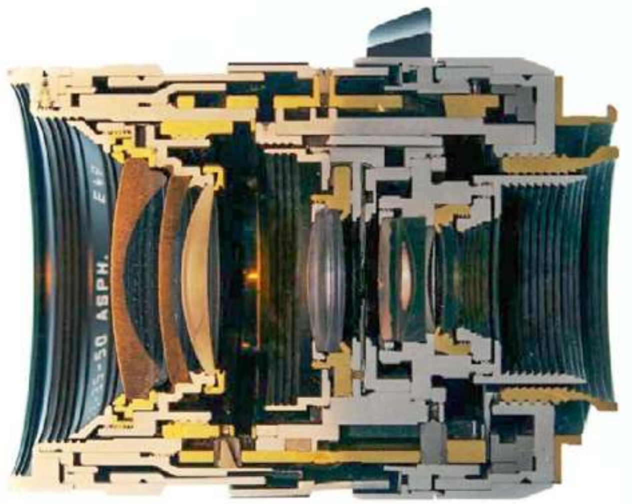
Cossman understood something that most engineers never learn: marketing is not a lesser skill than craftsmanship. It is an equally demanding art. Most people are strong in one area and weak in the other. The engineer who can build anything may not know how to sell it. The marketer who can sell anything may not understand what he is selling. This is not a flaw — it is an opportunity. The wisest thing an inventor can do is find the partner whose strength covers his weakness. Steve Wozniak could build a personal computer that changed the world. Steve Jobs could see what that computer meant to the world and convince it to care. Neither alone would have built Apple. Together, they built one of the most valuable companies in human history. Find your complement. Build together.

Know also that invention alone is not enough. There are brilliant ideas sitting in patent files right now, collecting dust, because their inventors believed a good idea would find its own investors. It will not. The path is rarely short, and it is never easy. Prepare for the hardships. Learn the business as seriously as you learn the optics. This magazine wishes to do both — to educate you in the world of optomechanics, and to share the business lessons that took a lifetime to learn. You need both. Every master who came before you needed both.

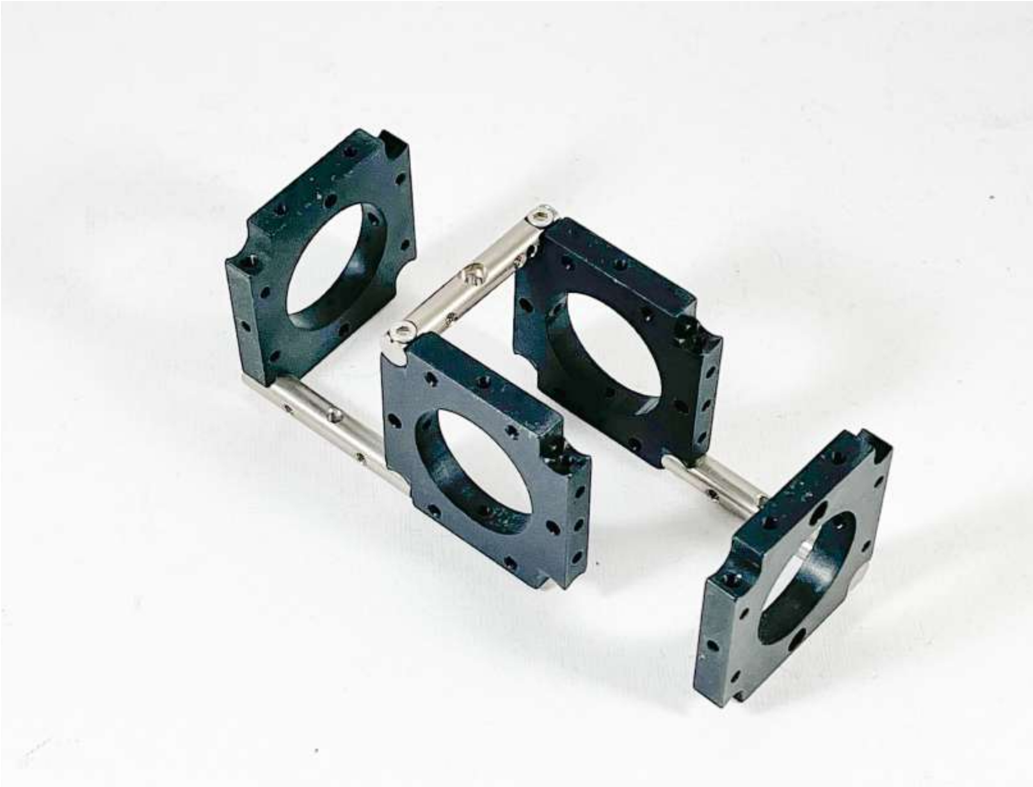
What you will leave behind, if you do the work honestly and share it freely, is a good story. One that may inspire generations you will never meet — engineers who will hold your words the way Keith Stewart's readers held his articles, grateful for knowledge passed forward without asking anything in return.

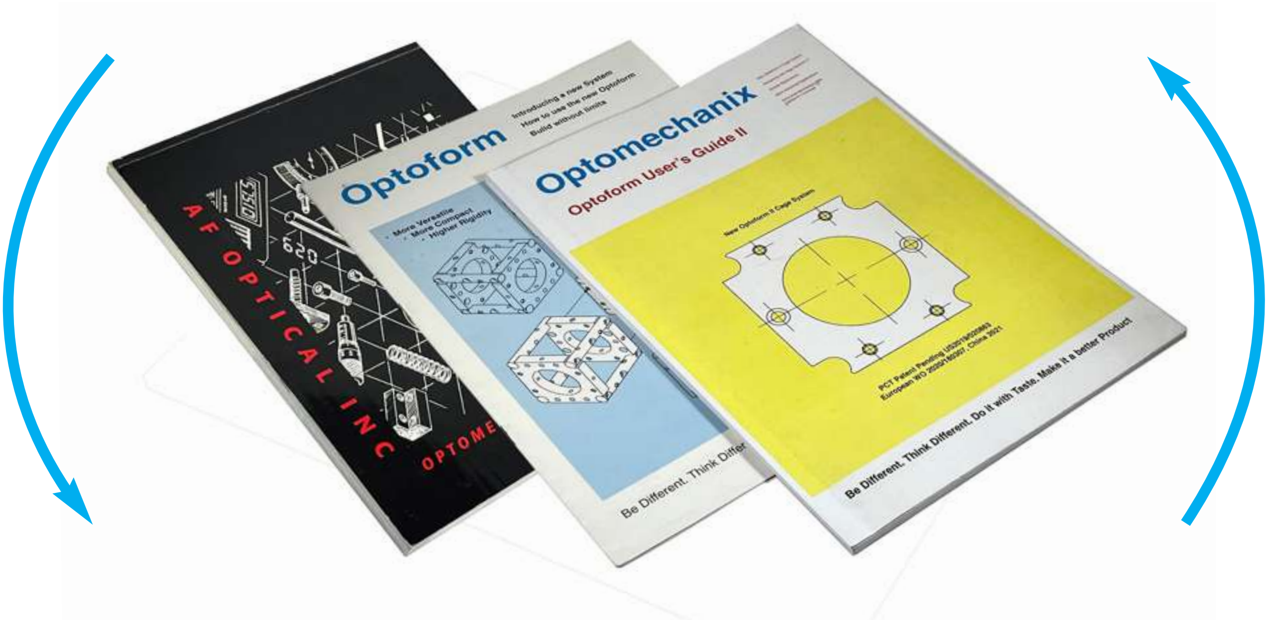
We are, each of us, trustees from the toolroom.

Master watchmaker Coung Dang at his work bench. Coung is a remarkable man, sharing everything he has learned without expecting anything back.



Cross section of Leica 35-50 mm lens OMiD muesum





Our Instruction Manuals

Optoform's user's manuals have been compiled to follow the tradition of optical erector sets. Every page is lavishly illustrated to show how each instrument is designed, and assembled together. As your knowledge of Optoform increases, so does the level of sophistication in your assemblies. Download from:

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