Optomechanix

Buccini Laser Interferometer

Minature Tilt/Rotation Stage

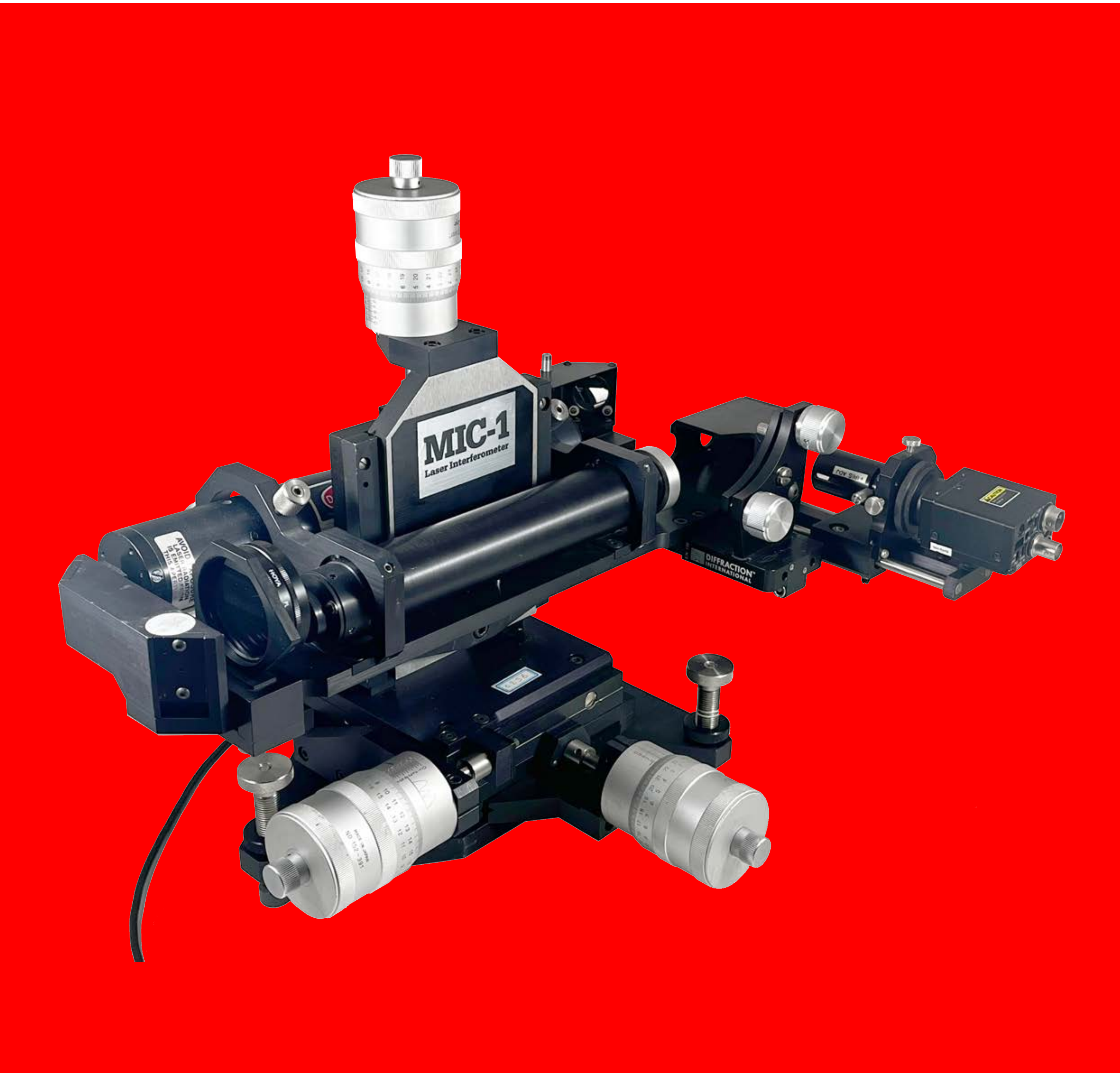
Surface Profiling Applications utilizing Buccini Interferometer

Testing Field Flatness of Lenses

Building an Optimized Beam Expander with Optoform

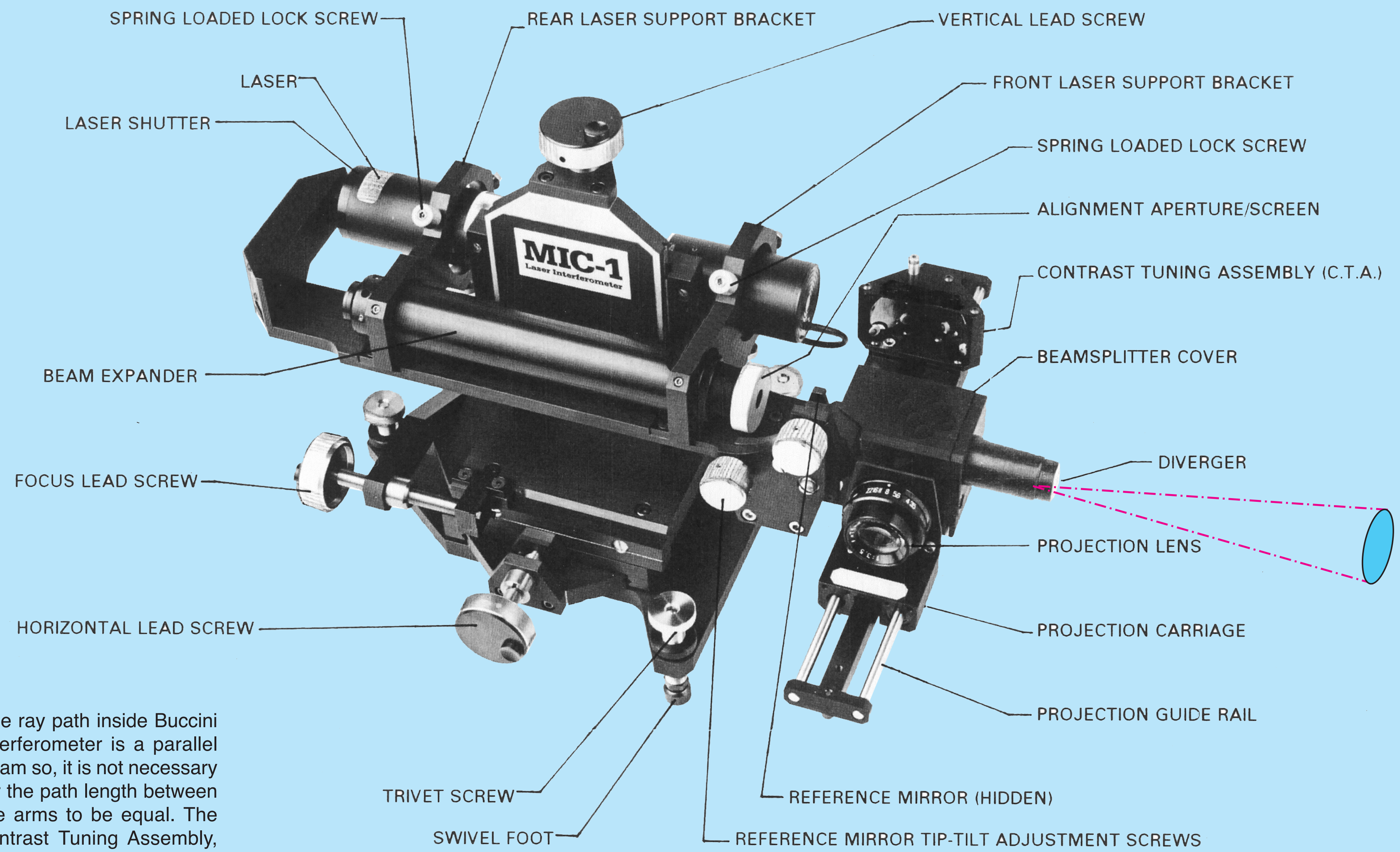
Interferometry Issue

Jan - March 2024



Technical journal of OMiD, Opto-Mechanical Institute of Design

BUCCINI INSTRUMENT COMPANY



The ray path inside Buccini interferometer is a parallel beam so, it is not necessary for the path length between the arms to be equal. The contrast Tuning Assembly, would normally be utilized for contrast enhancement, not as a delay line.

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Member of OSA
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Bob Marley (1945-1981)

Emancipate yourselves from mental slavery
None but ourselves can free our minds
Have no fear for atomic energy
'Cause none of them can stop the time

How long shall they kill our prophets
While we stand aside and look?
Ooh, some say it's just a part of it
We've got to fulfill the book

It's refreshing to hear this song at the time that people have rose up to fight for their civil liberties, and to not let our so called leaders use their intellect just for power and financial gain.

Palestine was once the home of Moslims, Jews and Christians whom for many many years lived in peace and harmony. Our wish is to bring all religions back together again through the sincerity, and just cause of the Palestinian people to liberate their land. President Biden says he wants to protect the Jews in Israel, we want them to be loved.

I would like to dedicate this issue to the **Palestinian People**, whose struggle may be expressed in this universal song by Bob Marley

Old pirates, yes, they rob I
Sold I to the merchant ships
Minutes after they took I
From the bottomless pit

But my hand was made strong
By the hand of the Almighty
We forward in this generation
Triumphantly

Won't you help to sing
These songs of freedom?
'Cause all I ever have
Redemption songs
Redemption songs

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Cover page photo: Buccini interferometer equipped with X-Y-Z micrometer heads

Front back: Parts description of Buccini interferometer from its user's manual

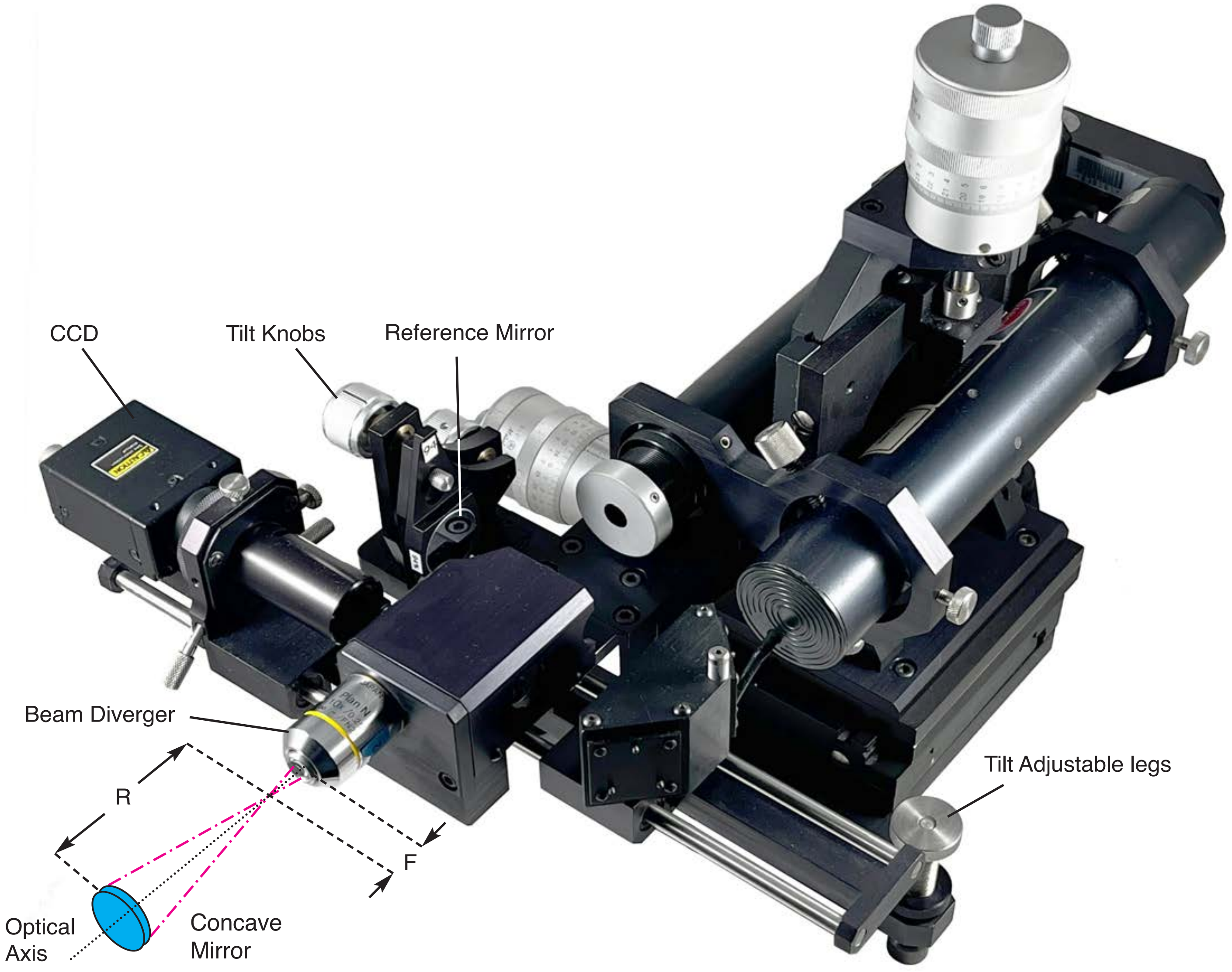
In This Issue ...

We have pretty much covered it all in microscopy with over 10 issues in the past. Microscopy is the most challenging instrument to prototype, and I think that was my obsession to prove the capabilities of the new Optoform design. Well, what about doing some interferometry with Optoform? That gives me a new purpose because interferometry would display the micromechanical stability of Optoform. As usual, we'll first learn how a professionally made interferometer works, and then we'll design, and build our own.

Buchini interferometer was designed by Jon Buccini, and meticulously hand crafted to a fine instrument. He built this instrument as if he wanted to build it for himself. John had his own machine shop, and must have hand made its first prototype. Every detail in this instrument is beautifully made, and assembled together to perfection. Only a machinist like myself could tell the detailed attention he must have paid on knurling of the control knobs, the surface finish, and close fit of its modular parts. He probably didn't get rich over this work, but that's not how I value things in the optical industry. I spent a month studying his design, and it was as if I sat with him in person, and he answered all my questions.

We'll briefly go over its design, and then in the next issue, we'll build our own interferometer with Optoform. One could also sit behind a computer, and design a perfect beam expander with Zemax but the actual performance of optical elements could not be verified until every one of them are tested, and verified. In this issue, we'll test a variety of optical elements first, to make a high-performance beam expander.

Ali Afshari
Editor in Chief
Optomechanix



Buccini interferometer uses folding optics to reduce its original length from 600 mm down to more than half.

Michaelson Interferometer

It's the simplest form of interferometer named after Michaelson who built it to measure the diameter of a star. I have posted a Youtube video covering his experiment. It uses a beamsplitter to combine two beams coming from a monochromatic light source such as a laser. The basic setup utilizes a spatial filter (Fig.1) to clean up the laser light by focusing it on a 5-10 micron pinhole. This causes the beam to spread out after passing through pinhole according to the f number of the lens (F/D). The beam is then collimated using a larger focal length lens, i.e., F = 150 mm to cover a large portion of the beamsplitter, and the other two mirrors for interference. By the way, the lenses don't have to be achromats because

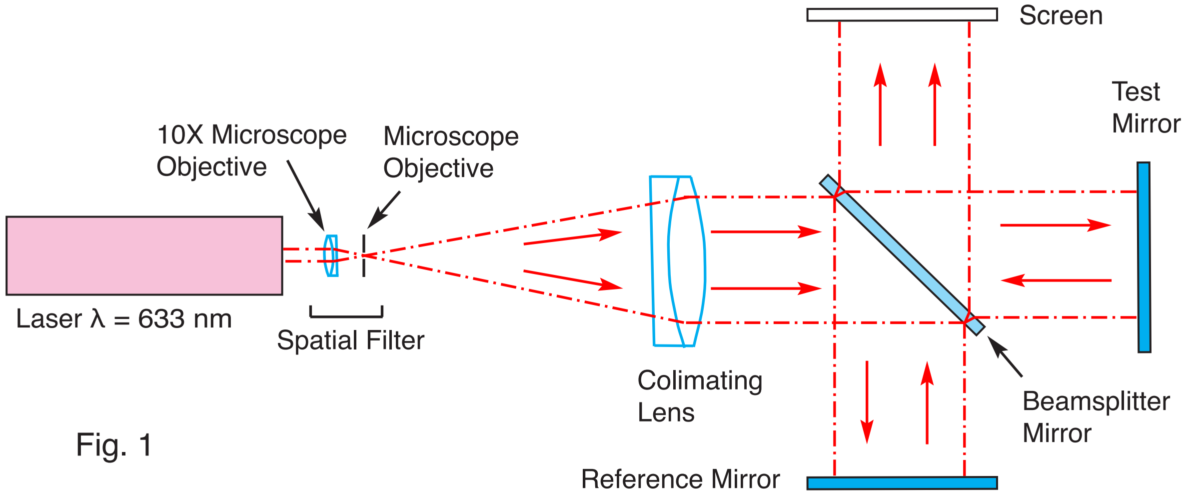


Fig. 1

we are dealing with monochromatic light, but if using a singlet, it must have been designed for the wavelength of the laser to have minimum aberrations. Going back to the spatial filter, it works by filtering the unwanted beams coming out of the laser beam by allowing only the center rays to pass through the pinhole. The result is a clean uniform beam suitable for interferometry.

In its basic arrangement above, Michaelson interferometer could be utilized in testing purposes. The test mirror's surface accuracy is basically checked against the surface flatness of a highly flat reference mirror. Any deviation of the test mirror's interference pattern from perfectly concentric fringes would reveal any errors across the test mirror (above).

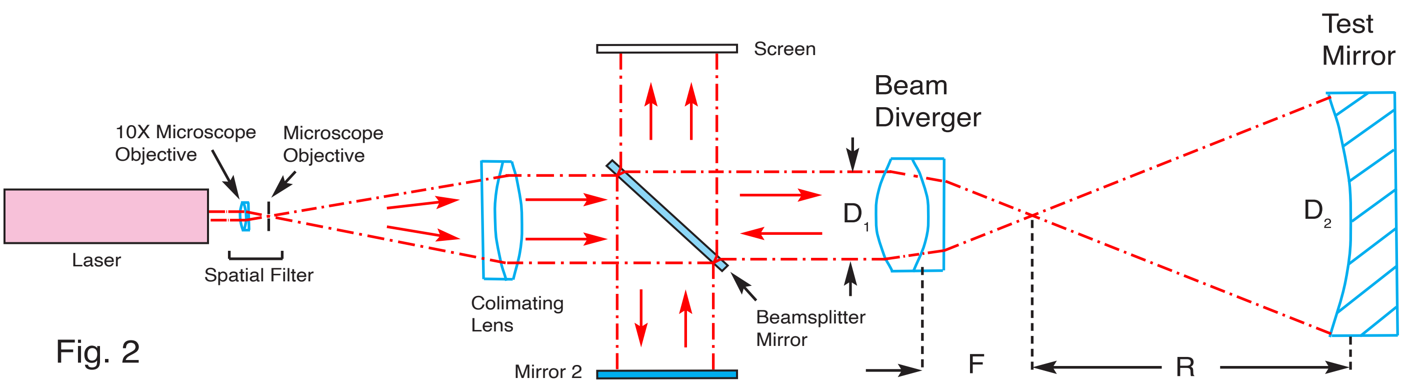
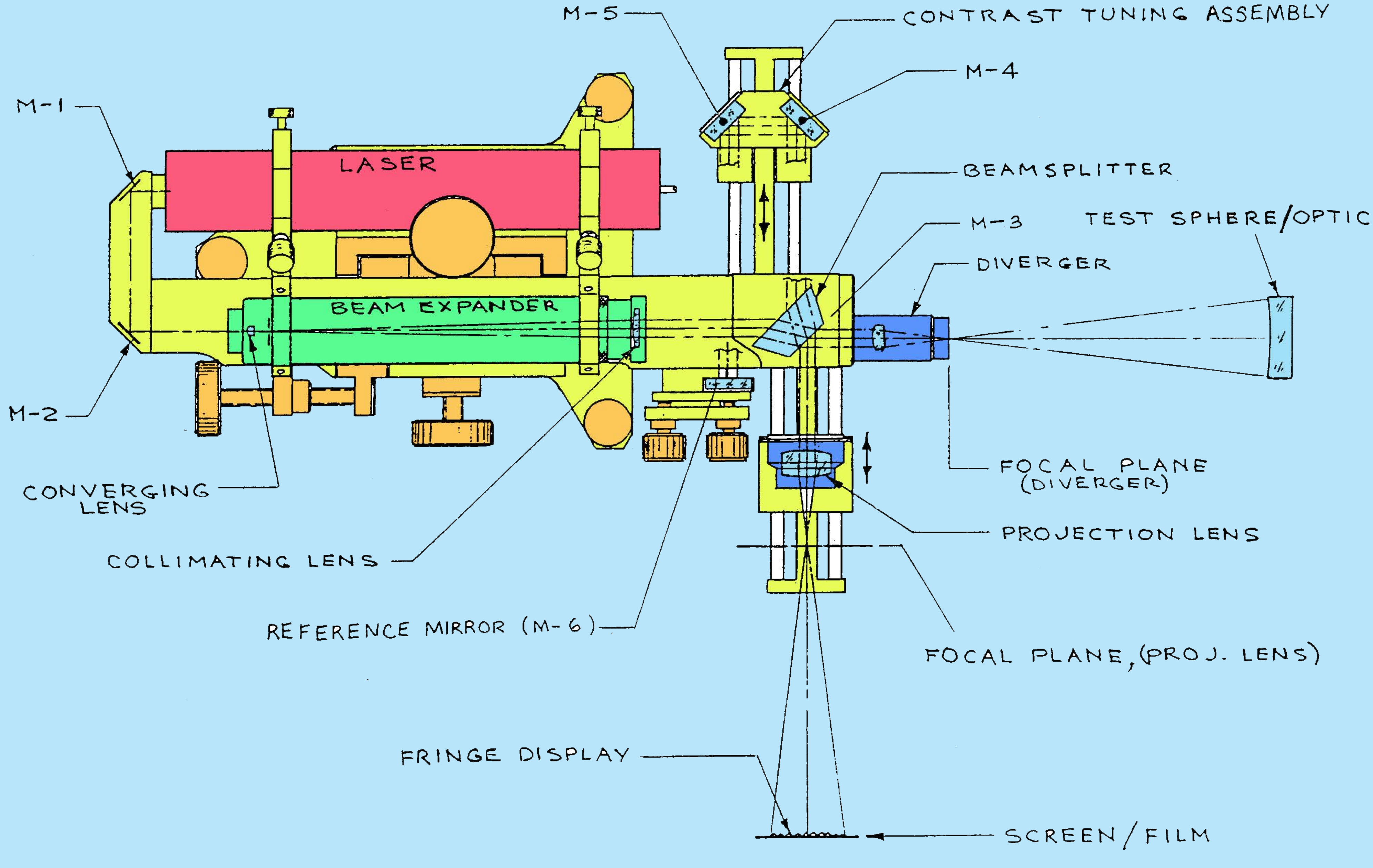


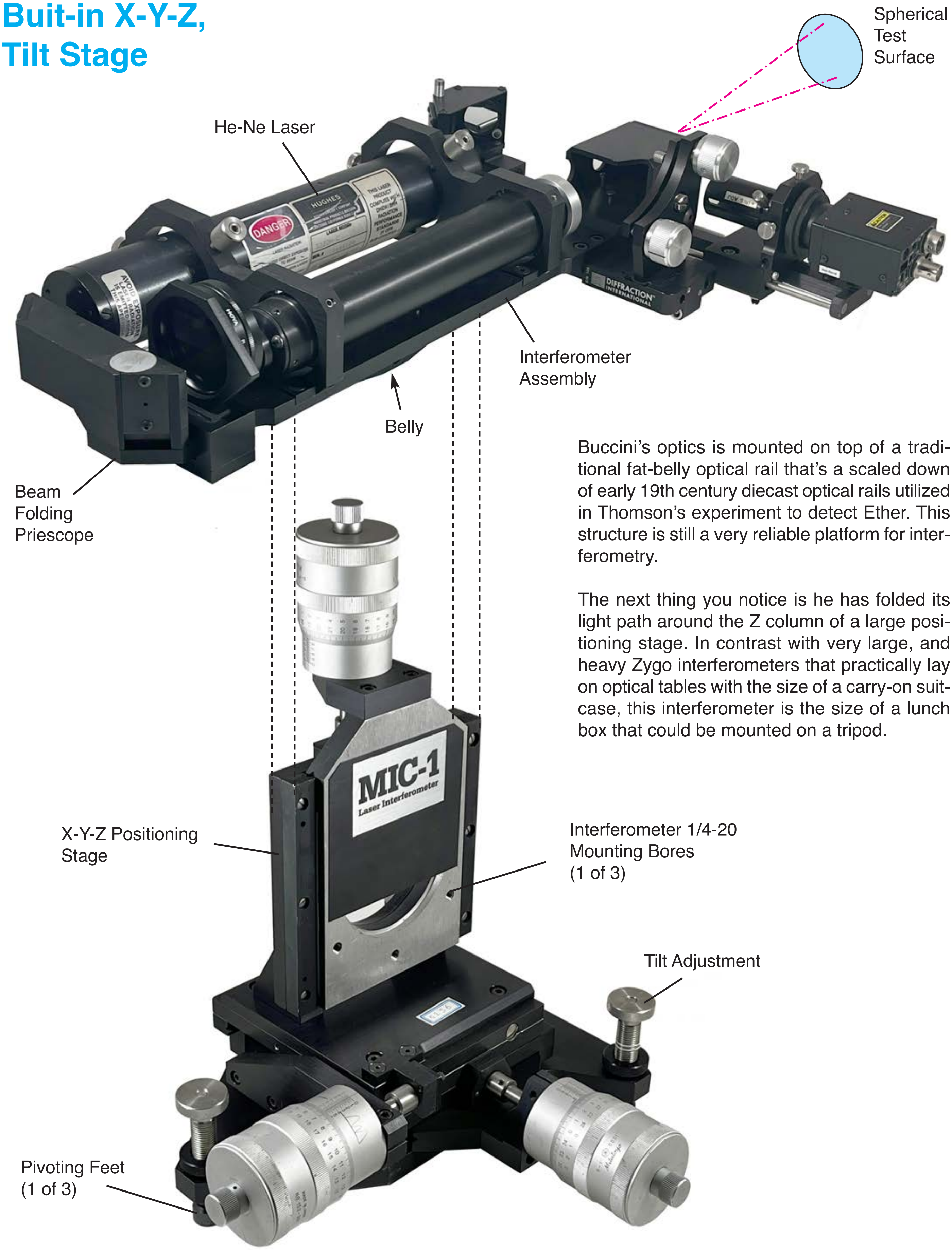
Fig. 2

Testing a Spherical Mirror

Fig. 2 shows the Michaelson interferometer discussed earlier to test the surface accuracy of a spherical mirror. The flat test mirror in Fig.1 is now replaced with a beam diverger to focus the beam at its focal point F. The beam then diverges out to cover the surface of a spherical mirror. Basically to cover the entire surface of the test mirror, the f number of the beam diverger F/D_1 should match the f number of the test mirror 2R/D. In this arrangement, we are comparing the curved surface of the spherical mirror with a perfectly flat (1/10 λ or better) reference mirror. I have seen reference mirrors as good as 1/20 wave. I will show you how the wavefront is curved through the beam diverger to match the curvature of the spherical mirror, and how it gets flat again when it goes back through the diverger.


M-5
CONTRAST TUNING ASSEMBLY
M-4
M-1
LASER
BEAMSPLITTER
M-3
TEST SPHERE/OPTIC
DIVERGER
BEAM EXPANDER
M-2
CONVERGING LENS
FOCAL PLANE (DIVERGER)
PROJECTION LENS
COLLIMATING LENS
REFERENCE MIRROR (M-6)
FOCAL PLANE, (PROJ. LENS)
FRINGE DISPLAY
SCREEN/FILM

Buit-in X-Y-Z, Tilt Stage



Buccini's optics is mounted on top of a traditional fat-belly optical rail that's a scaled down of early 19th century diecast optical rails utilized in Thomson's experiment to detect Ether. This structure is still a very reliable platform for interferometry.

The next thing you notice is he has folded its light path around the Z column of a large positioning stage. In contrast with very large, and heavy Zygo interferometers that practically lay on optical tables with the size of a carry-on suitcase, this interferometer is the size of a lunch box that could be mounted on a tripod.

Buccini's overall compact design: The X-Y-Z / Tilt stage is sandwiched between the laser tube, and beam expander. The X-Y-Z stage is controlled by three 2" diameter Mitutoyo mics, whereas the tilt adjustment screws have pivoting feet. This simple but reliable design has +/-25 mm XYZ positioning, and +/- 10° tilt adjustment range to handle a variety of surface testing challenges.

How to Use Buccini Interefromter

Buccini interferometer uses a microscope objective to send out a beam focused at its focal point (below). To test a telescope mirror, this beam then diverges out like a cone to cover its entire surface. This is why Buccini offered different objectives to match the f-number of the mirror such as f/4, f/8 or f/10. One of the challenges in examining such spherical mirror (such as found in Celestron Schmidt telescopes) is to focus the focal point of the interferometer's microscope objective on the exact focal radius of the mirror. That's where Buccini's X-Y-Z stage becomes useful because both axis must be precisely in line, and that's where the tilt stage is also utilized. As shown below, the wavefront coming back from the test mirror is checked against the perfect surface of a reference flat mirror inside the instrument.

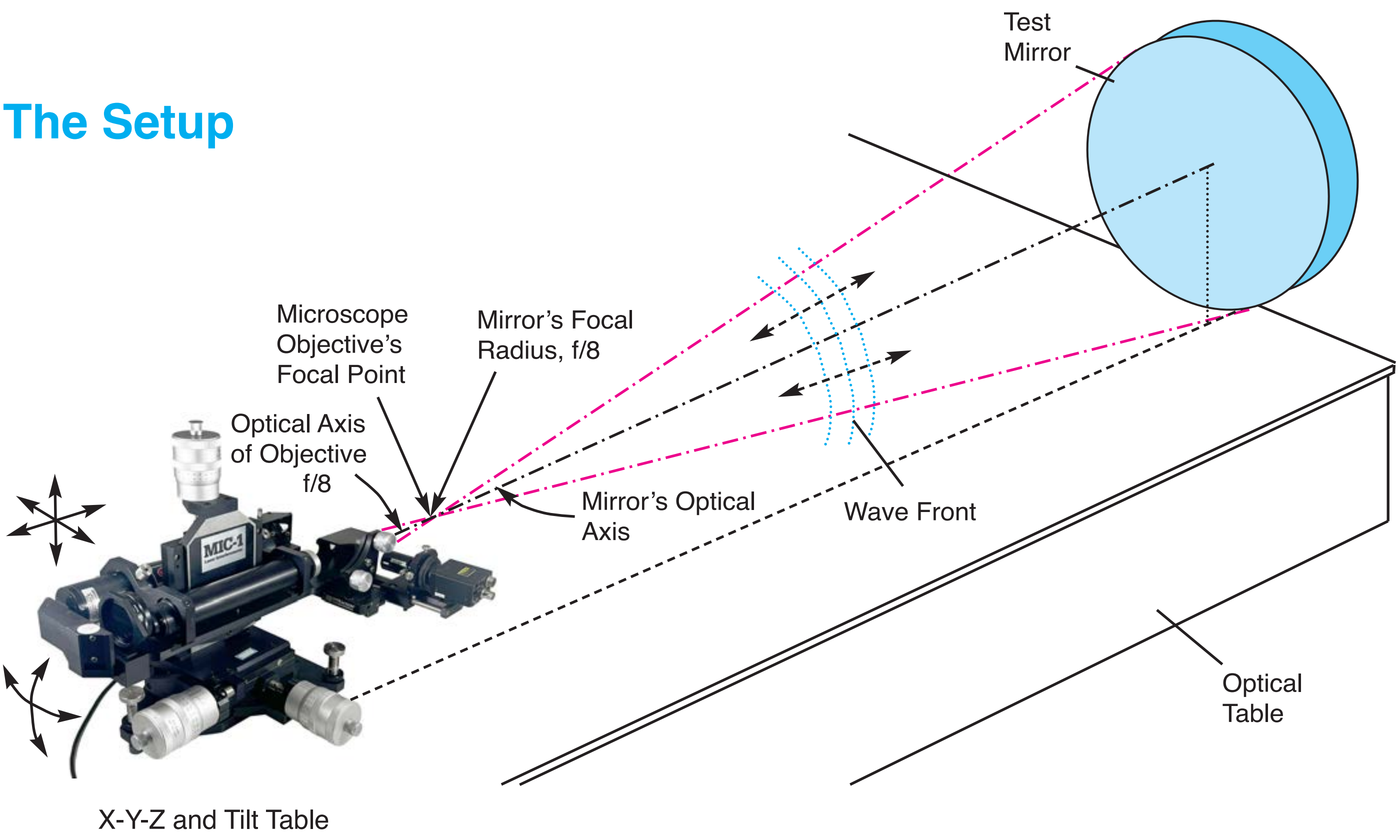
Basically, the wavefront coming back to the instrument is compared with a perfectly shaped reference mirror to produce interference fringes that are then measured by software. The reference mirror is mounted on a piezo driven stage, and is pushed forward in nano steps, causing the interference pattern to scan over the mirror surface. The software algorithm monitors the interference lines passing over the surface to make its measurements. The result is graphically displayed on the screen, showing a 3D profile of the mirror surface.

Buccini interferometer is designed to work properly without needing a vibration isolation table. The internal light path of this instrument (page 5) shows how the beam emerging from the laser is cleaned up by a spatial filter, then expanded to a parallel beam. The dove-looking prism is a smart way of eliminating unwanted reflections ordinarily produced by beamsplitter plates or cubes. The back face of this prism is semi-Aluminum coated to reflect off the beam coming from the test mirror to a viewing screen or CCD camera. The reference mirror is aligned through what looks like a delay line that exists in most interferometers. In this design, it's not.

Because the internal light path of Buccini interferometer is parallel, the delay line does not match the optical path lengths between the test, and reference mirrors. Instead, it acts as a contrast enhancing device to enhance the clarity of fringes. The mirror's focal radius (radius of curvature) is the point where a beam is sent to the mirror, and it's reflected right back to its origin. Buccini offers various beam divergers to match the f number of the test mirror, in this case the spherical mirror of a Schmidt Cassegrain telescope. Through this beam diverger (or microscope objective), the parallel beam inside the interferometer is focused at this point. Then the entire interferometer needs to be physically tilted to be exactly be in line with the beam coming back from the mirror's surface.

Now that we pretty much covered the interferometer hardware, I will cover its inner parts, and the stage the stage is mounted on. More details of the positioning capability of the interferometer is shown below, and on the opposite page.

The Setup



John Buccini (1924-2017) was born in Providence, Rohde Island. A man of great creative talent, John became a national and world recognized mechanical and optical designer, and created a number of state-of-the-art inventions for several industries including manufacturing, the space program, and even advanced nuclear fusion.

Buccini interferometer parts count:	TOTAL: 179
Mechanical Parts	50
Screws, Washers, Springs:	100
Linear Bearings:	4
O-Rings	5
Optical Components:	11
Ball Pivot Joint	1
Piezo Driver + Card + Cable	3
He-Ne Laser + Power Supply	2
Video Camera + Power Supply + Cable:	3

X-Y-Z / Tilt Stage parts Count:	TOTAL: 91
Mechanical Parts:	35
Ball Bearings:	3
Micrometers:	3
Screws, and washers:	44
Linear Bearing Ways:	6

Total Parts Count:	270

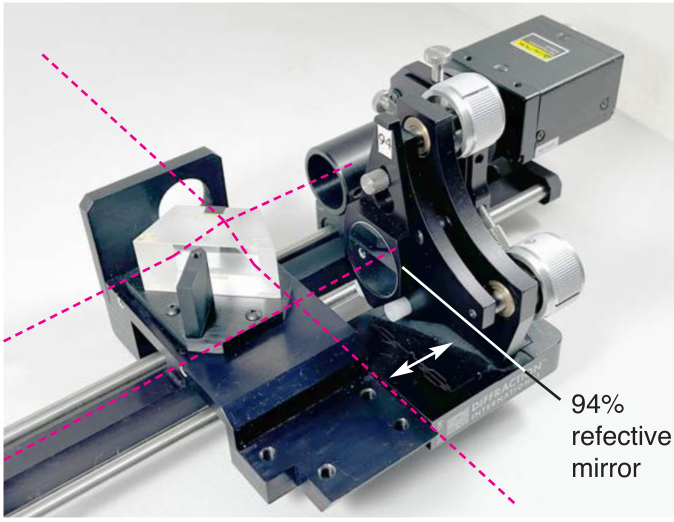
The total number of parts in Buccini are around 270, all of which are custom made. It's one of the best handmade instruments of its kind. It is still a minimalist design. To anyone who wants to copy it, I would say try copying something easier! It's not going to look or function as good if it's not made by those same hands. It's perfection for optomechanics.

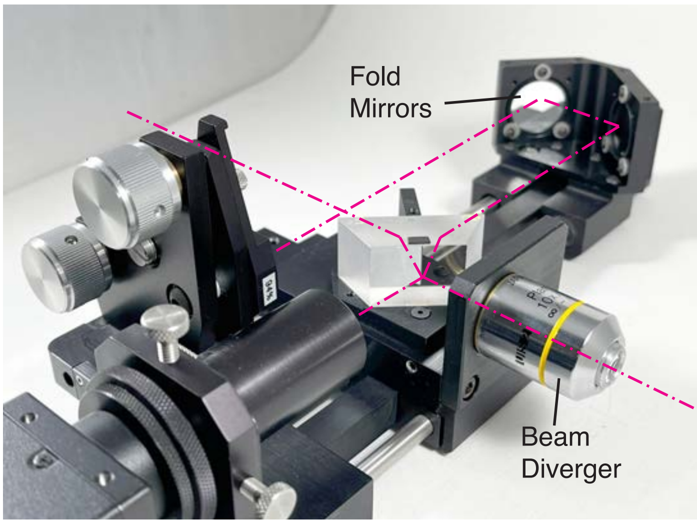
Buccini Interferometer's Internal Design, and individual parts

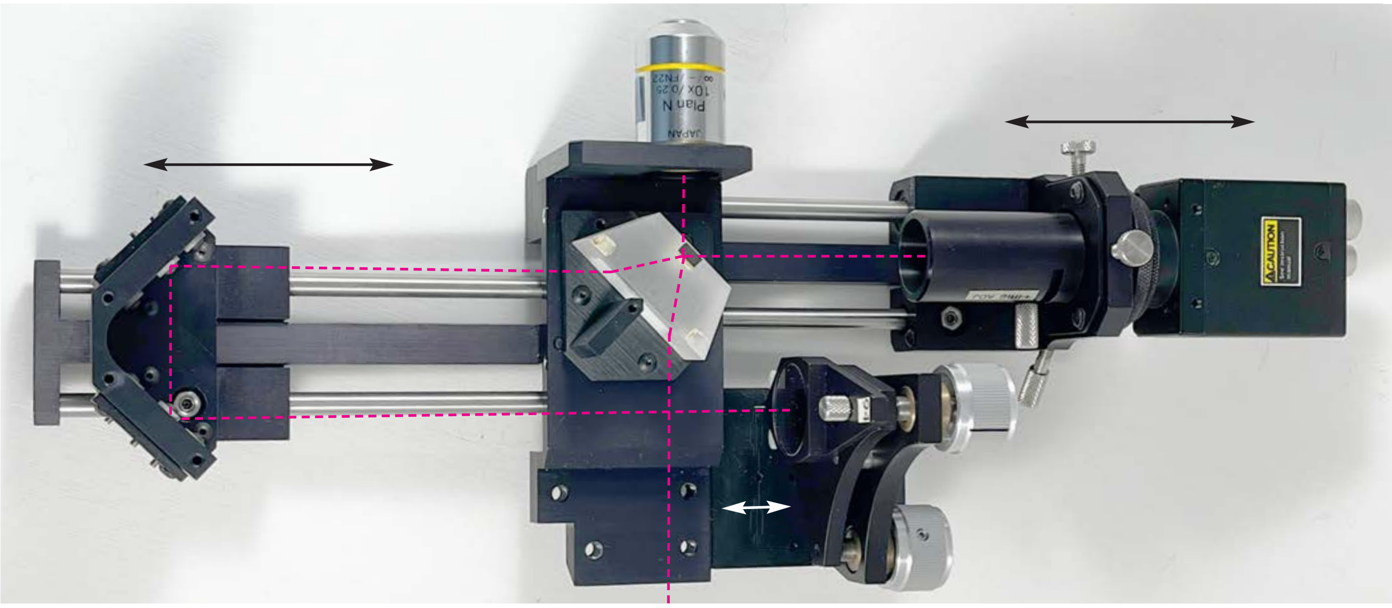
Frontal view of how the interferometer is setup to examine the surface quality of a concave mirror is shown on page 3. The focal length of the beam diverger, or a microscope objective with planar field of view (having less than 1/10 wave spherical aberration) is focused on the focal radius of the mirror. Also, the axis of beam propagation is lined up exactly between the diverger, and the mirror via the finely adjustable tilt legs.

The final adjustment is made by reference mirror tilt knobs. There is a software driven piezo actuator beneath this stage that pushes the fringes across the test mirror to calculate its surface contour, to display it on the computer screen. The software is supplied by Wells Research with user friendly graphic interface.

In Buccini, amazing attention has been paid to details. Every component has been made with great care, and I will give it a grade 10/10. One reason must have been because John himself was a machinist, and knew how good quality parts should look like. I don't even know if he outsourced the parts or he hand made them himself. Many of the parts must have been CNC machined, and knowing the cost of these instruments, I am sure he wouldn't have ordered more than 10-25 pieces at a time. The design is very optimized, and one can't imagine to do a better job to improve it. I was particularly impressed with the design of the linear bearing carriers for both the camera, and the delay line. He utilized a combination of linear bearings, and back plungers to provide a smooth travel, and it provides incredible feel to it when using. The friction, and positioning convenience is perfect. The CCD camera, and its zoom-like imaging lens with miniature iris diaphragm is also cleverly designed.







The light path inside the interferometer through the central prism with 50% Aluminum coating: Utilizing this prism eliminates the ghost image inherent in beamsplitter designs. There is obviously a shift of optical axis that is compensated for. The challenge in designing the piezo actuated flexture stage (white arrow, above) in translating the reference mirror, is to maintain its parallelism throughout its travel range.

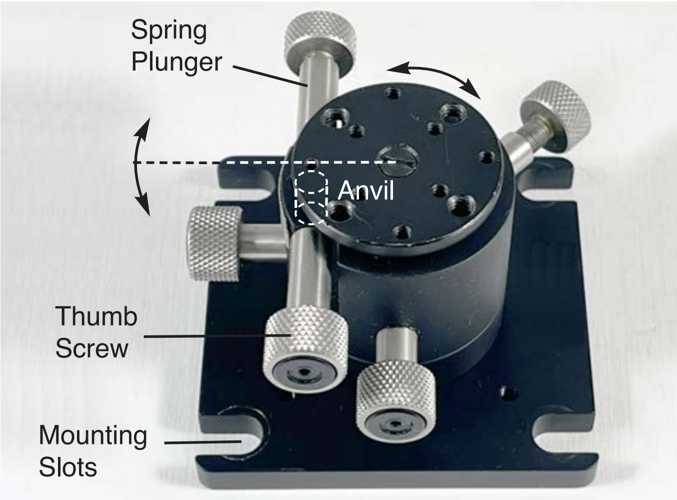
Newport/Micro Control Mini-Tilt Stage

By Ali Afshari

This is a miniature tilt stage, originally a Micro Control design in France, sold under Newport brand. I also remember seeing these in earlier Spindler & Hoyer catalog. We'll utilize this stage later to build an interferometer testing setup or instrument. I chose this stage to discuss how a very difficult stage could be built with very minimum parts, and it is this design style that has led the industy to its current state of the art optomechanical engineering.

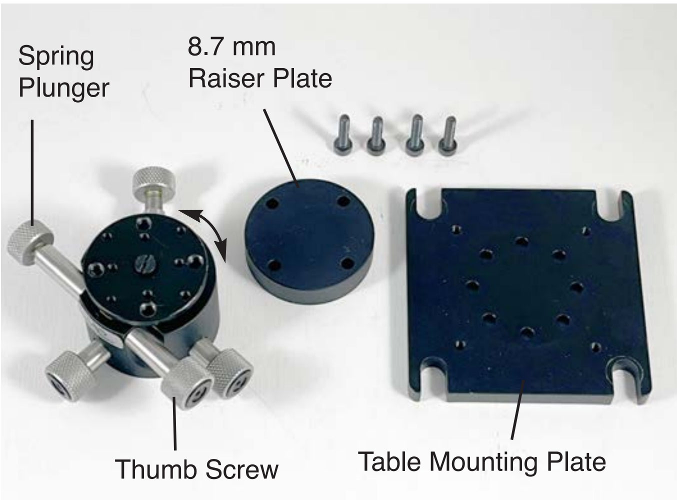
Good designs don't come easy, and this is definitely one design you could learn from to become a good engineer. This tilt platform allows both rotation, and tilt adjustment for a prism. The general application of this stage would be to secure a beamsplitter cube in interferometry, and an equilateral cube in spectroscopy. What we'll be using it for is to rotate a glass block in the field of view of an interferometer to align its surface exactly with the laser wavefront coming out of the interferometer, and to send it back in.

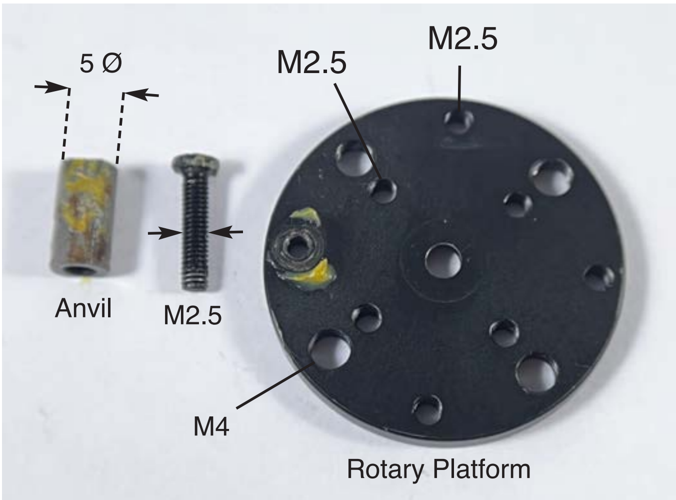
At the center of this stage is a precision ball joint that is secured to the main housing. The top plate is secured to a control arm that is secured to the center of this ball joint. Without any other parts added, the top platform could now both rotate, and tilt. The rotation function is controlled by a spring plunger, and thumb screw combination that is explained below. The tilt function is achieved by a spring plunger, and two thumb screws that push against the bottom end of the control rod. The bottom of the control rod could be seen on page 11 with the cover plate removed.



The top (left), and bottom view (right) of the tilt/rotary stage shows its many control thumb screws. This is actually a simple design if you know what those knobs are for. The rotary stage is controlled by a thumb screw, facing a spring plunder on the other end (left). The spring plungers in this unit are precision made which I will discuss in detail.

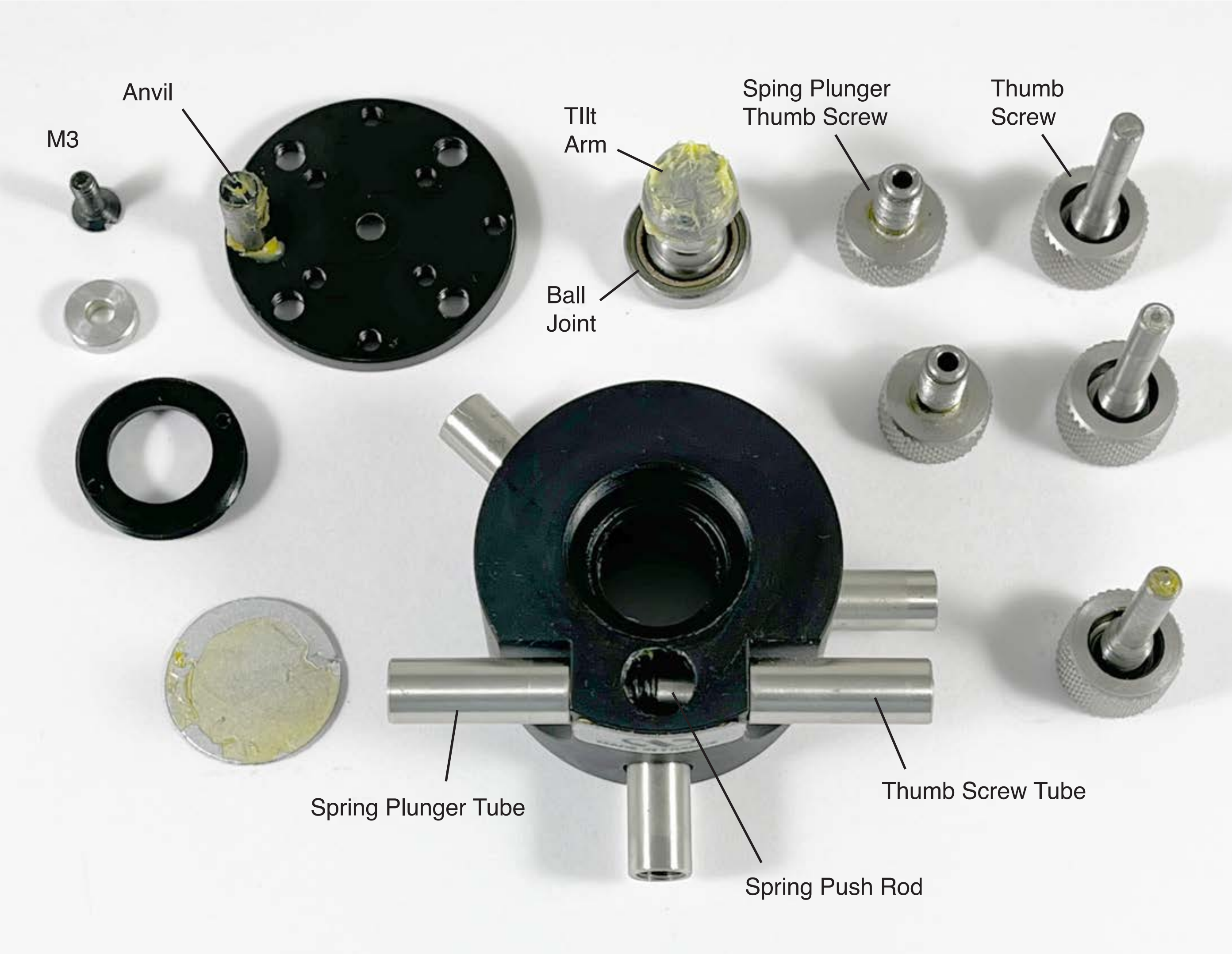
Specifications: Tilt range: +/- 5°. Rotation Range: +/- 5° Prism Platform: 32 mm Ø, Height: 29 mm, 8.7 mm Raiser Pl.





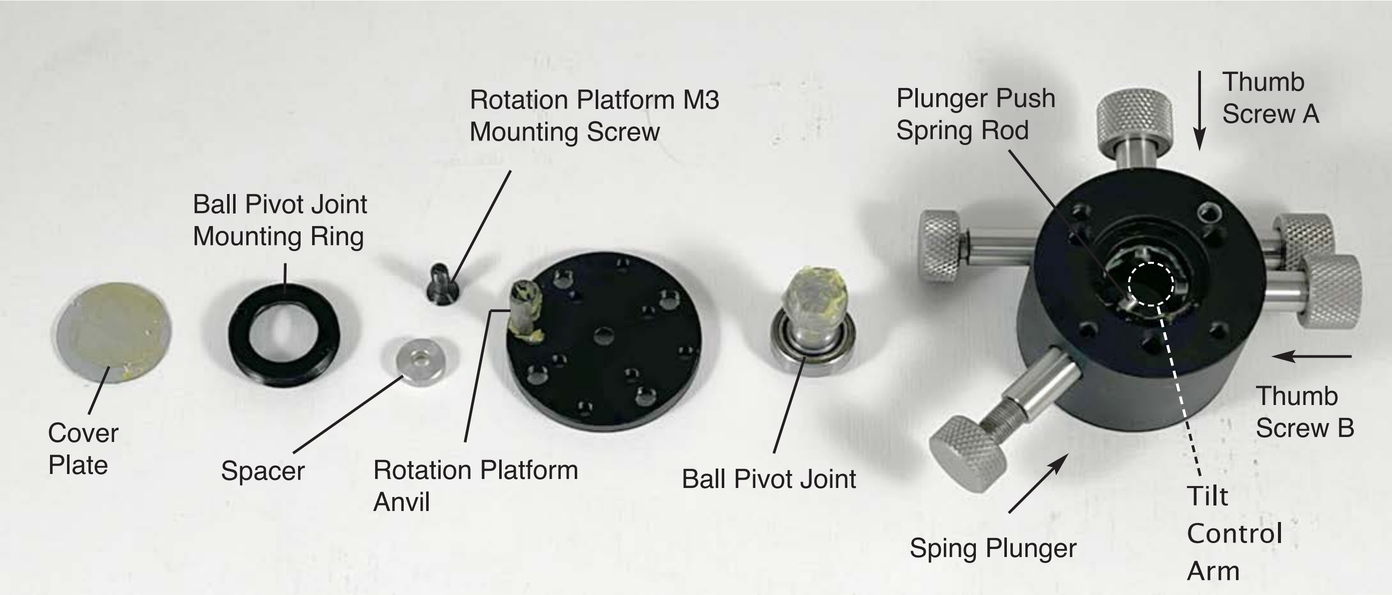
The tilt/rotation plate is taken off to show its parts. Obviously, to cause a rotation, the thumb screw would need to push against a rod (right) attached to the rotary plate while the spring plunger would be pushing it from the opposite end.

As can be seen on page 13, there are two thumb screw rods that are pushing against the control arm. There is also a spring plunger that is pushing against the control arm at its opposite end. So, the tilt adjustment is achieved by the two thumb screws. One of the best ideas in this design is the spring plunger's thumb screw could be turned all the way in to lock the tilt platform at any desired angle. The thumbscrews do not have a X-Y function, they only have tilt function.

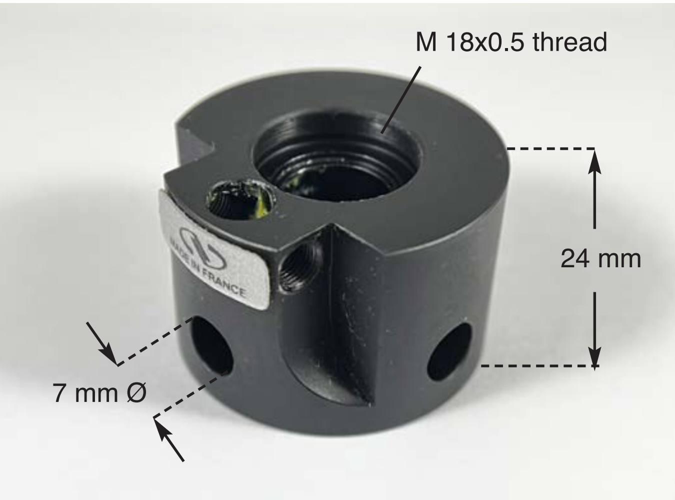


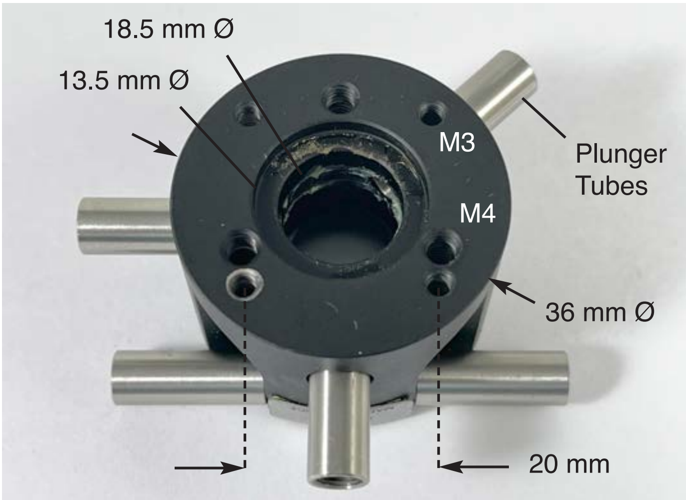
Upper view of the stage completely disassembled to show its inner pieces. The best way to produce such stage is to avoid too many variants in the assembly hardware: Thumb screws, and plungers are all the same size, with same thread. All the thumb knobs in this this design have 12 mm diameter O.D. The satin finish and the knurling on them is superb.

Detail of Ball joint (left) thumb screws, and custom-made spring plungers. The thumb screw tube, and the spring plunger tube are exactly the same size. Only the plunger, and thumb screws are made different, but are made 2-3 of each.



Bottom view of the satge reveals its inner parts: It looks like a difficult custom-made tilt stage, but every component in this design is designed to optimize the number of its necessary parts. This is a minimalist design, and it's a high-quality stage with a good finish, with the right look and feel. I have utilized this in an interferometry setup, and it's very stable.





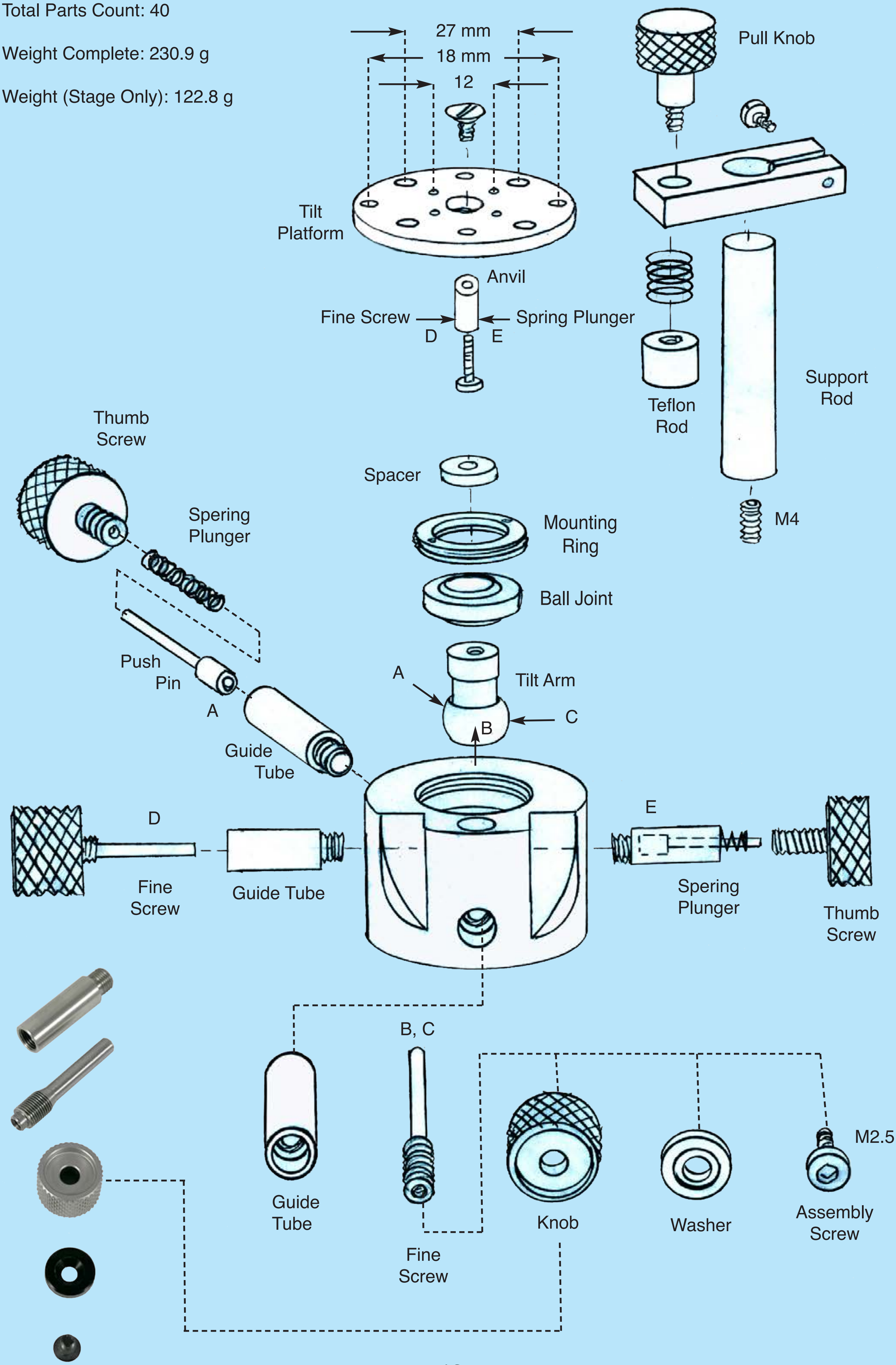
top and bottom view of the stage housing shows the angular position, and elevation of the plunger tubes. The counter-bored depth of M5 threads are chosen such that all the spring plungers, and push screws use the same plunger tubes.

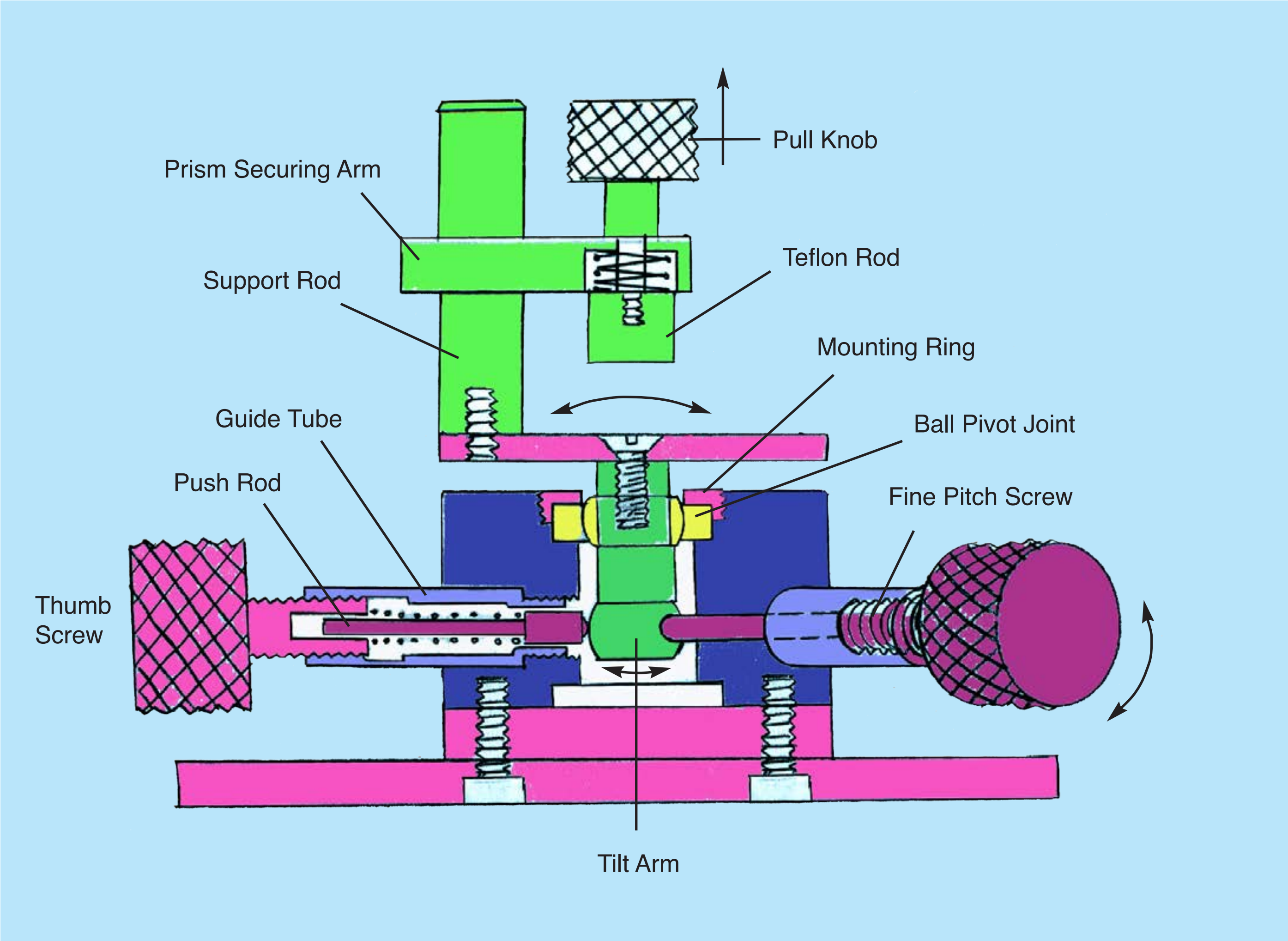
Components of the spring plunger (left), and ball joint (right) which provides the tilt function for the top plate. The close up of the thumb screw (right) shows the 2.2 mm center bore to allow the spring plunger rod to have room to go in. It is the bottom of this bore that pushes in the spring rod when the thumb screw is tuned all the way in to lock the stage.

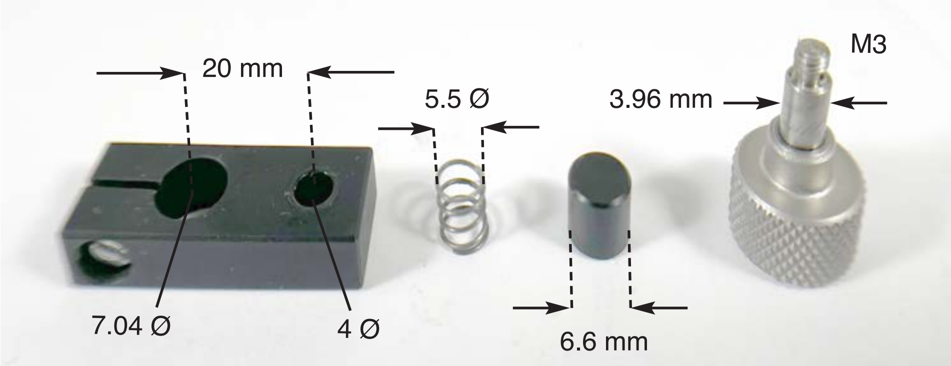
Total Parts Count: 40

Weight Complete: 230.9 g

Weight (Stage Only): 122.8 g



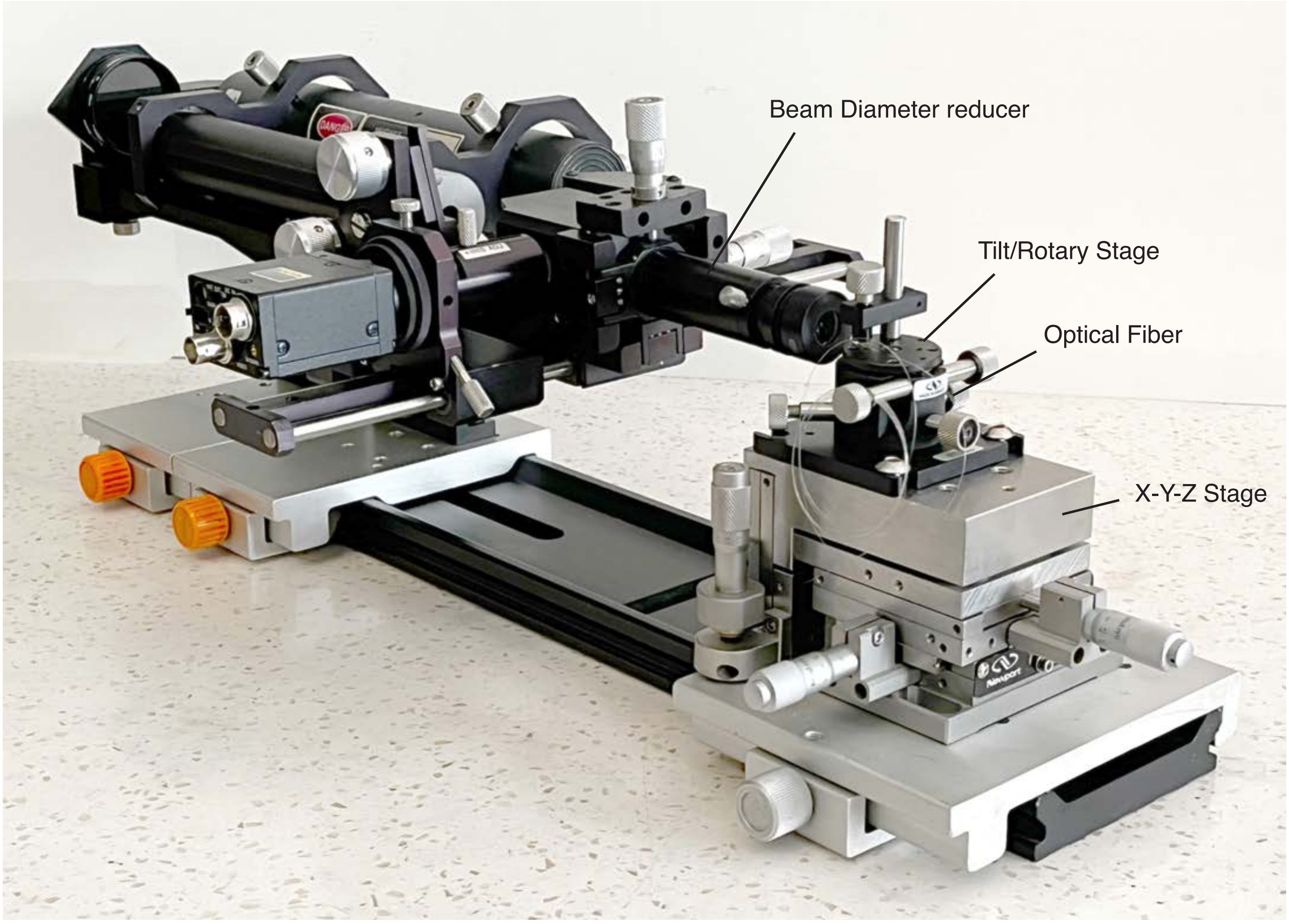




Anatomy of the prism support assembly shows much attention to details. The spring tension bellow the pull knob should not exceed the spring pressure of spring plungers.

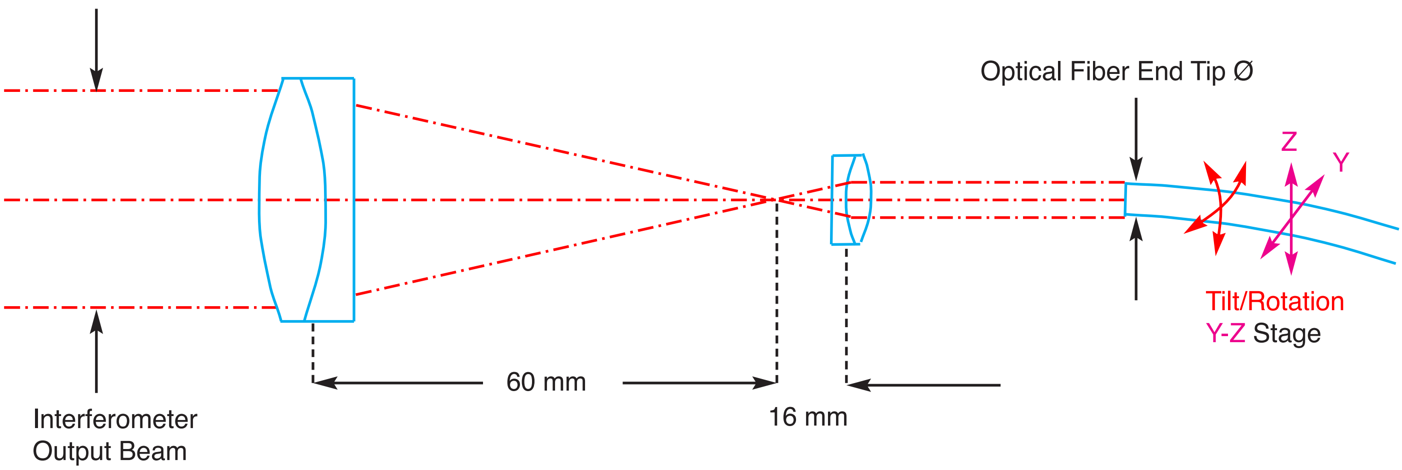
Secondly, the 7 mm support rod should be slightly smaller than its clamping bore on the support arm. All these details tell the difference about a good design.

Surface Profiler to Examine the Polished End of a Fiber

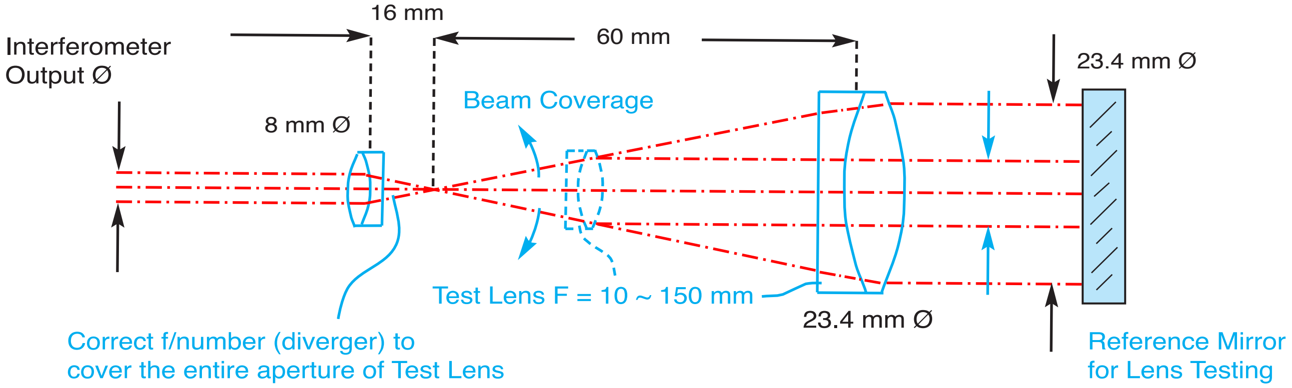


Above, test setup to examine the surface flatness of a polished optical fiber end. The interferometer is equipped with a reversed beam expander to cover a very small area of interest, or a field of view of 1 mm in diameter.

This is an application of the laser interferometer to examine the polished surface quality of an optical fiber. To accomplish this, its beam is reduced in size by a reversed beam expander. To accomplish this, two achromats are utilized with a reducing ratio of focal lengths (below). In this example, the demagnification is 16/60 = 0.62. The wavefront from the interferometer would be projected flat at fiber's tip provided that the achromats are well manufactured to better than 1/10 wave wavefront quality. Plano convex lenses may also be found to perform as well because this is a monochromatic design but high quality achromats are usually easier to find than singlets. A surface profiling software could also be calibrated with a reference flat mirror prior to testing, to compensate for lens aberrations.



How to Build a wavefront Corrected Beam Expander

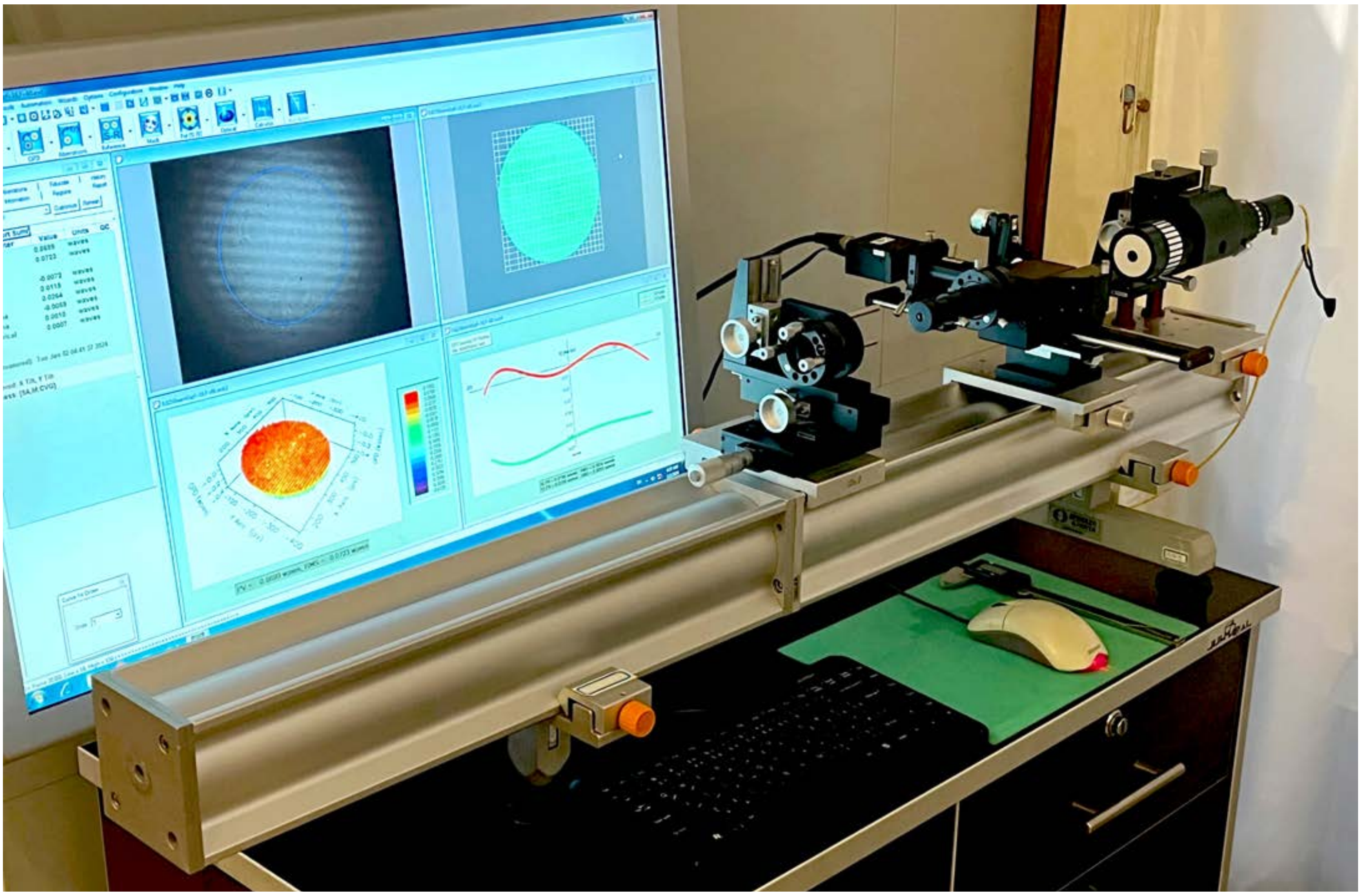


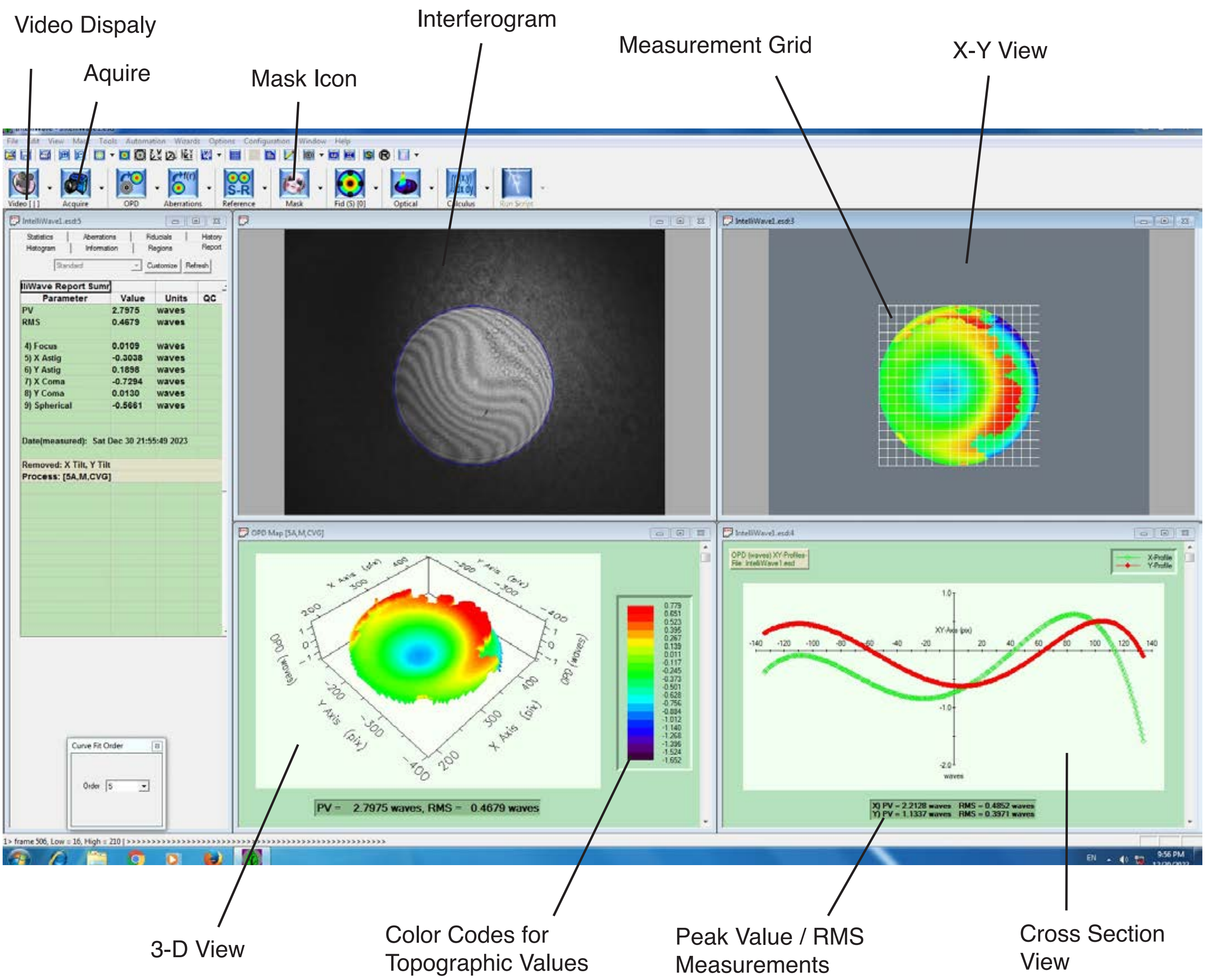
This design is easier to draw but much difficult to implement. One reason is 1/10 wave accuracy lenses are not that easy to find. So, let's say we want to build this beam expander, how would you actually do it then? Well, we'll first need to measure the wavefront flatness of each of these lenses to see how good they are, and then how we could utilize them to build our beam expander. We'll study many Achromats, plano convex PCX, and Biconvex BCX lenses. We'll even look at some quartz lenses. Pay attention to the different lens types, and their wavefront performance. You'll find a mixture of performances, some of them very unpredictable. I always thought of BCX lenses as poor performers but they are not.

How lenses are tested

Let's use the above illustration to show how we are going to test lenses (labeled in blue). The left Achromat would represent the beam diverger, while the larger achromat represents the lens being tested. The reference mirror is first measured to get its profile, and to save it. Since the reference mirror we are using isn't perfect, the software (opposite page) allows subtracting its errors from each lens measurement. So here's our first dilemma: Changing the beam diverger would change our measurement parameters such as the measured profile of the reference mirror.

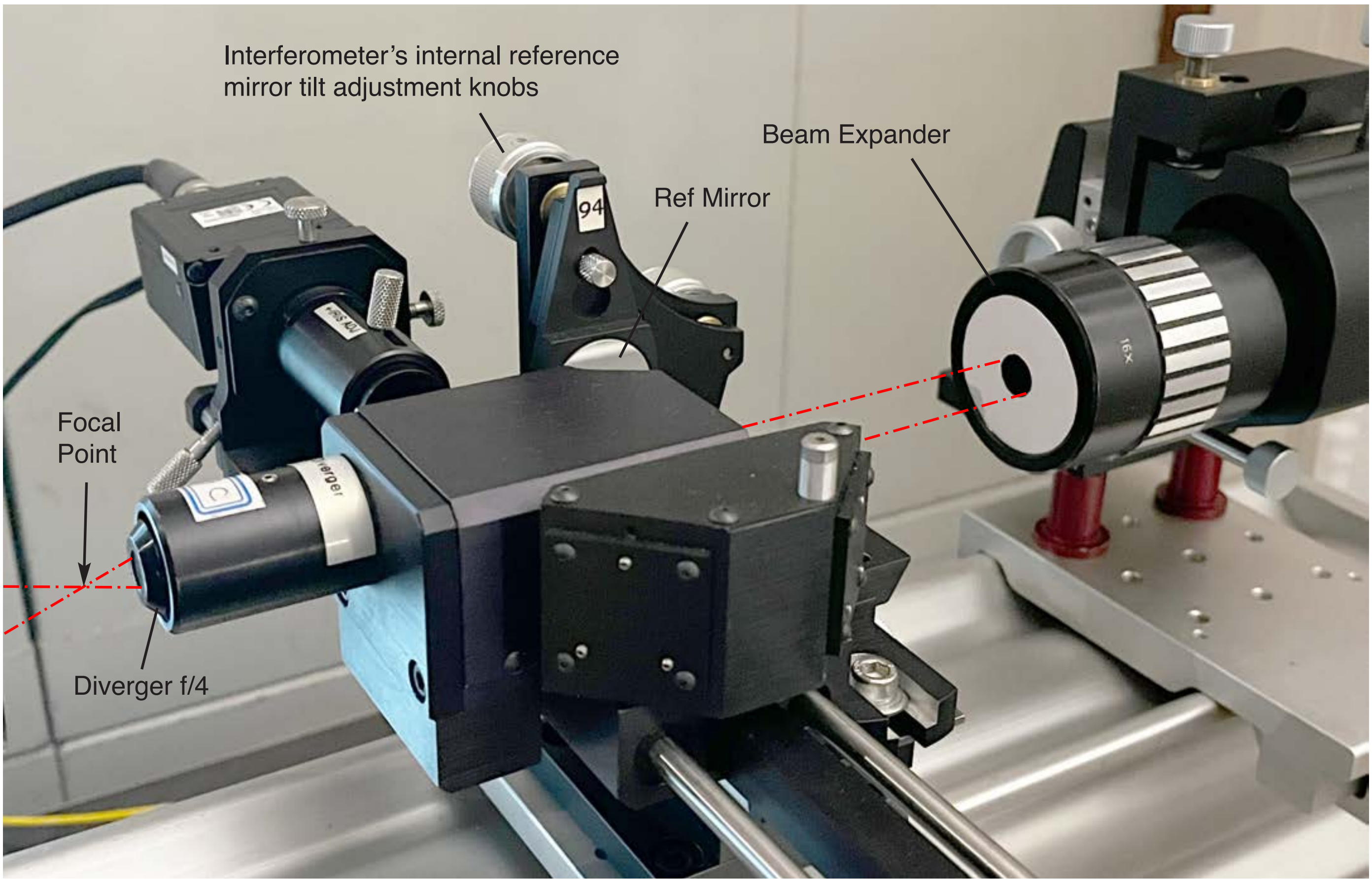
Some of Optoform's inventory of Achromats, and singlets ranging from f = 10 mm to f = 150 mm. All our 25 mm lens mounts are compatible with Micromax system with M23.4x0.75 thread, and compatible with Spindler & Hoyer/Linos lens cells. This thread compatibility allows direct assembly of optical assemblies such as a beam expander using Micromax tubing. See page 36 for the final assembly.



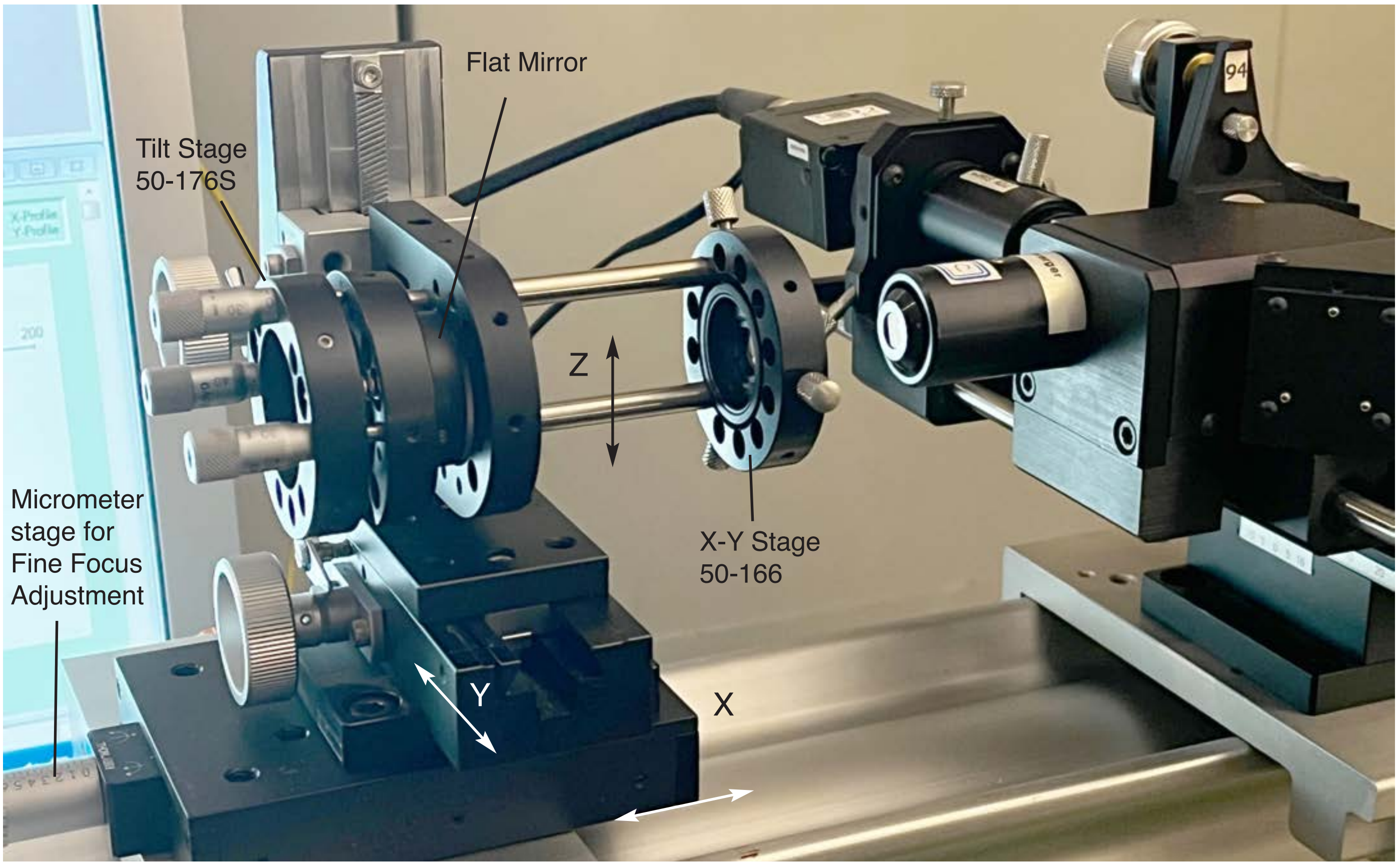


Video Dispaly
Aquire
Mask Icon
Interferogram
Measurement Grid
X-Y View
3-D View
Color Codes for
Topographic Values
Peak Value / RMS
Measurements
Cross Section
View

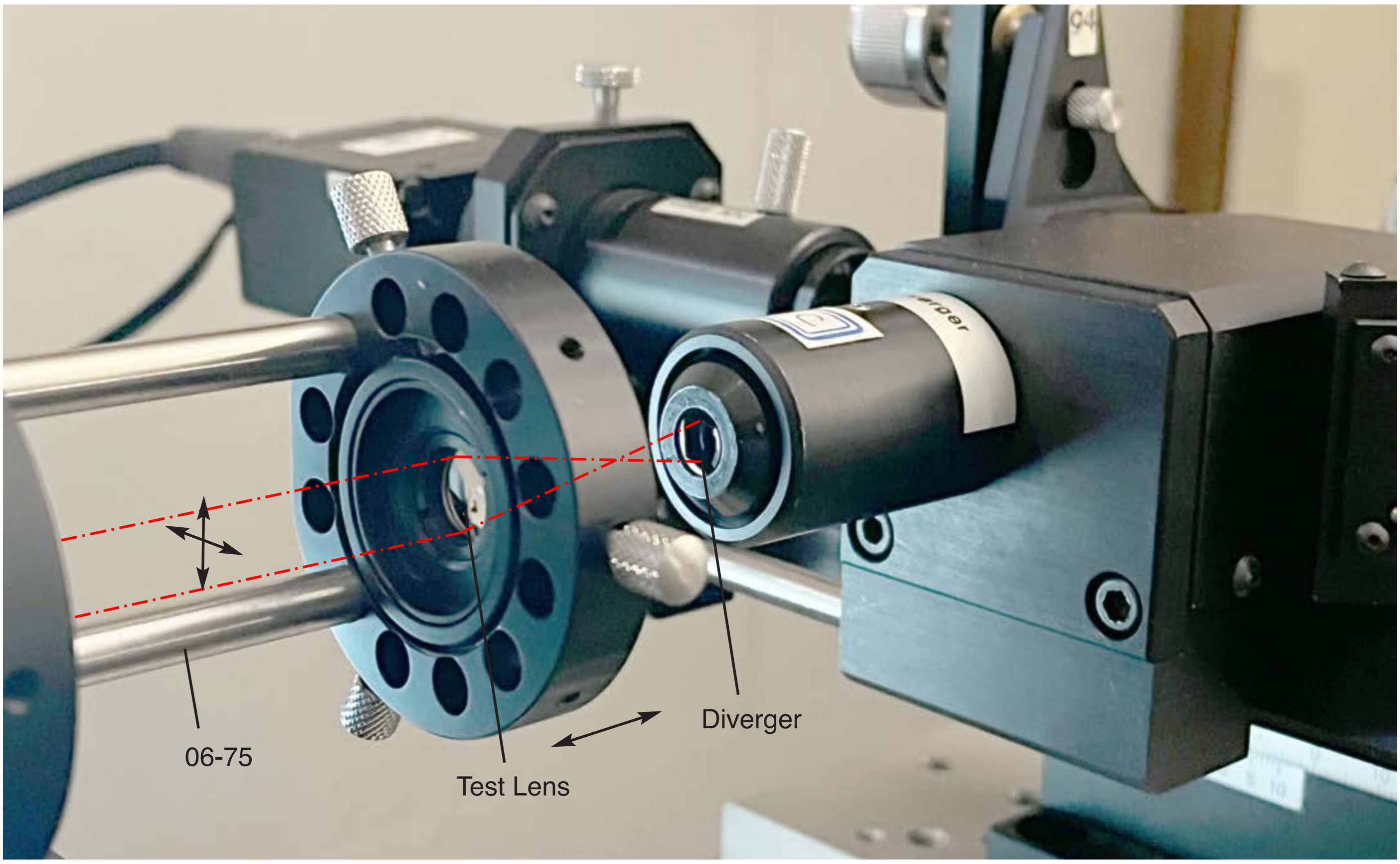
Setting up the interferometer



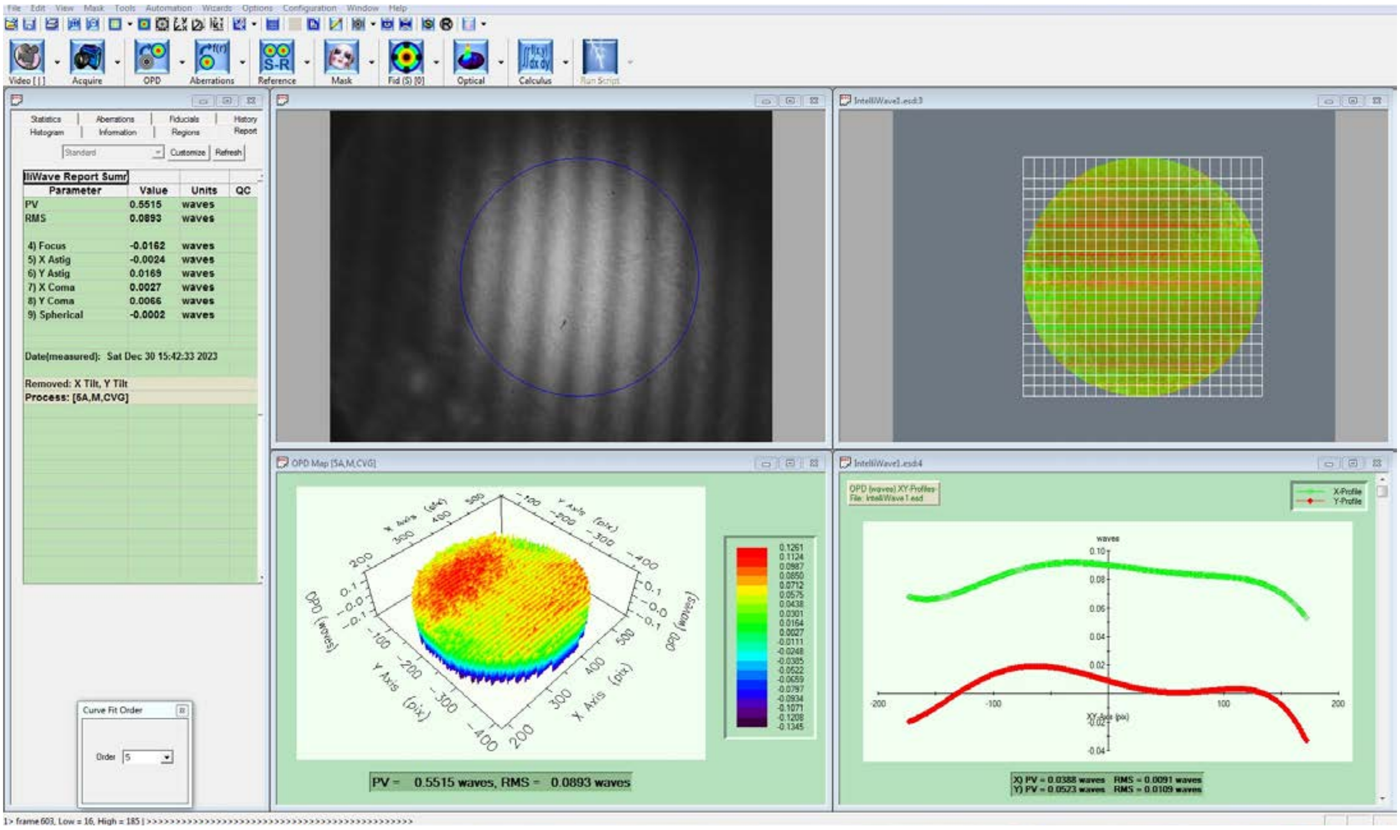
Overview of the setup utilizing the X-95 optical rail, and perfect lab syages.



1) A flat reference mirror better than 1/10 wave is mounted on tilt stage 50-178S to align with interferometer's reference mirror with the diverger, and test lens removed. The reference mirror is centered using the X-Y-Z stage, and locked in place. The fringes are centered on the camera.

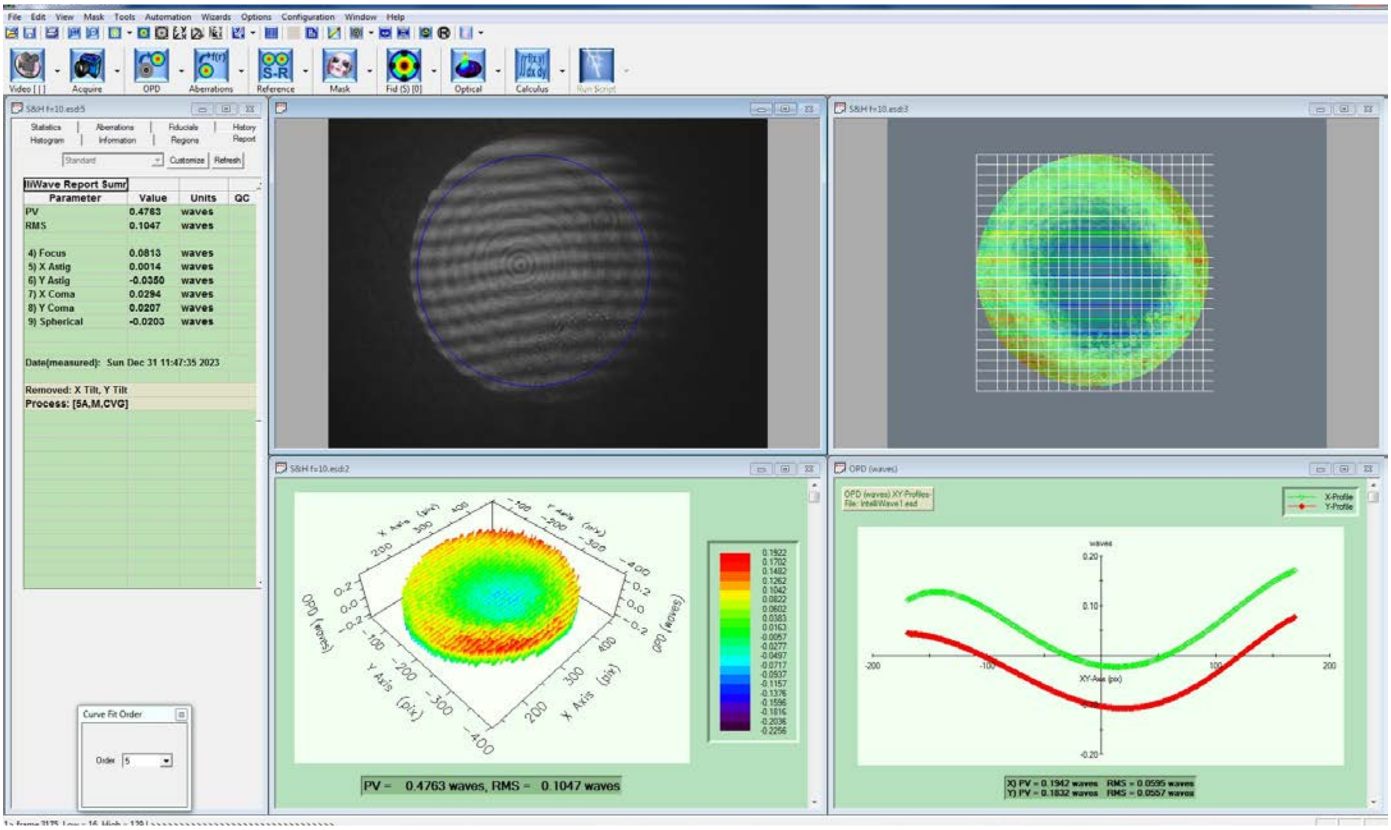


2) With the beam diverger installed, each test lens is mounted on X-Y holder 50-166. The lens is perfectly focused to get interference fringes. The fringes are centered via interferometer's internal reference mirror tilt adjustment knobs.



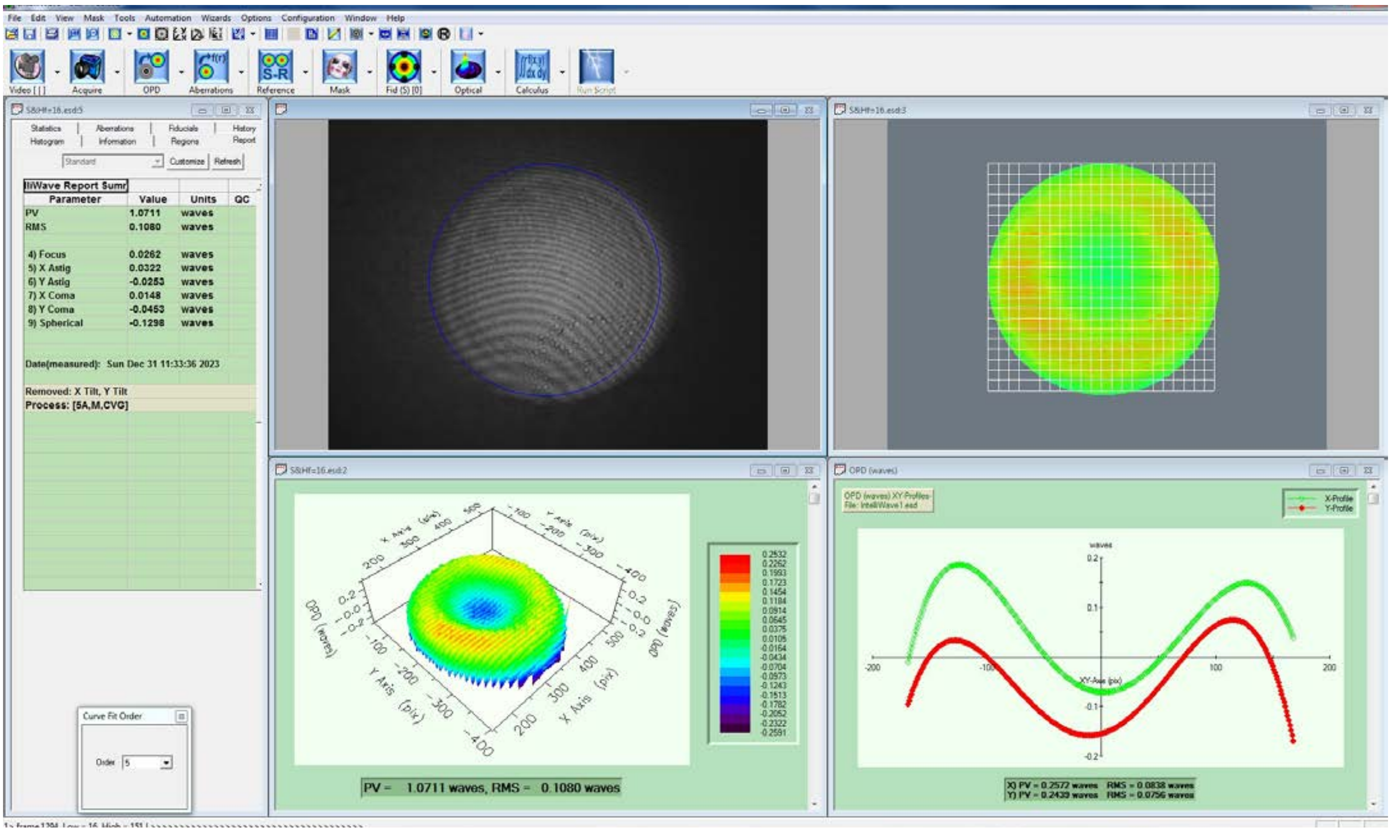
Flat Mirror

Acquired profile of the flat reference mirror tested against interferometer's internal reference mirror. The claimed flatness was stated 1/10 wave or better, and turned out to be correct.



F = 10

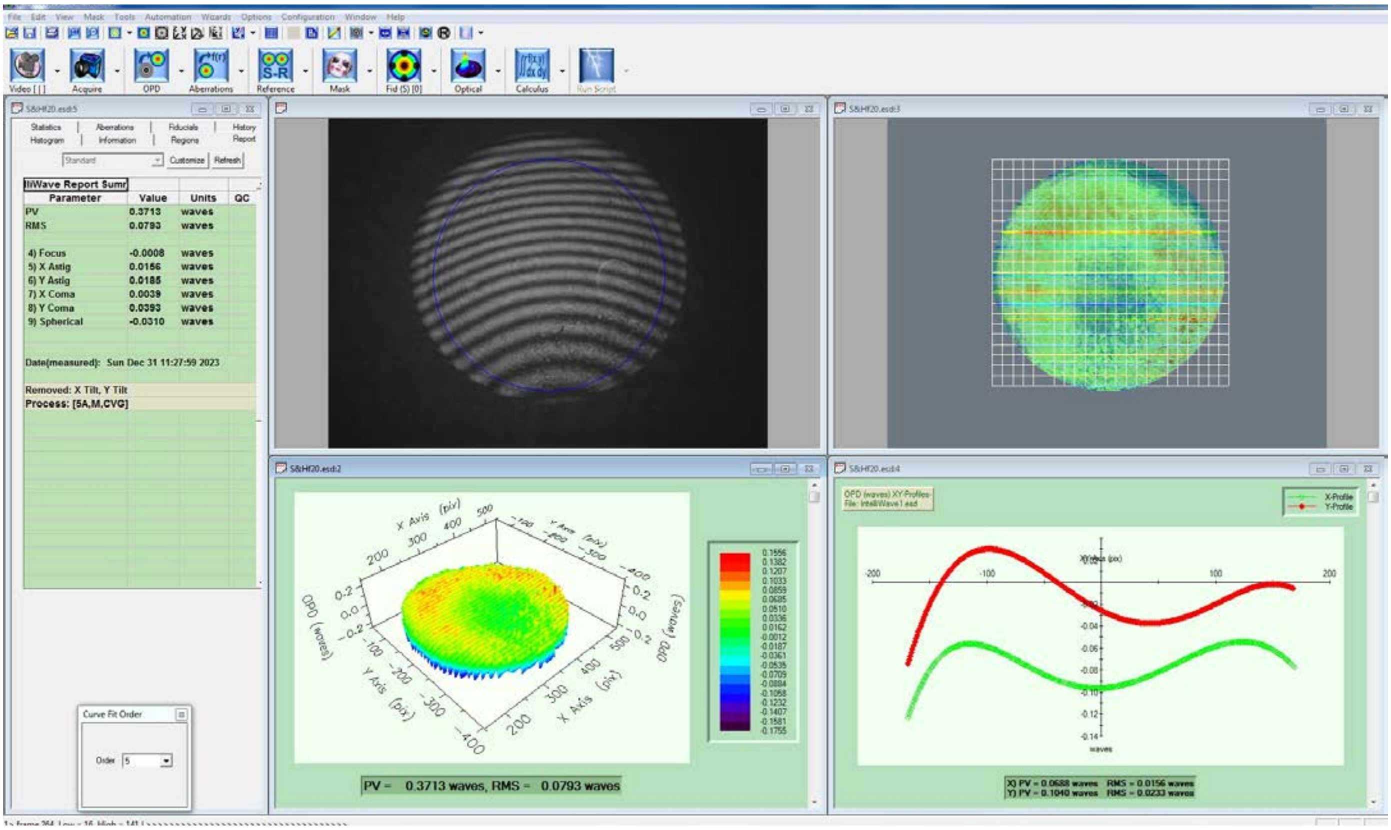
The f = 10 mm, D = 5 mm Ø CA achromatic lens test shows 0.2 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-314**



F = 16

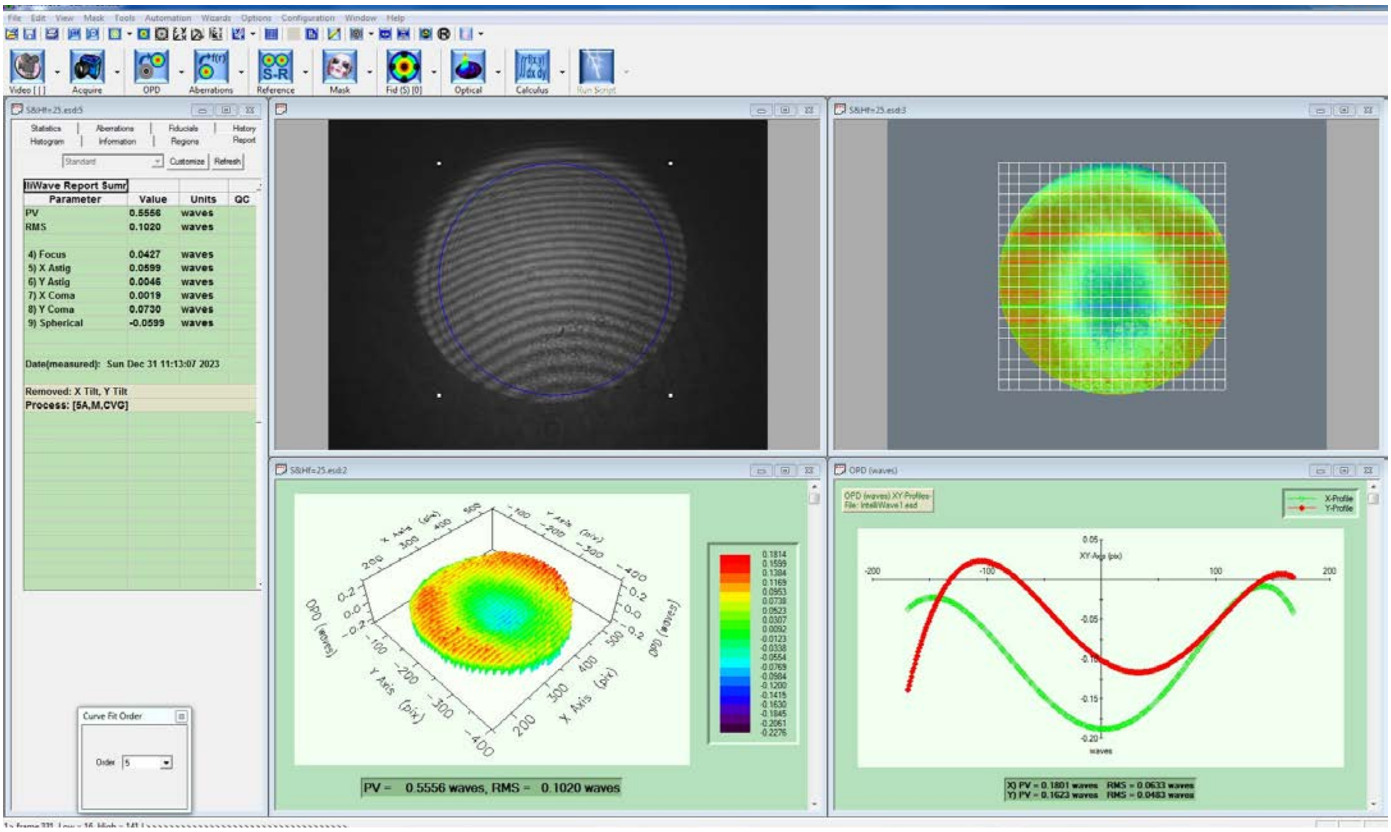
The f = 16 mm, D = 7 mm Ø CA achromatic lens test shows 0.3 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-316**

Achromats



F = 20

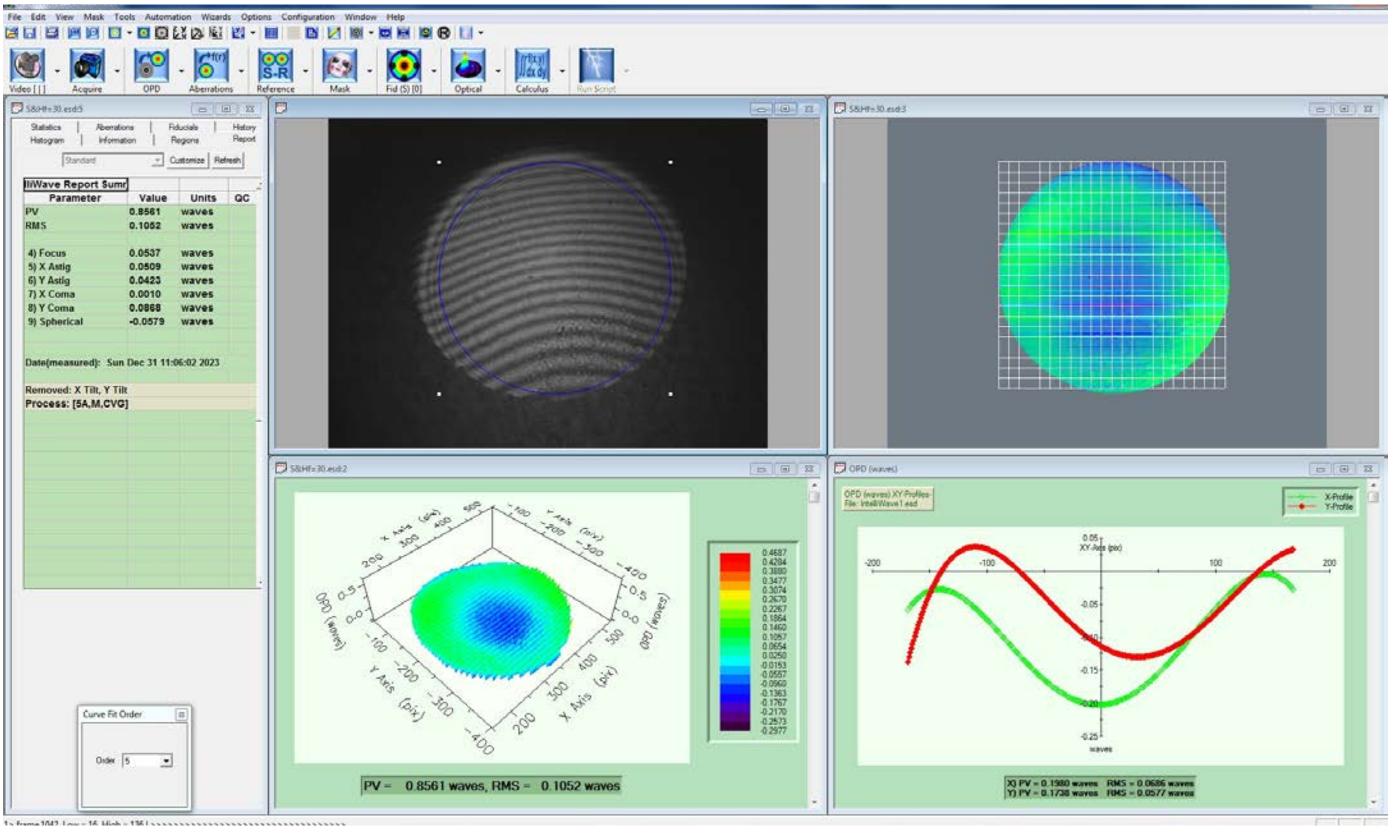
The f = 20 mm, D = 9 mm Ø CA achromatic lens test shows 0.3 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-318**



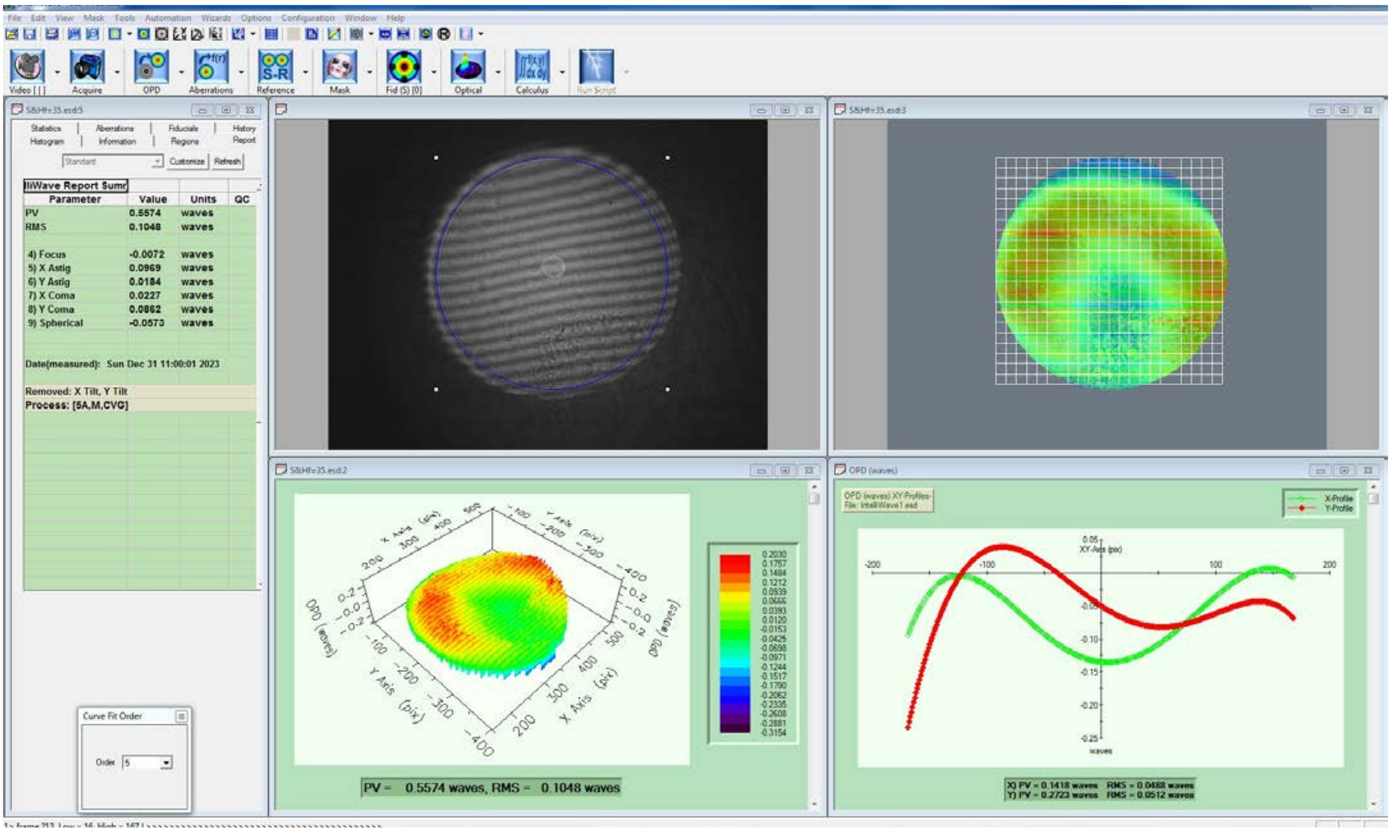
F = 25

The f = 25 mm, D = 11.5 mm Ø CA achromatic lens test shows 0.2 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-320**

Achromats

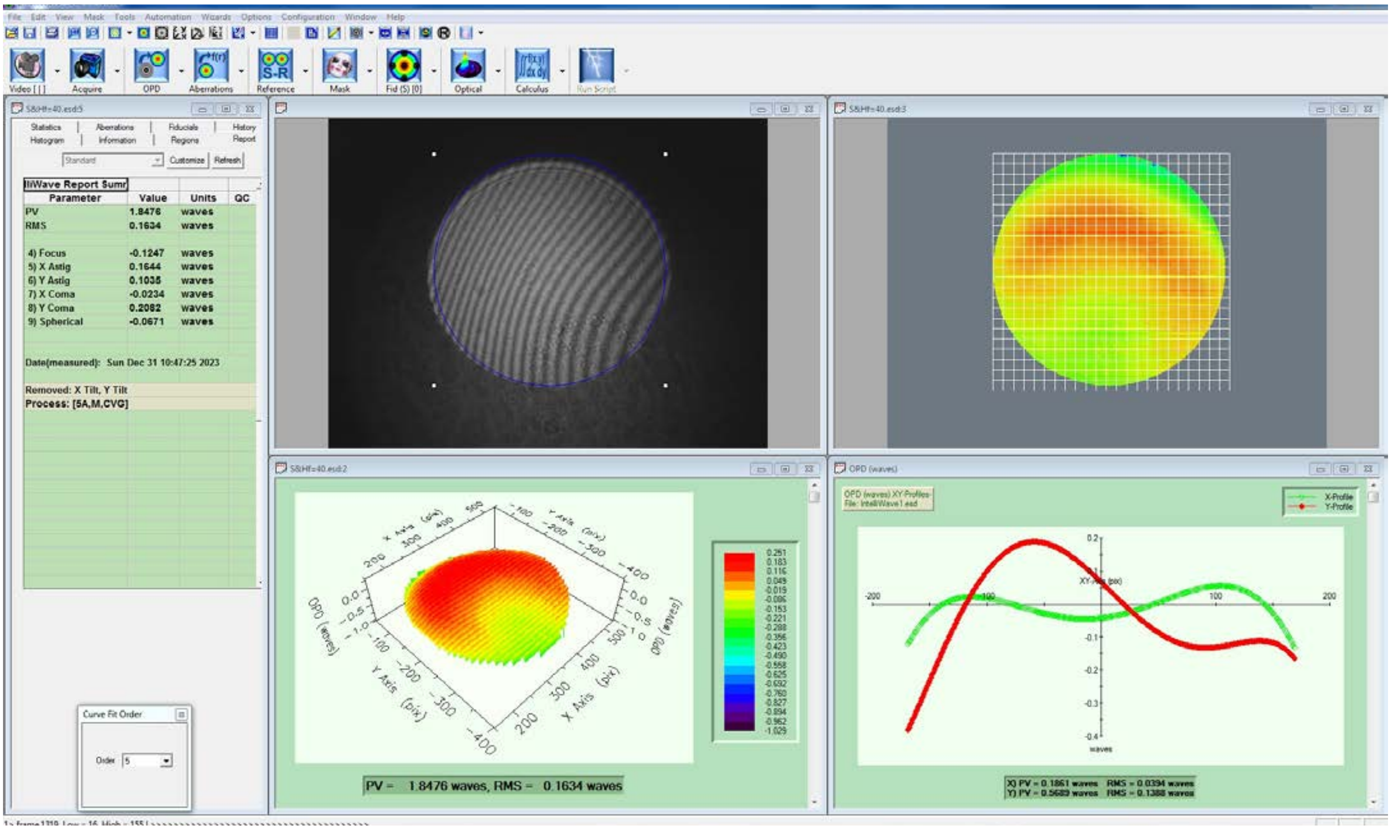


F = 30 The f = 30 mm, CA = 11.5 mm Ø achromatic lens test shows 0.2 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-322**



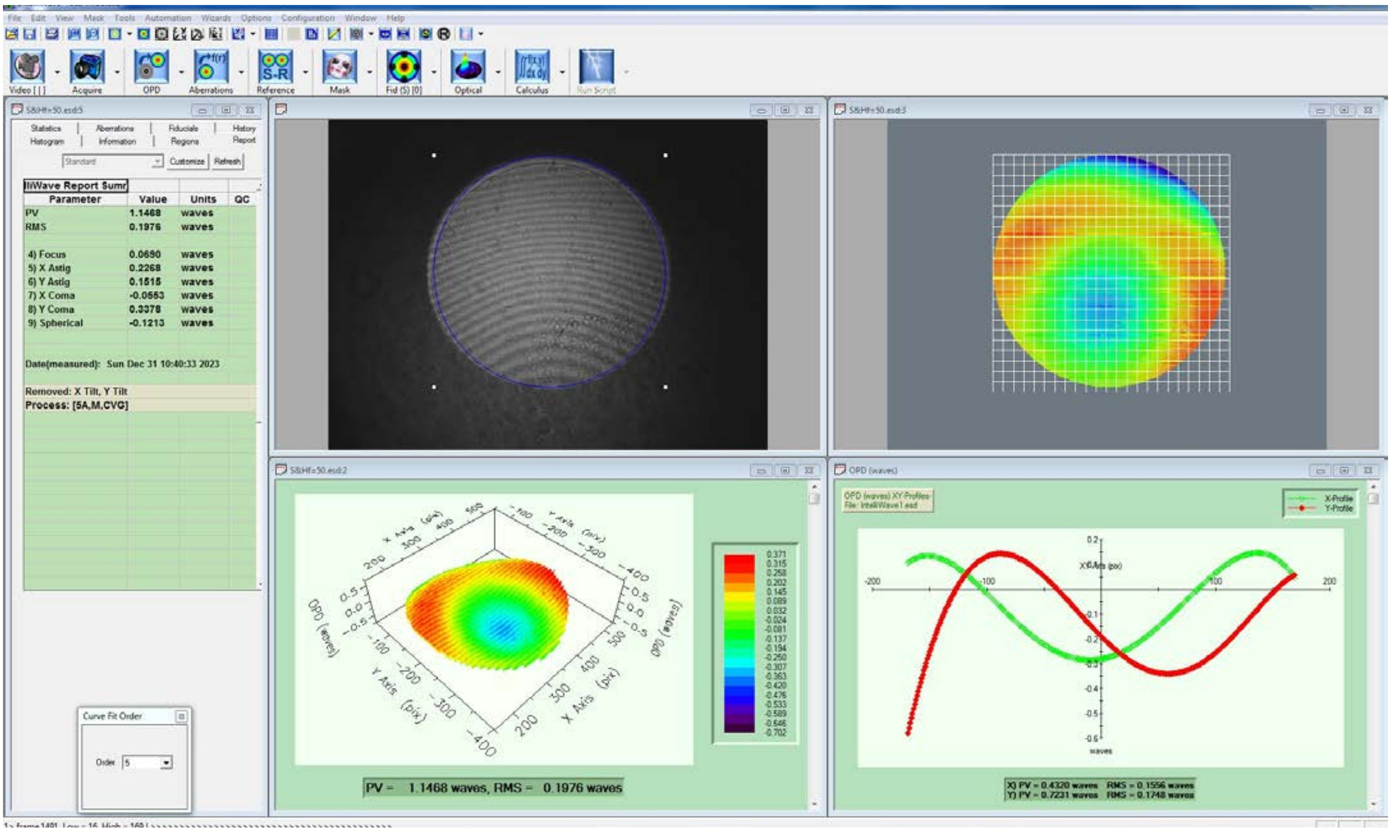
F = 35 The f = 35 mm, CA = 11.5 mm Ø achromatic lens test shows 0.3 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-324.** You could see the performance of these lenses < 35 mm are starting to go down. Since all these tests were performed using the same diverger, I suspect these measurements only covered the center area of lenses than full aperture.

Achromats



F = 40

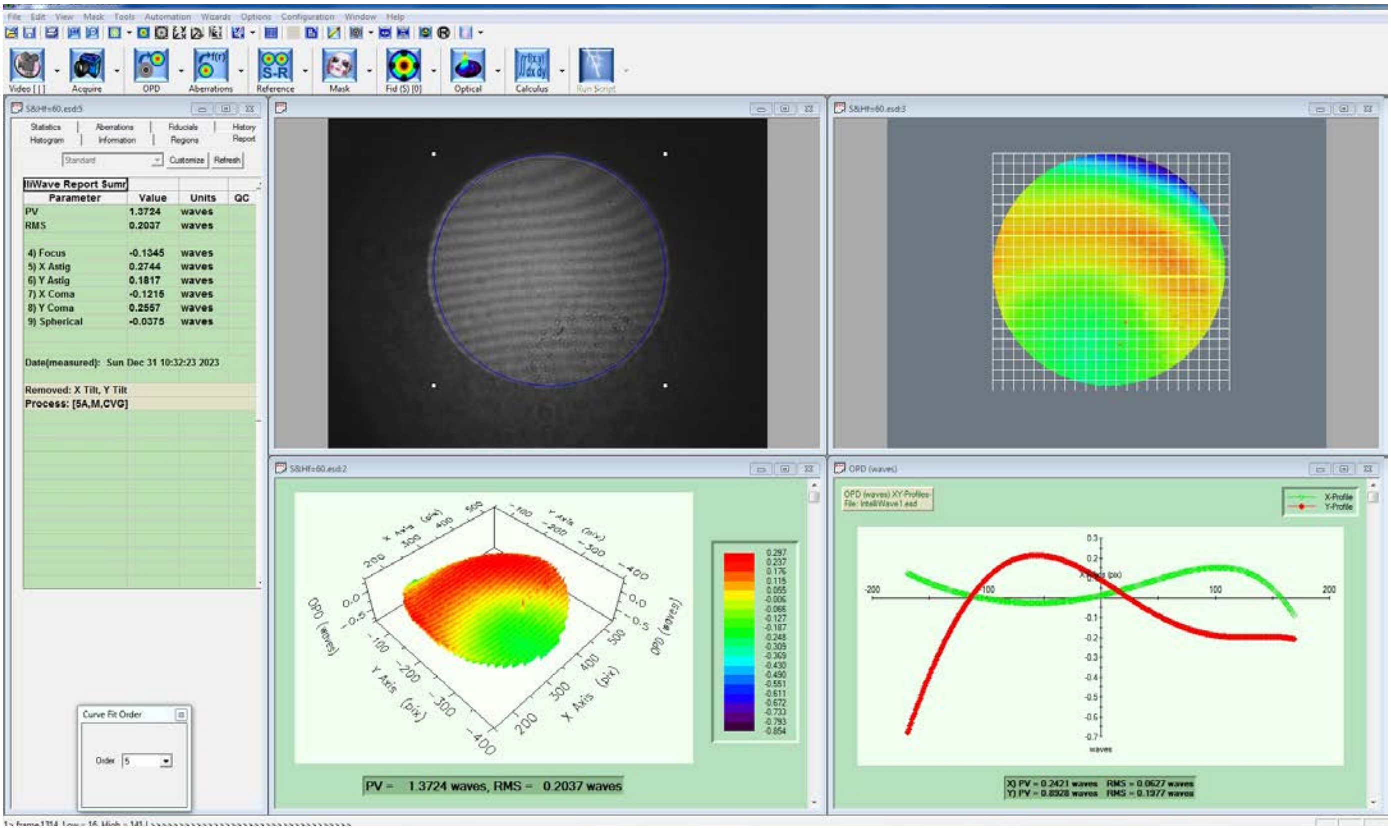
The f = 40 mm, CA = 17 mm Ø achromatic lens test shows 0.6 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-326**



F = 50

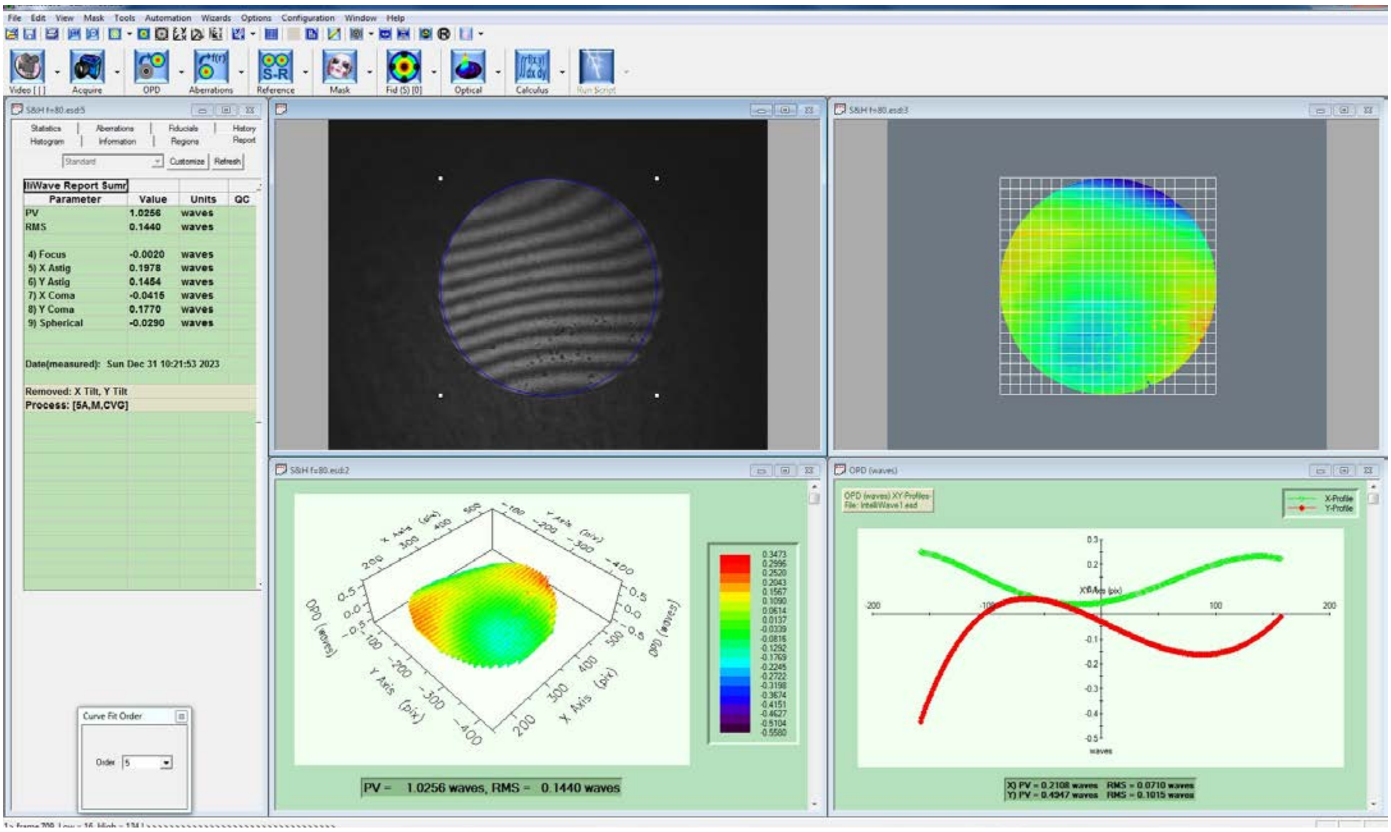
The f = 50 mm, CA = 17 mm Ø achromatic lens test shows 0.8 wave field flatness.
Wave length = 635 nm, Catalog N0. **20-328.** I think this degradation is because the diverger is now covering the entire aperture of these longer focal length lenses.

Achromats



F = 60

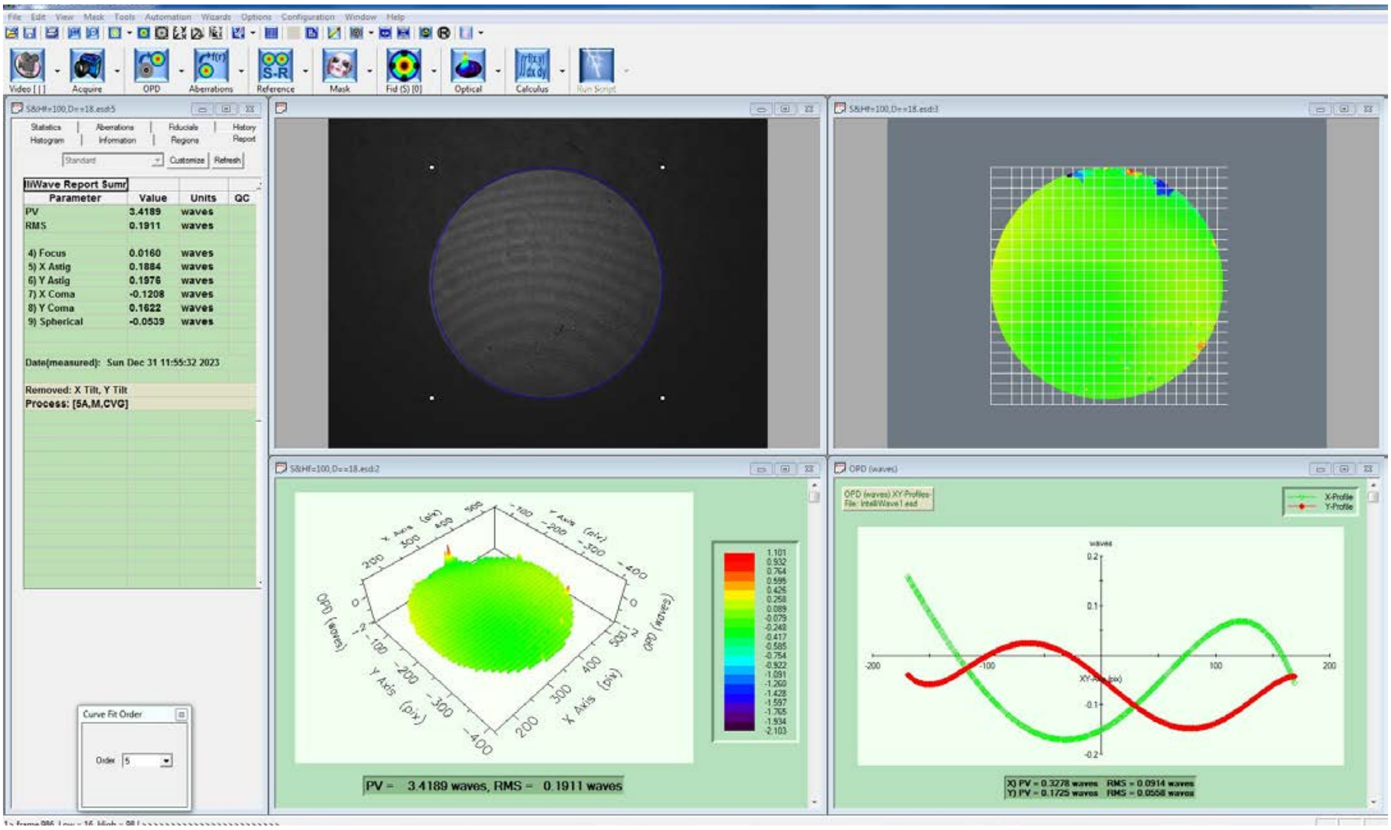
The f = 60 mm, CA = 17 mm Ø achromatic lens test shows 1.0 wave field flatness. Wave length = 635 nm, Catalog N0. **20-332.** The performance of this lens is way down, and this was the lens we were planning to use.



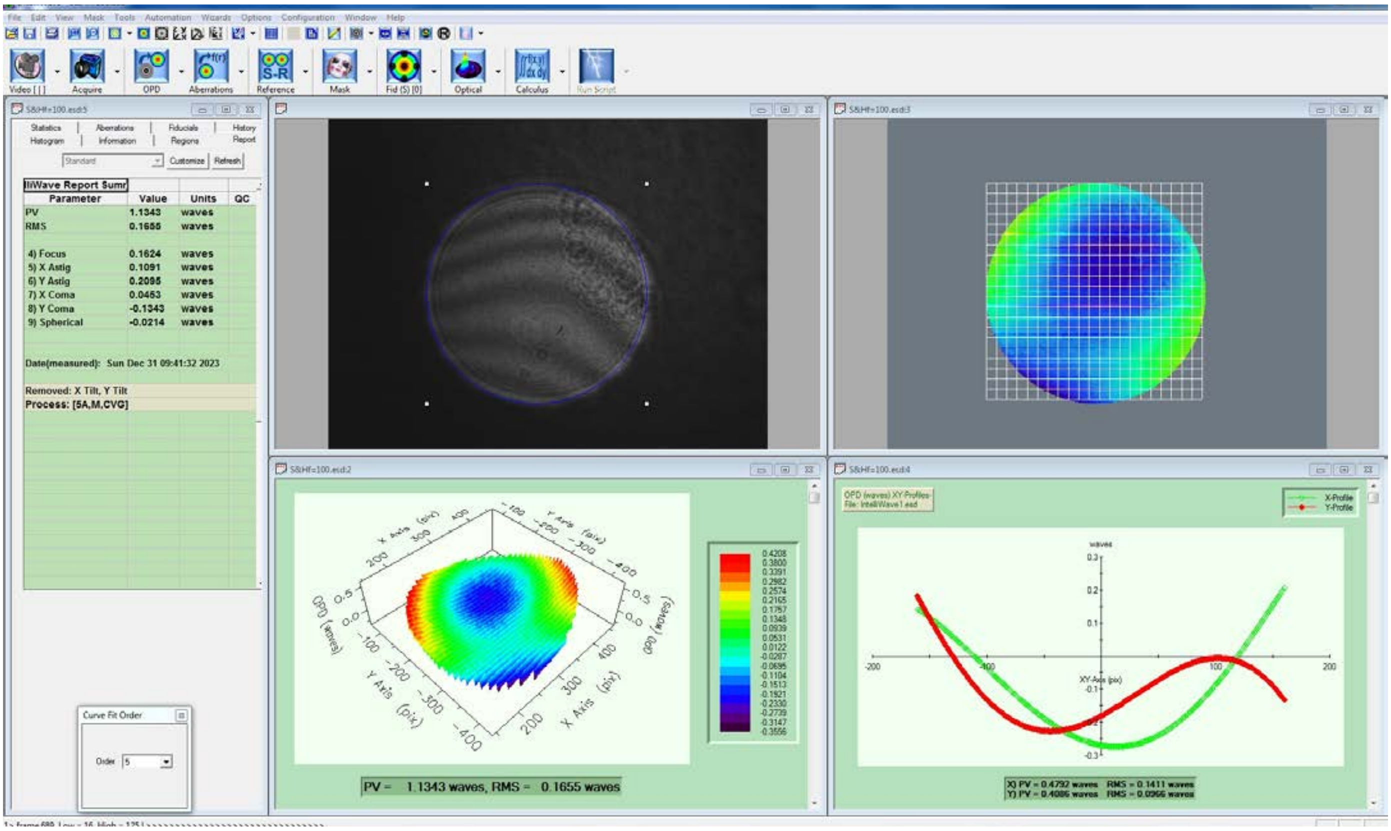
F = 80

The f = 80 mm, CA = 17 mm Ø achromatic lens test shows 0.55 wave field flatness. Wave length = 635 nm, Catalog N0. **20-338.**

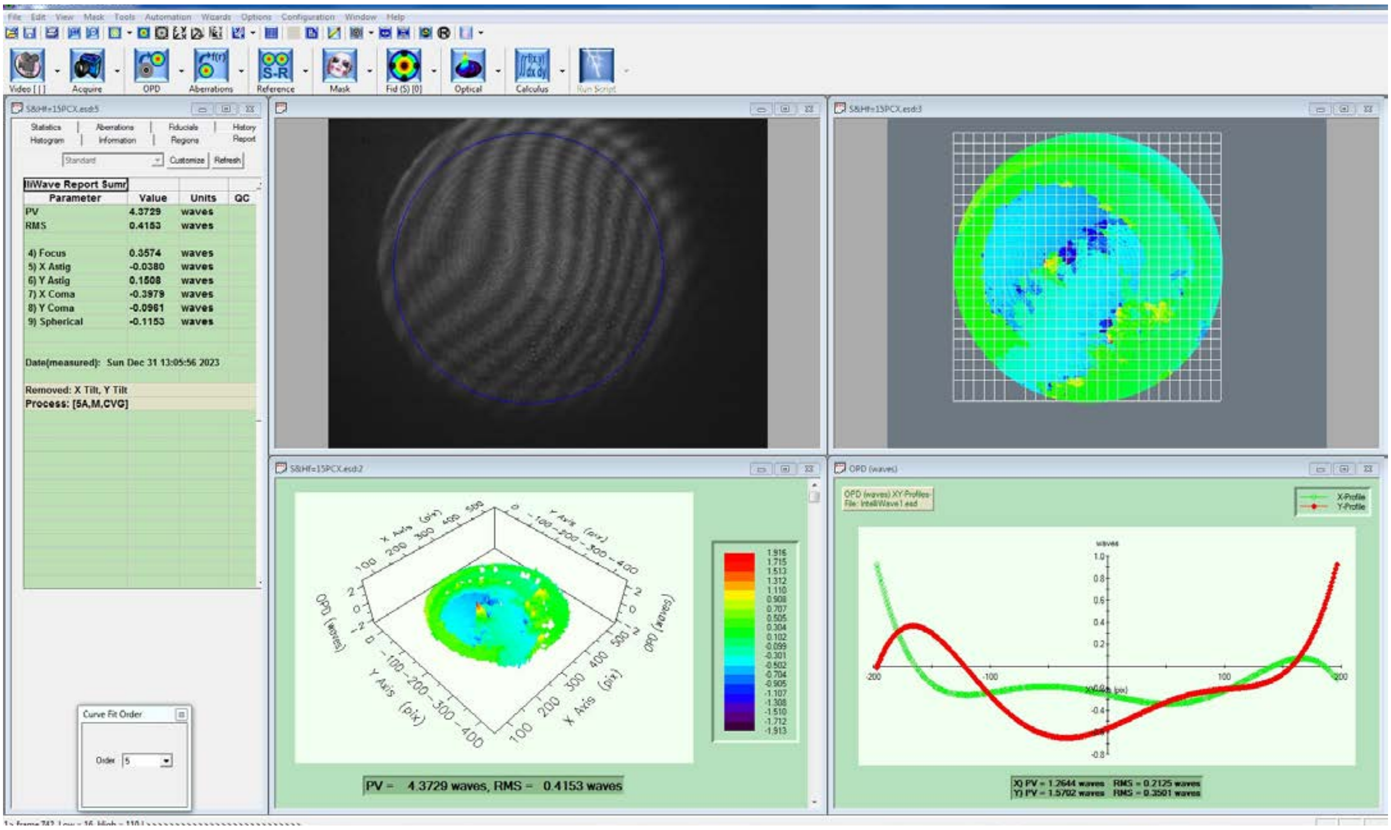
Achromats



F = 100 The f = 100 mm, CA = 17 mm Ø achromatic lens test shows 0.45 wave field flatness. Wave length = 635 nm, Catalog N0. **20-346**

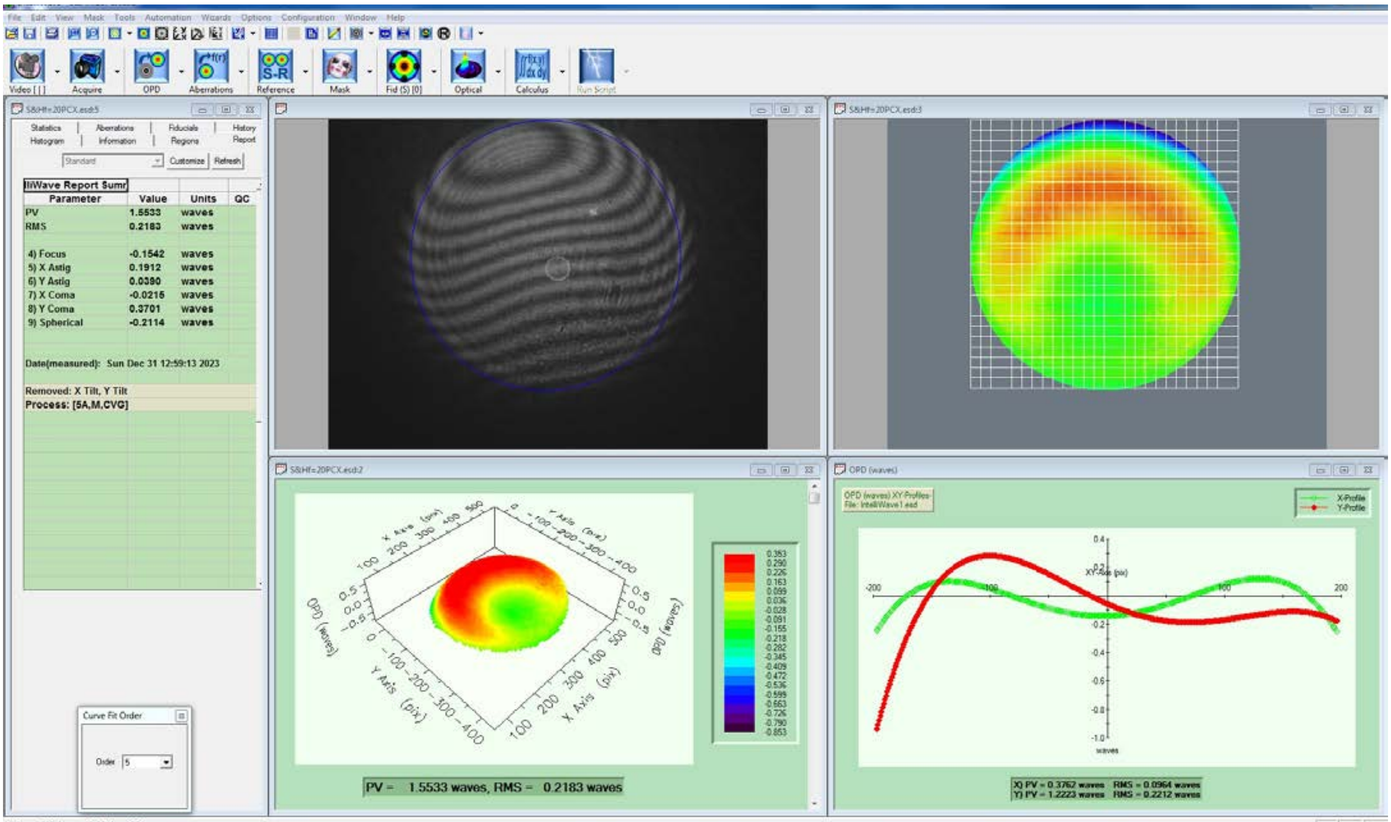


F = 100 The f = 100 mm, CA = 21.4 mm Ø achromatic lens test shows 0.45 wave field flatness. Wave length = 635 nm, Catalog N0. **20-348.** Its decrease in performance is due to its larger diameter, and it's a thicker lens.



F = 15 PCX

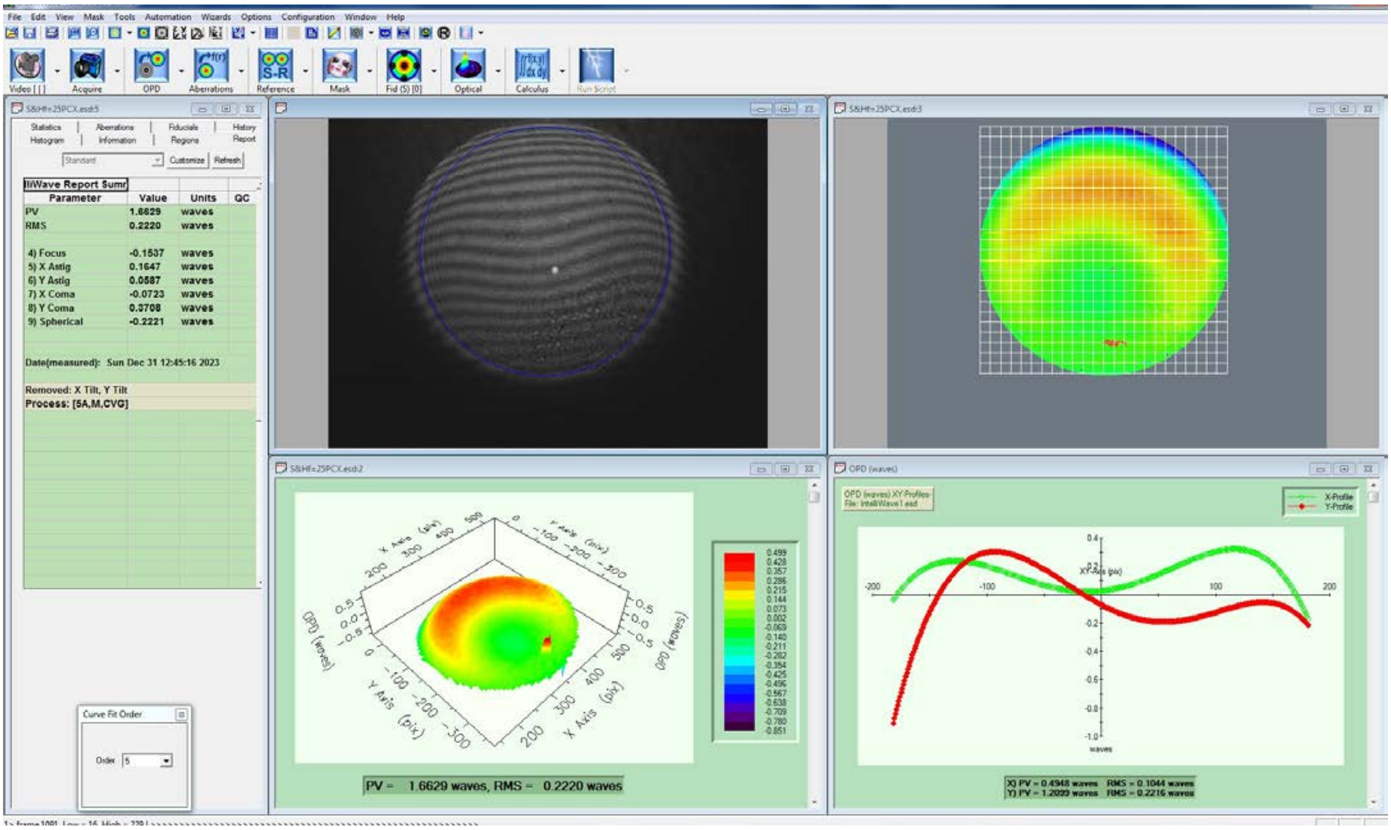
The f = 15 mm, CA = 9 mm Ø singlet lens test shows 1.6 waves field flatness.
Wave length = 635 nm, Catalog N0. **20-002**



F = 20 PCX

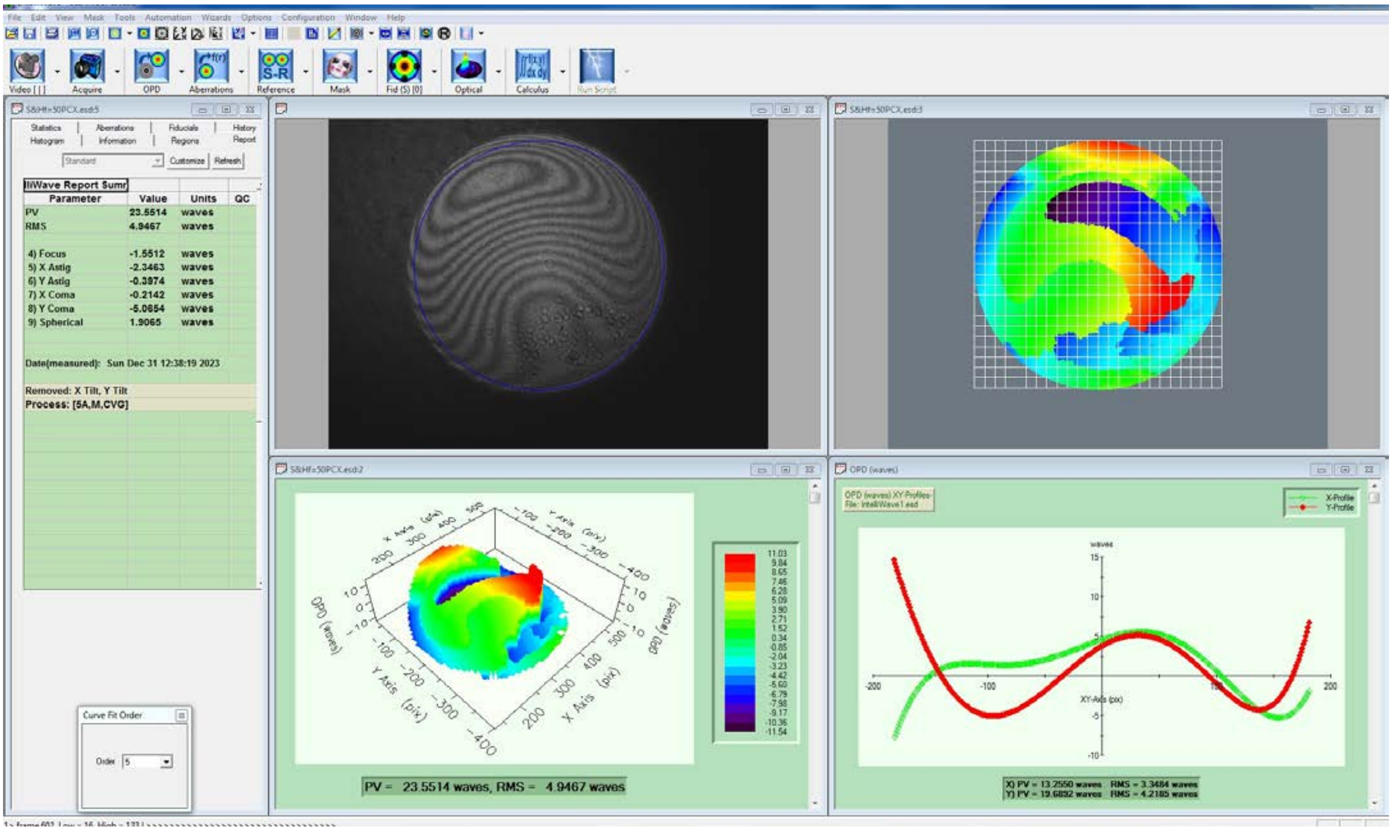
The f = 20 mm, CA = 11.5 mm Ø singlet lens test shows 1.4 waves field flatness.
Wave length = 635 nm, Catalog N0. **20-004**

Singlets BK7



F = 25 PCX

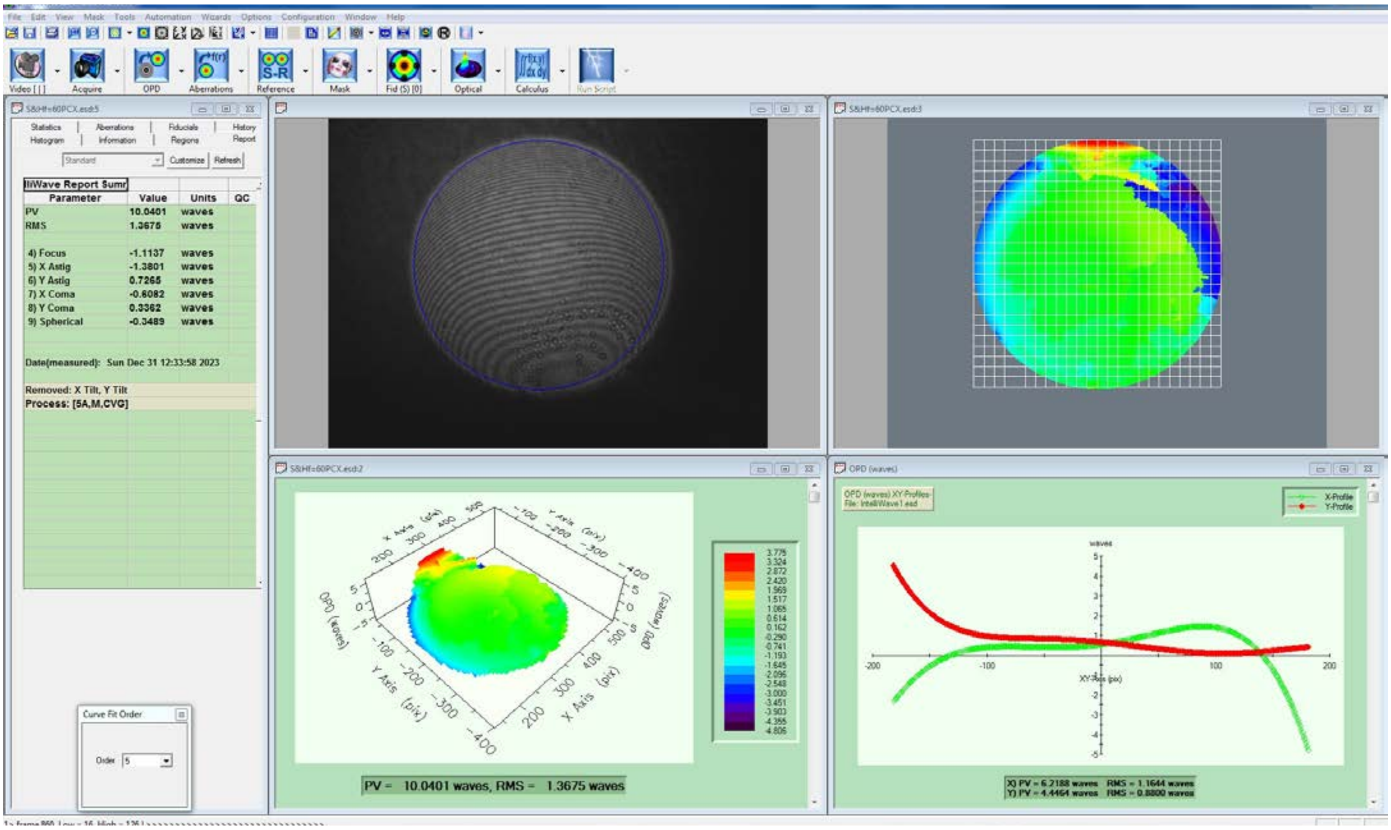
The f = 25 mm, CA = 11.5 mm Ø singlet lens test shows 1.3 waves field flatness. Wave length = 635 nm, Catalog N0. **20-006**



F = 50 PCX

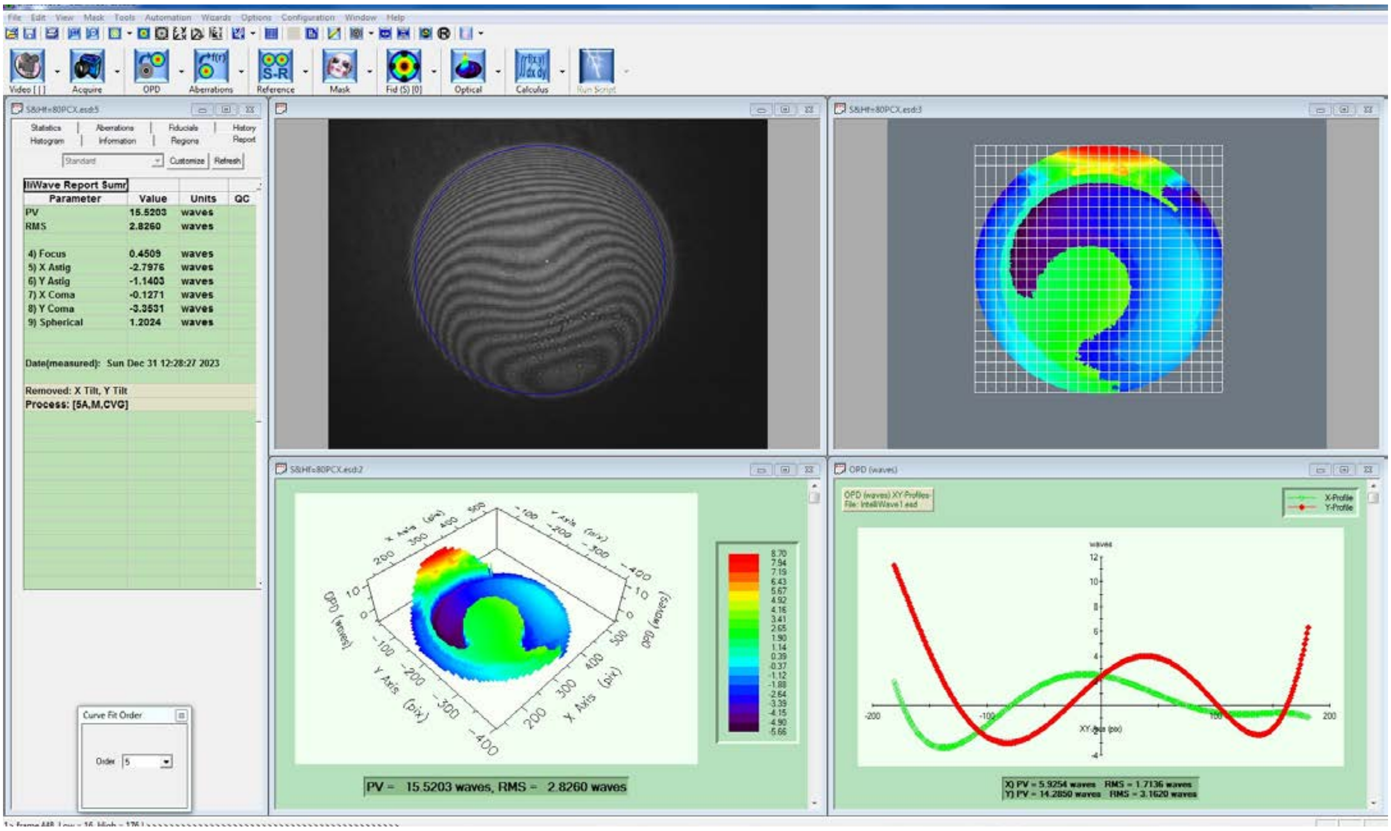
The f = 50 mm, CA = 21.4 mm Ø singlet lens test shows 20 waves field flatness. Wave length = 635 nm, Catalog N0. **20-012.** Apparently there must have been an error in this setup.

Singlets BK7



F = 60 PCX

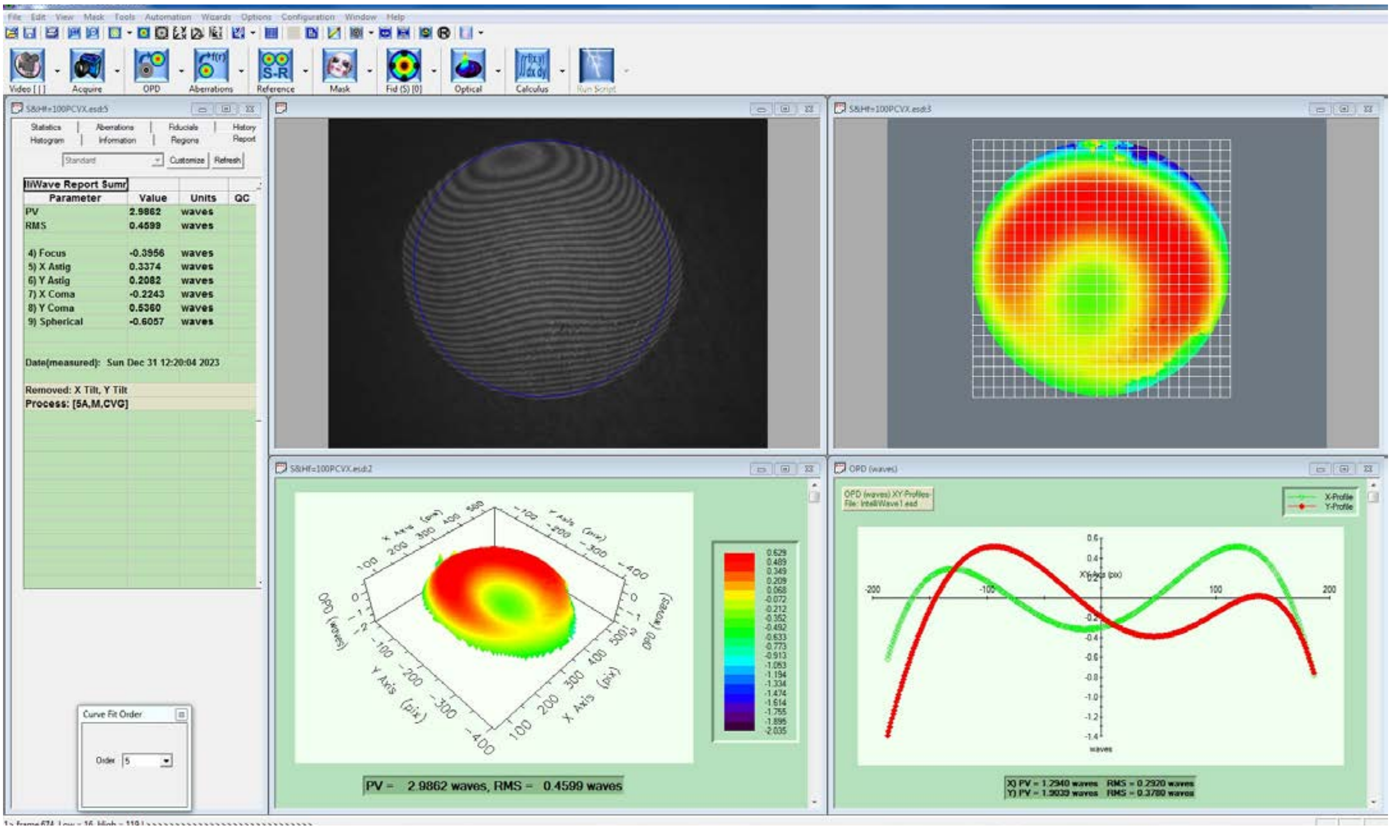
The f = 60 mm, CA = 21.4 mm Ø singlet lens test shows 5 waves field flatness. Wave length = 635 nm, Catalog N0. **20-014**



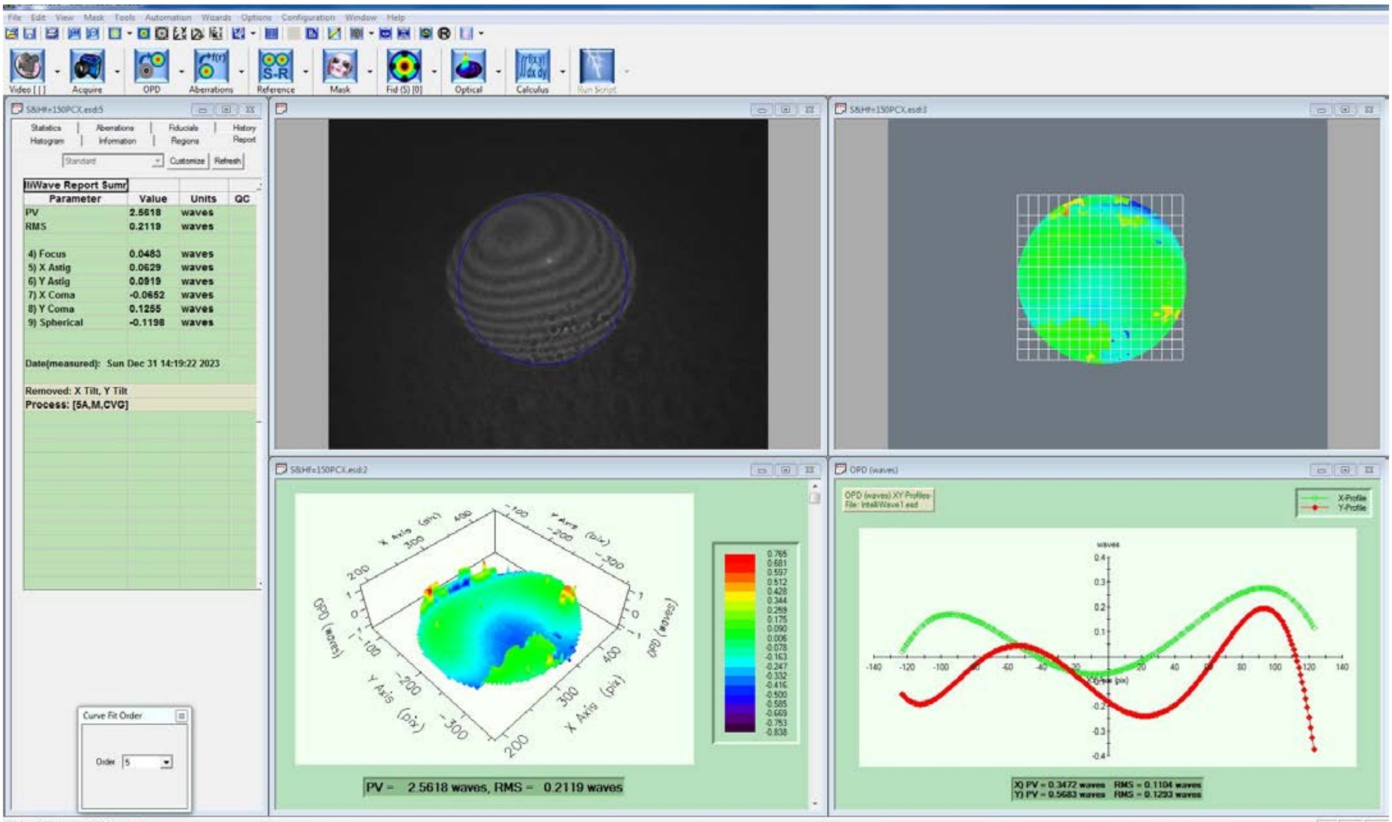
F = 80 PCX

The f = 80 mm, CA = 21.4 mm Ø singlet lens test shows 15 waves field flatness. Wave length = 635 nm, Catalog N0. **20-016.** Apparently there must have been an error in this setup.

Singlets BK7

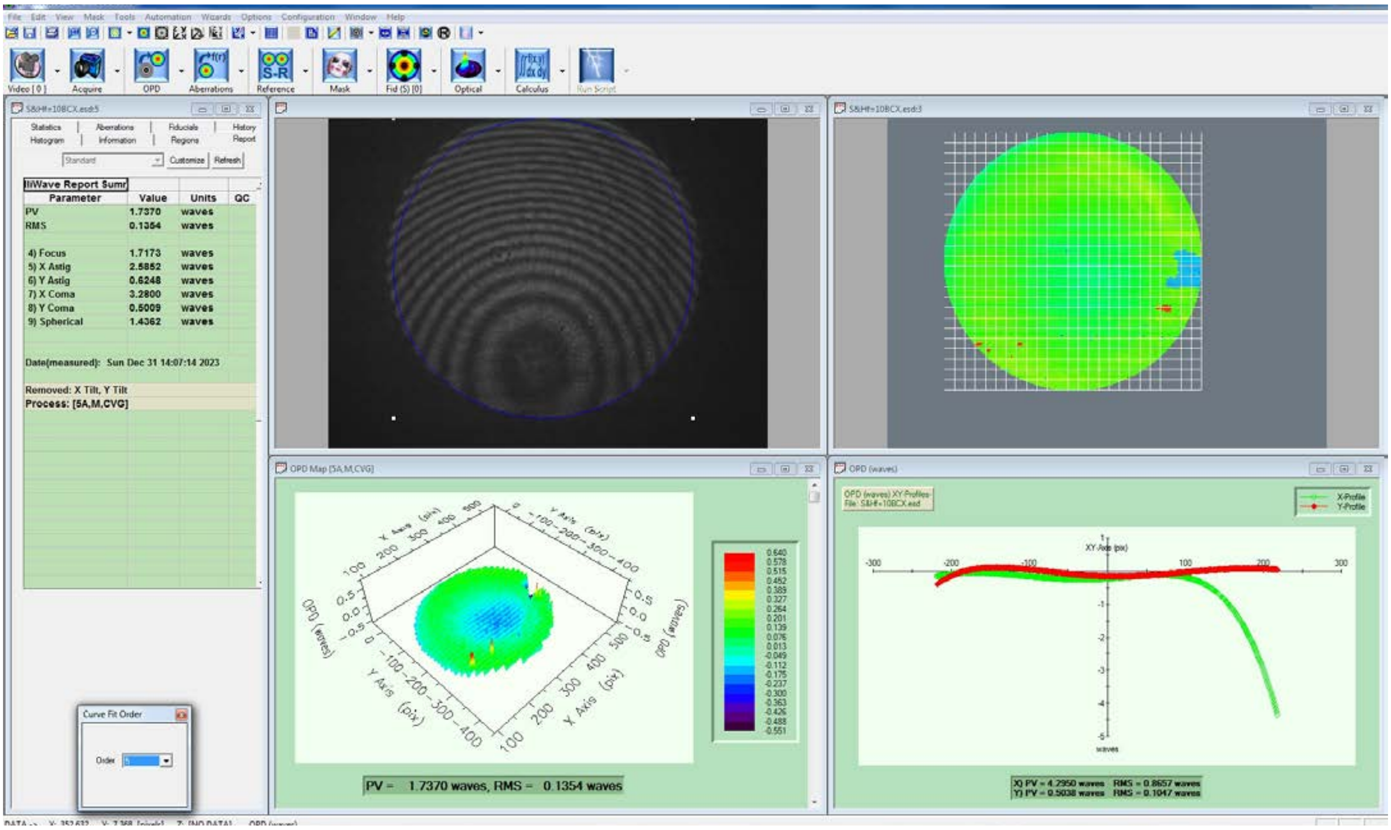


F = 100 PCX The f = 100 mm, CA = 21.4 mm Ø singlet lens test shows 2 waves field flatness. Wave length = 635 nm, Catalog N0. **20-020**



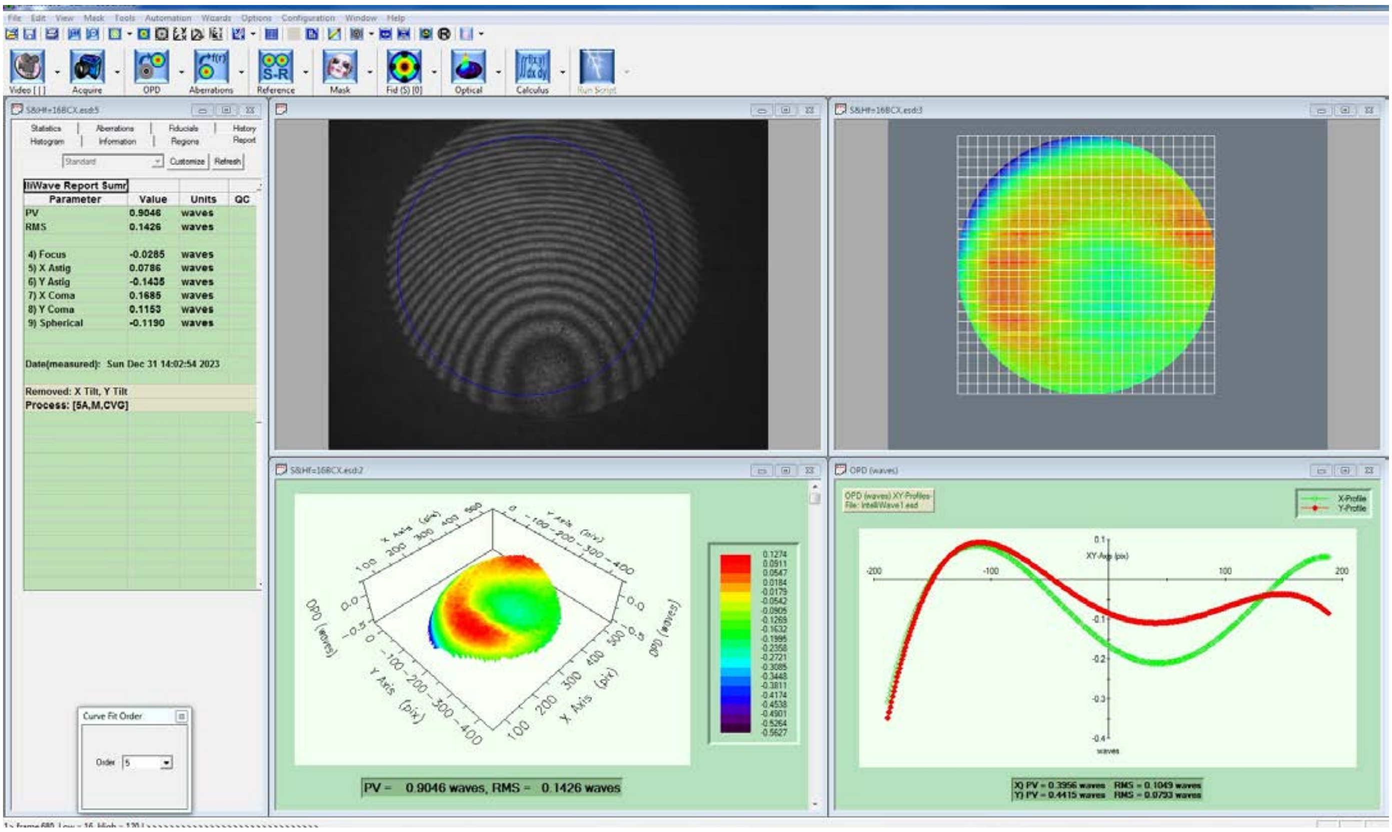
F = 150 PCX The f = 150 mm, CA = 21.4 mm Ø singlet lens test shows 0.3 waves field flatness. Wave length = 635 nm, Catalog N0. **20-022**. As one could see from its smaller image size (above left) the diverger's beam is overfilling the full aperture area.

Singlets BK7



F = 10 BCX

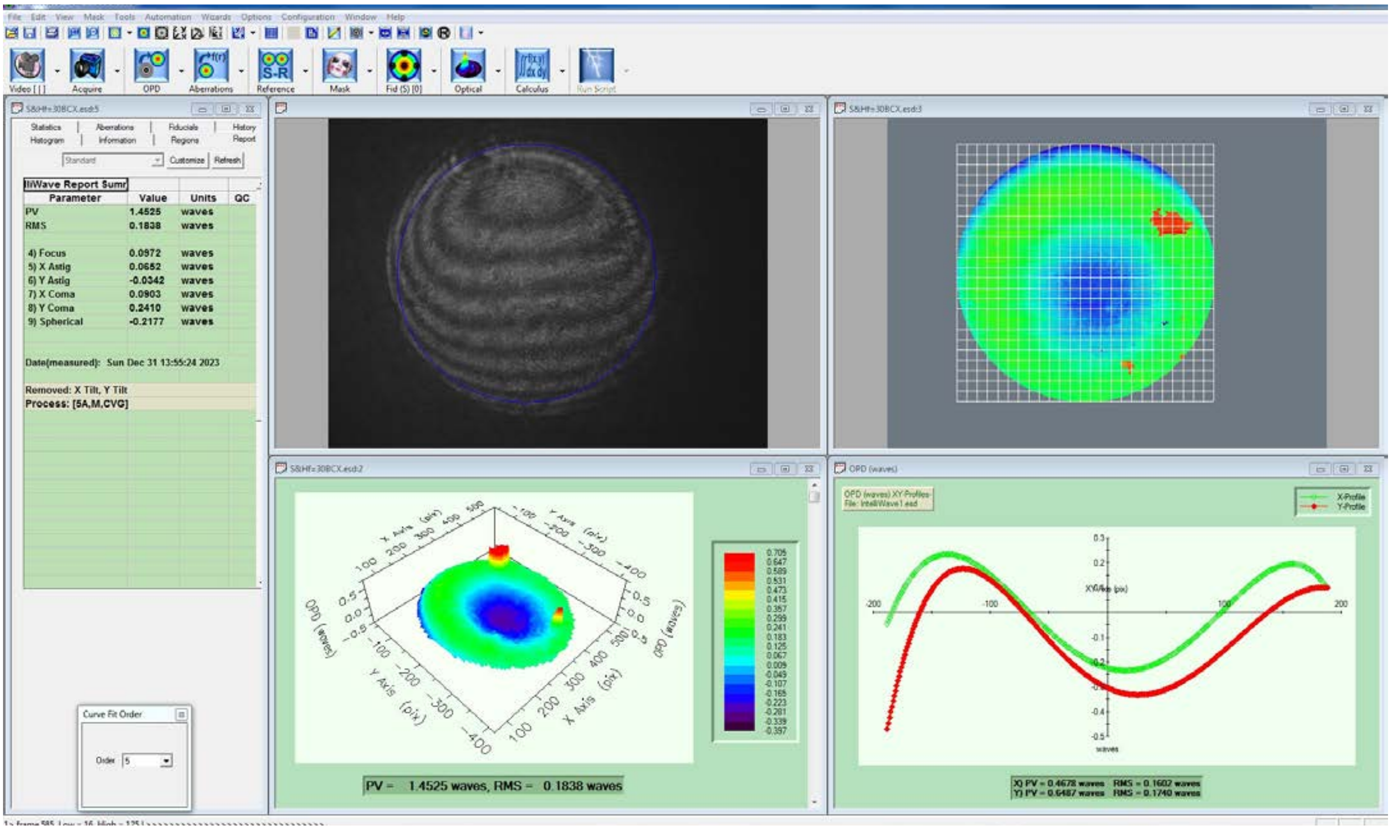
The f = 10 mm, CA = 9 mm Ø singlet lens test shows 1 waves field flatness.
Wave length = 635 nm, Catalog N0. **20-104**



F = 16 BCX

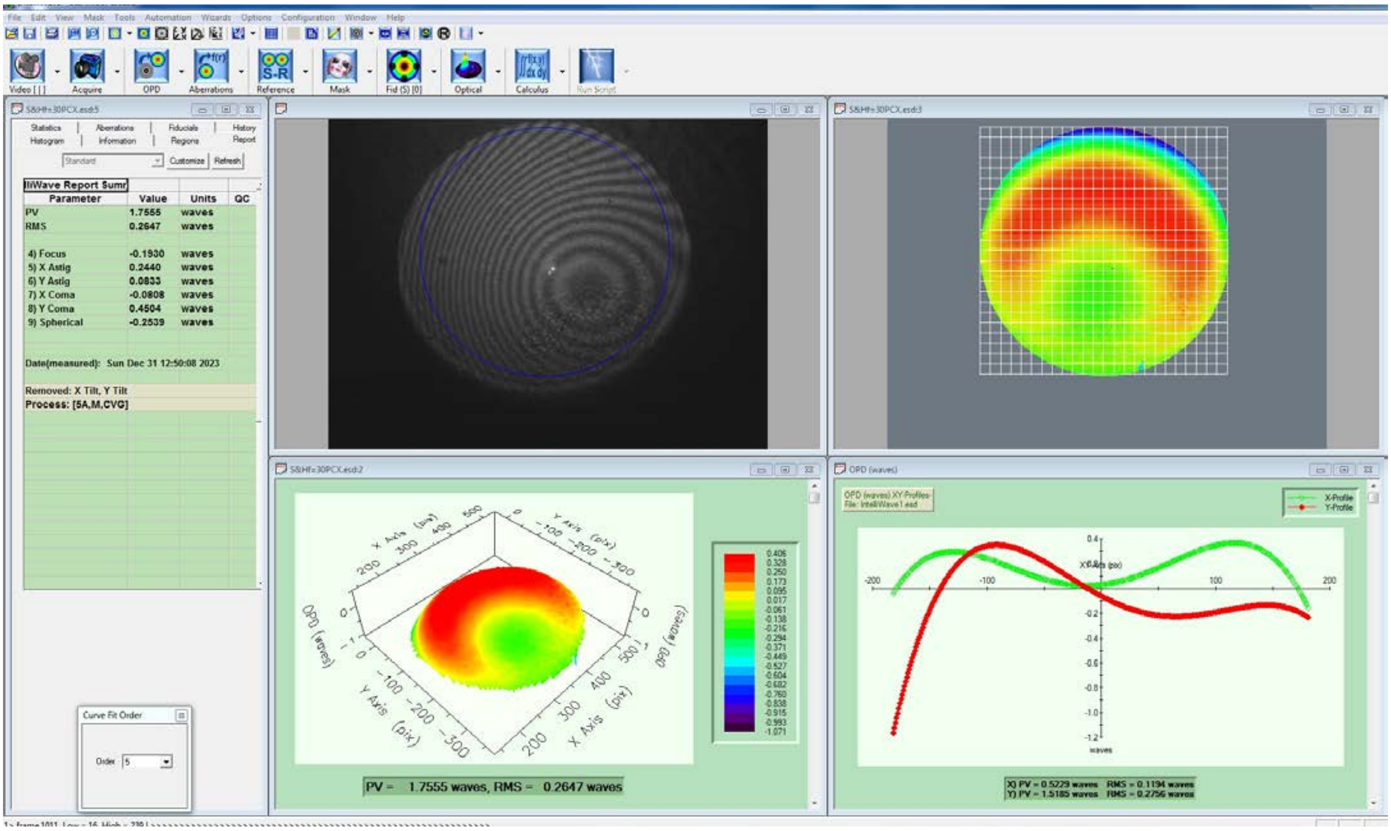
The f = 16 mm, CA = 11.5 mm Ø singlet lens test shows 0.45 waves field flatness.
Wave length = 635 nm, Catalog N0. **20-106**

Singlets BK7



F = 20 BCX

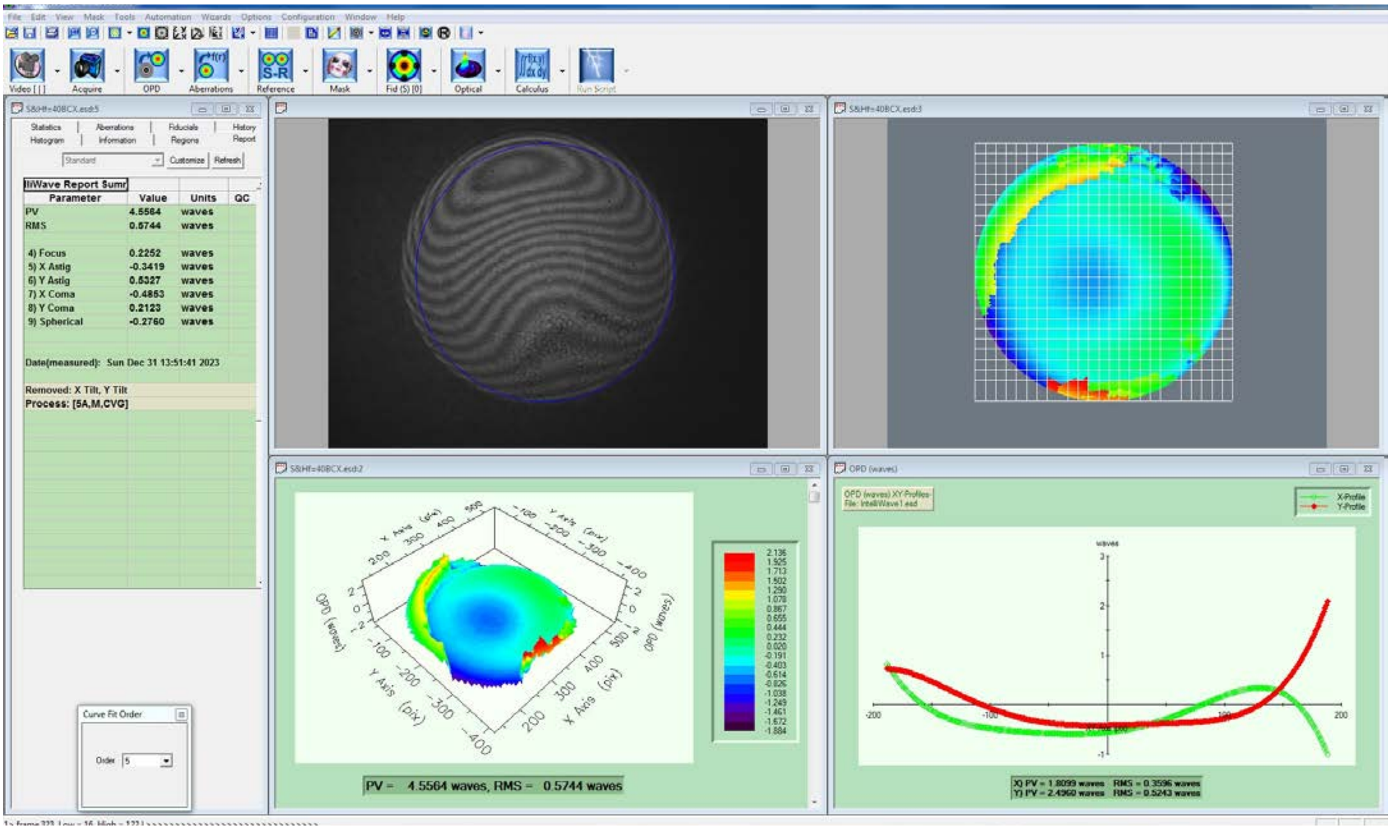
The f = 20 mm, CA = 21.4 mm Ø singlet lens test shows 0.7 waves field flatness. Wave length = 635 nm, Catalog N0. **20-110**



F = 30 BCX

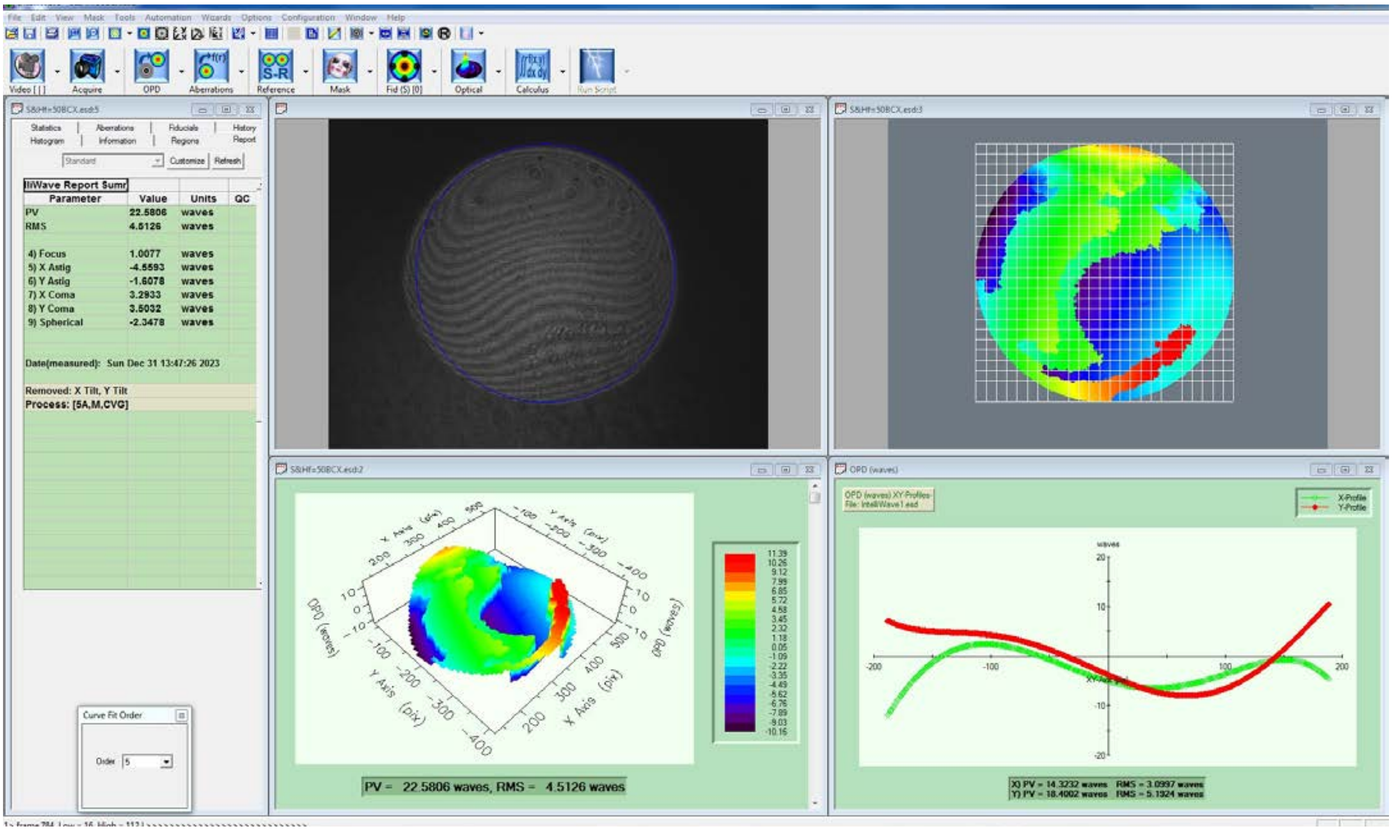
The f = 30 mm, CA = 21.4 mm Ø singlet lens test shows 1.6 waves field flatness. Wave length = 635 nm, Catalog N0. **20-116**

Singlets BK7



F = 40 BCX

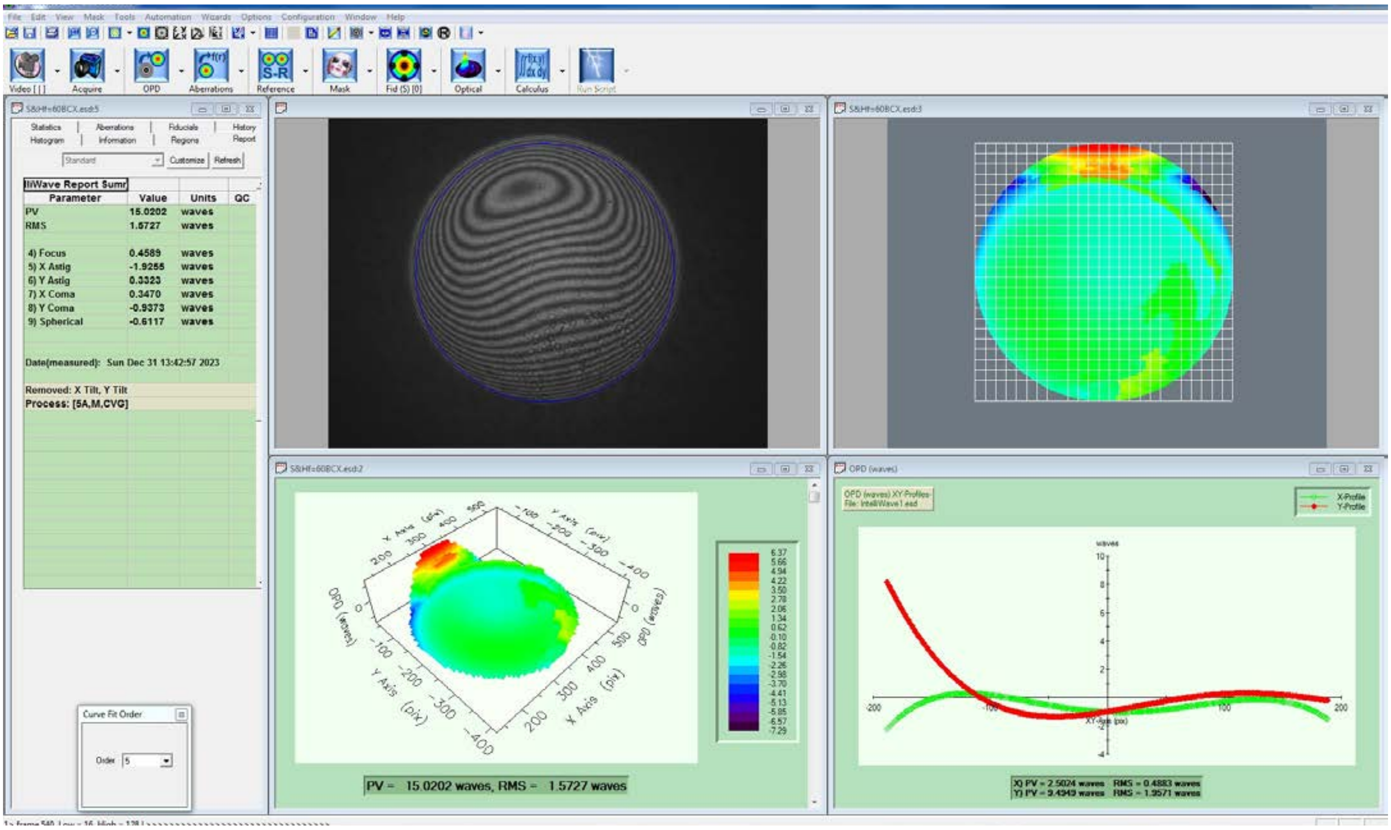
The f = 40 mm, CA = 21.4 mm Ø singlet lens test shows 2.5 waves field flatness. Wave length = 635 nm, Catalog N0. **20-118**



F = 50 BCX

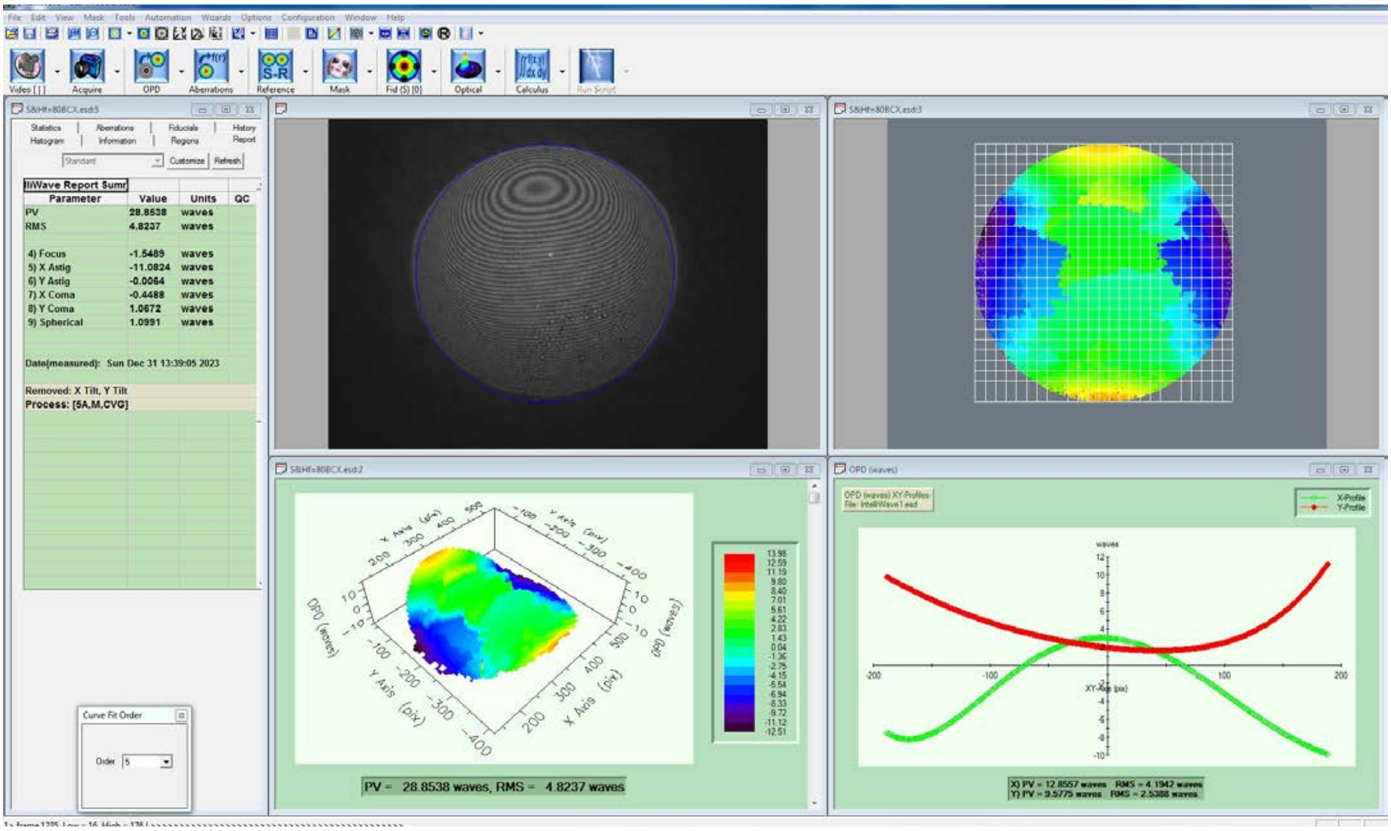
The f = 50 mm, CA = 21.4 mm Ø singlet lens test shows 18 waves field flatness. Wave length = 635 nm, Catalog N0. **20-120.** Apparently there must have been an error in this setup.

Singlets BK7



F = 60 BCX

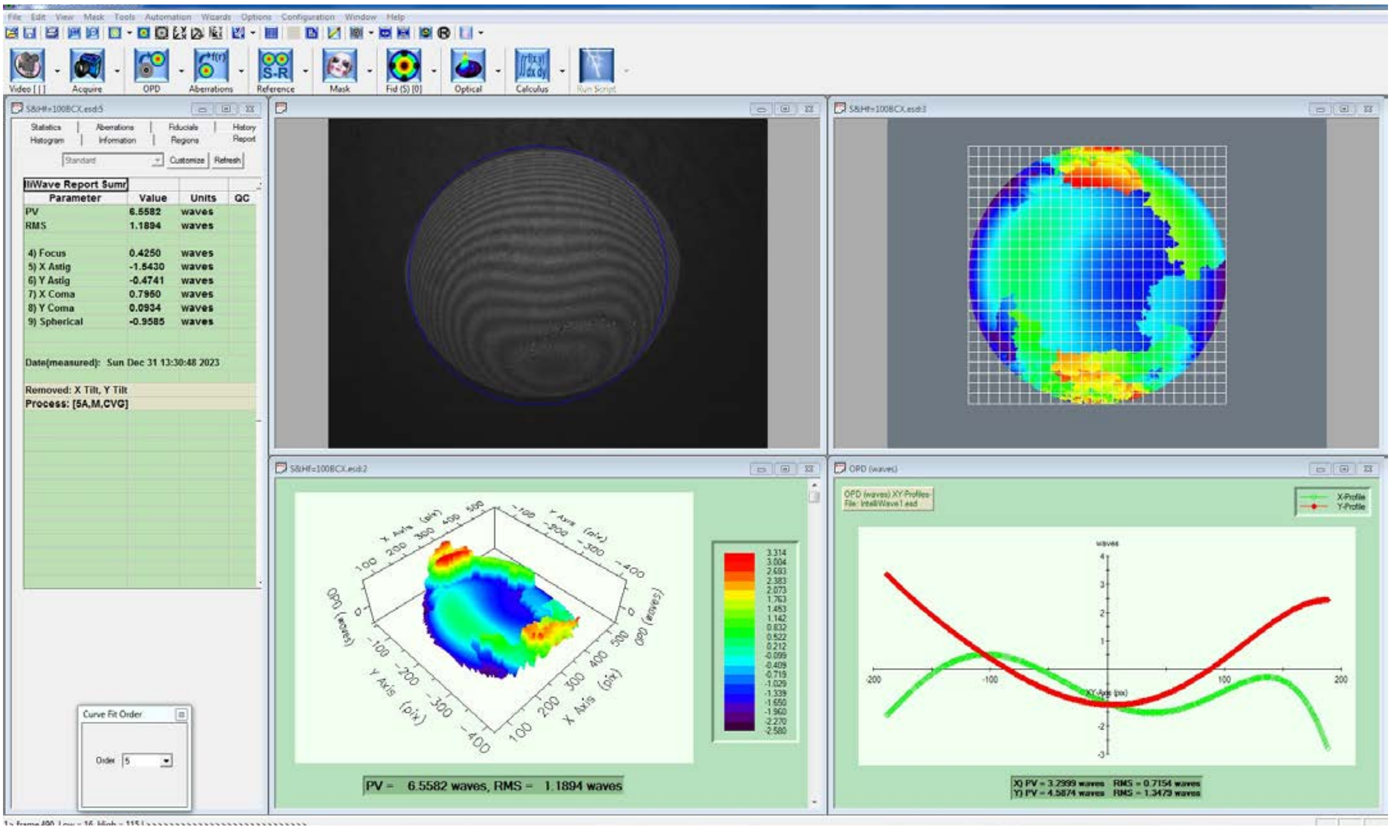
The f = 60 mm, CA = 21.4 mm Ø singlet lens test shows 11 waves field flatness. Wave length = 635 nm, Catalog N0. **20-122.** There looks to be an error in this setup.



F = 80 BCX

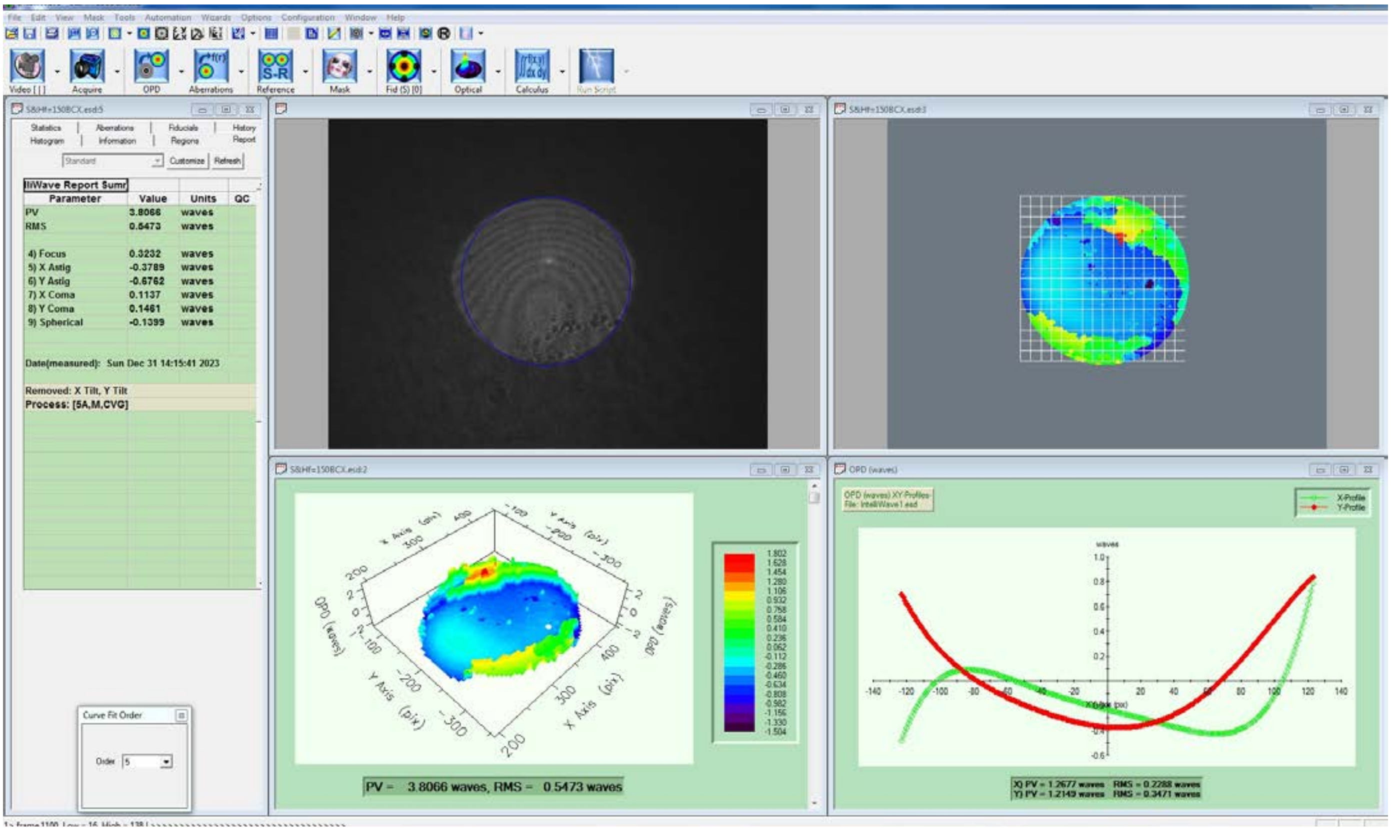
The f = 50 mm, CA = 21.4 mm Ø singlet lens test shows 10 waves field flatness. Wave length = 635 nm, Catalog N0. **20-124.** There looks to be an error in this setup.

Singlets BK7



F = 100 BCX

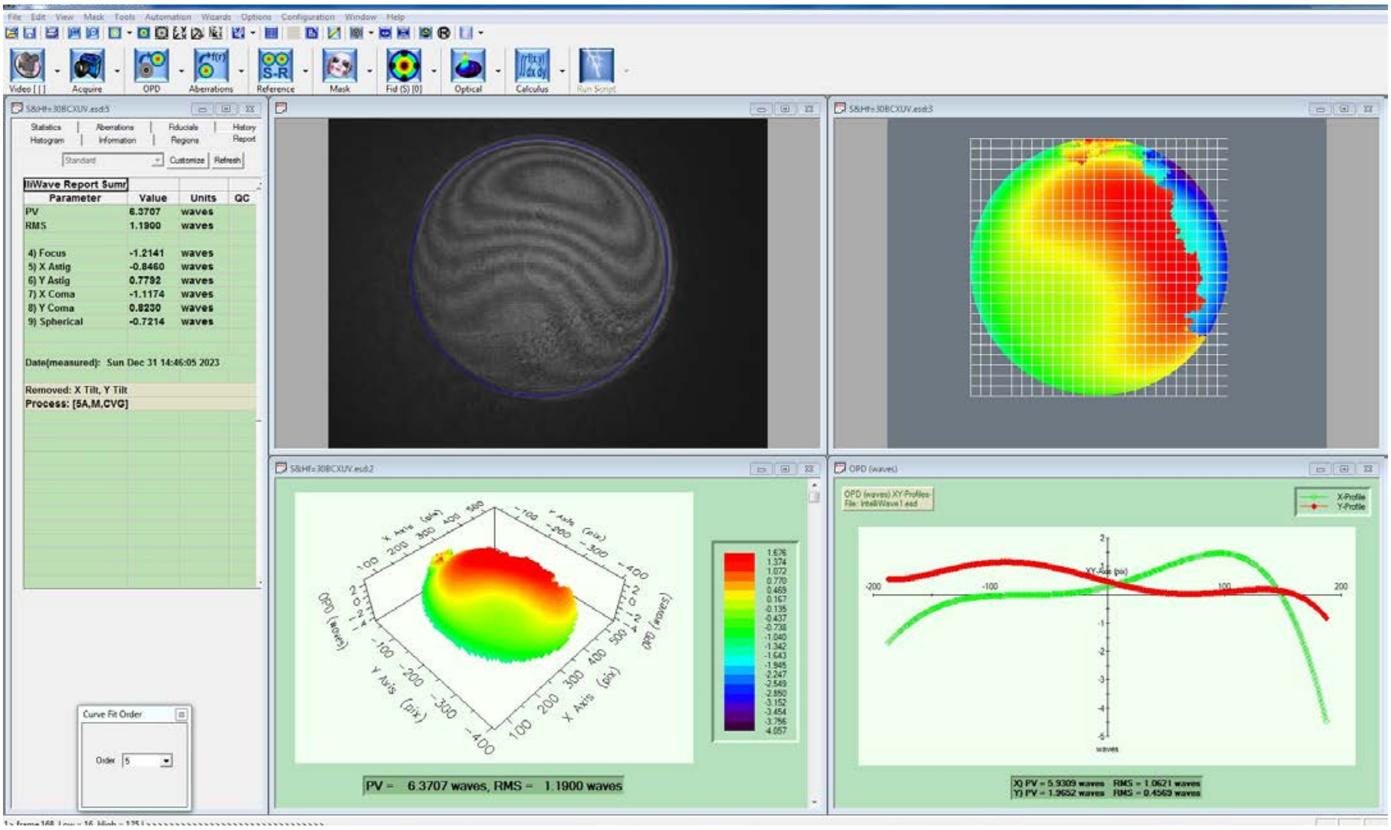
The f = 100 mm, CA = 21.4 mm Ø singlet lens test shows 5 waves field flatness.
Wave length = 635 nm, Catalog N0. **20-126**



F = 150 BCX

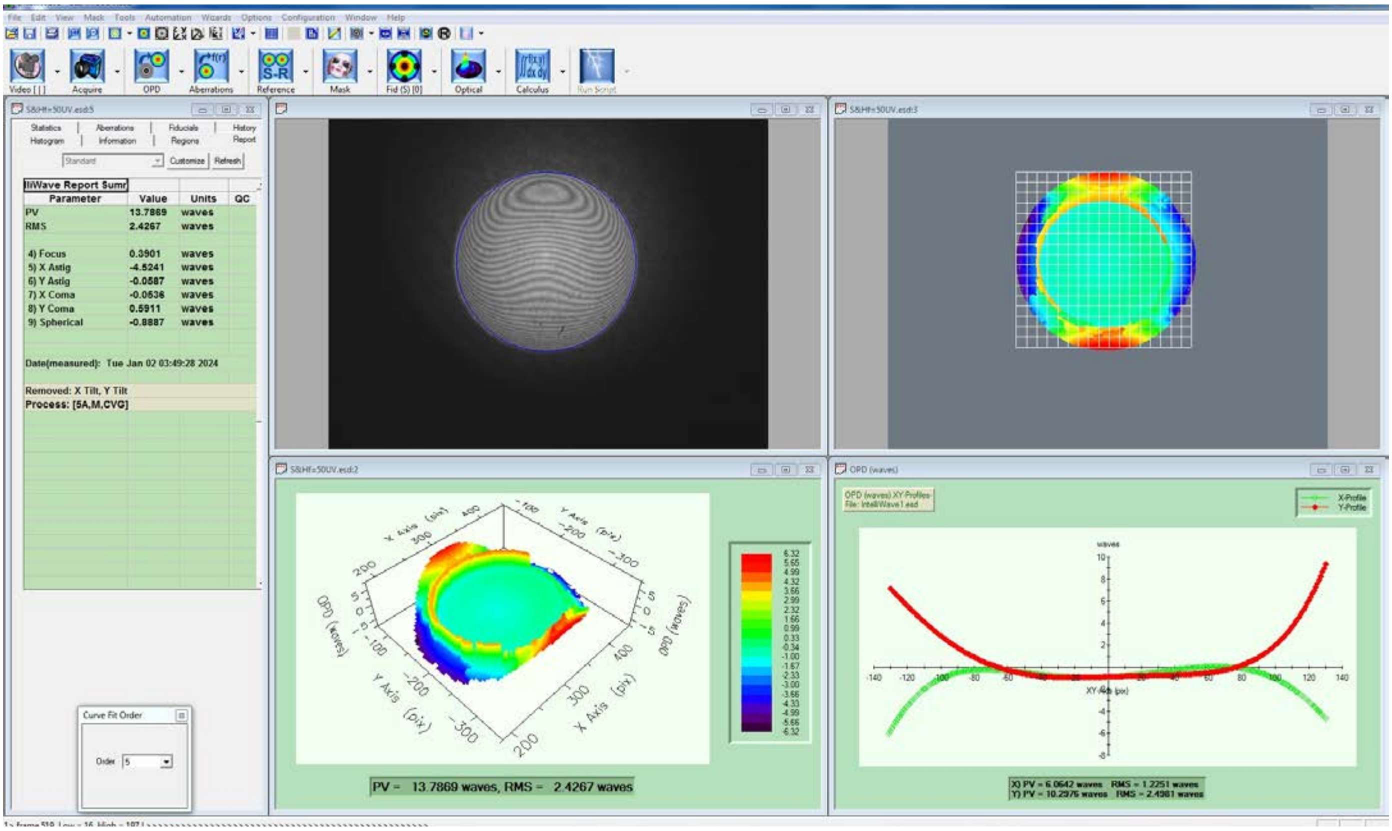
The f = 150 mm, CA = 21.4 mm Ø singlet lens test shows 1.2 waves field flatness.
Wave length = 635 nm, Catalog N0. **20-128**

Singlets BK7



F = 30 BCX UV

The f = 30 mm, CA = 21.4 mm Ø singlet lens test shows 2 waves field flatness. Wave length = 635 nm, Catalog N0. **20-116UV**



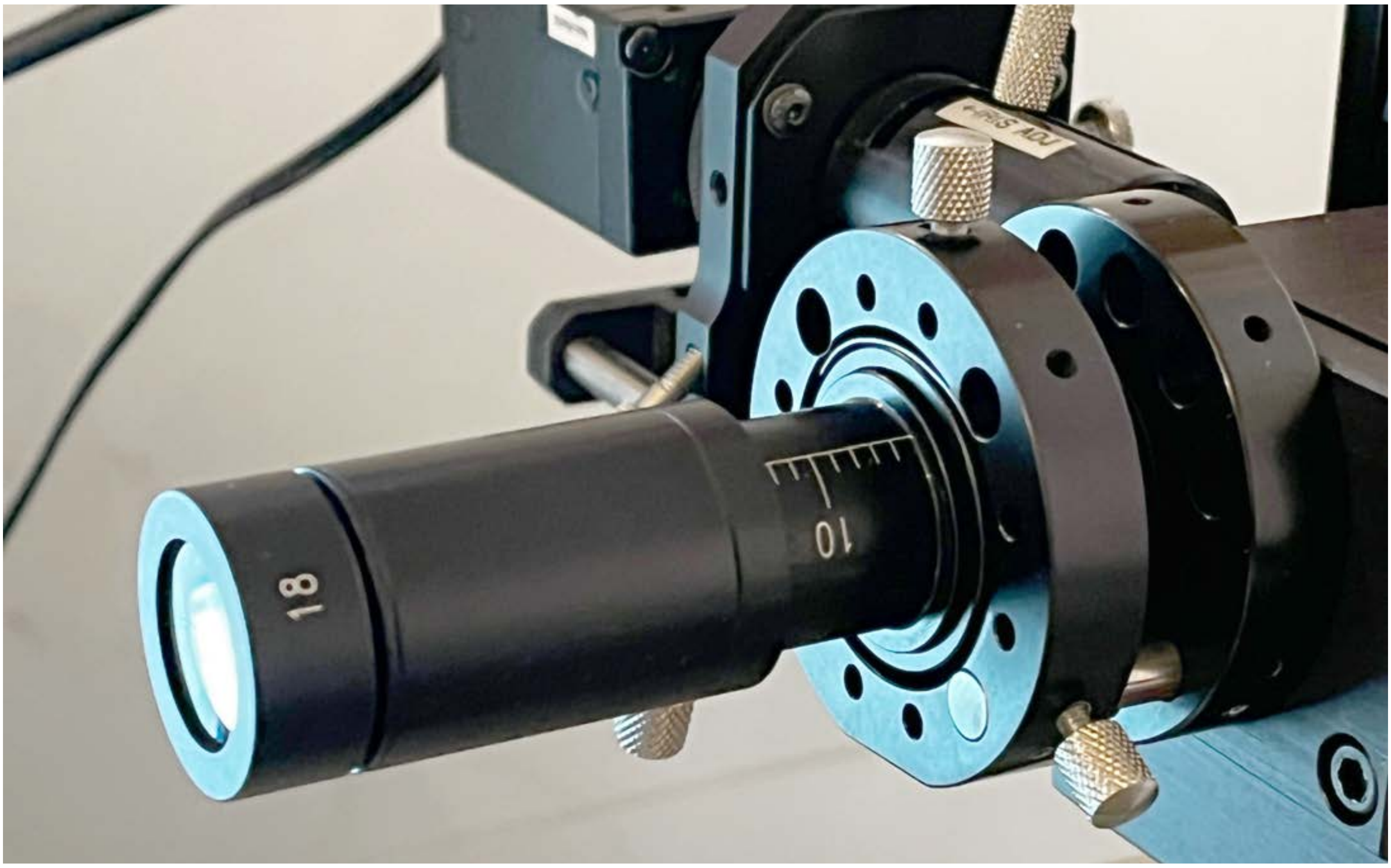
F = 50 BCX UV

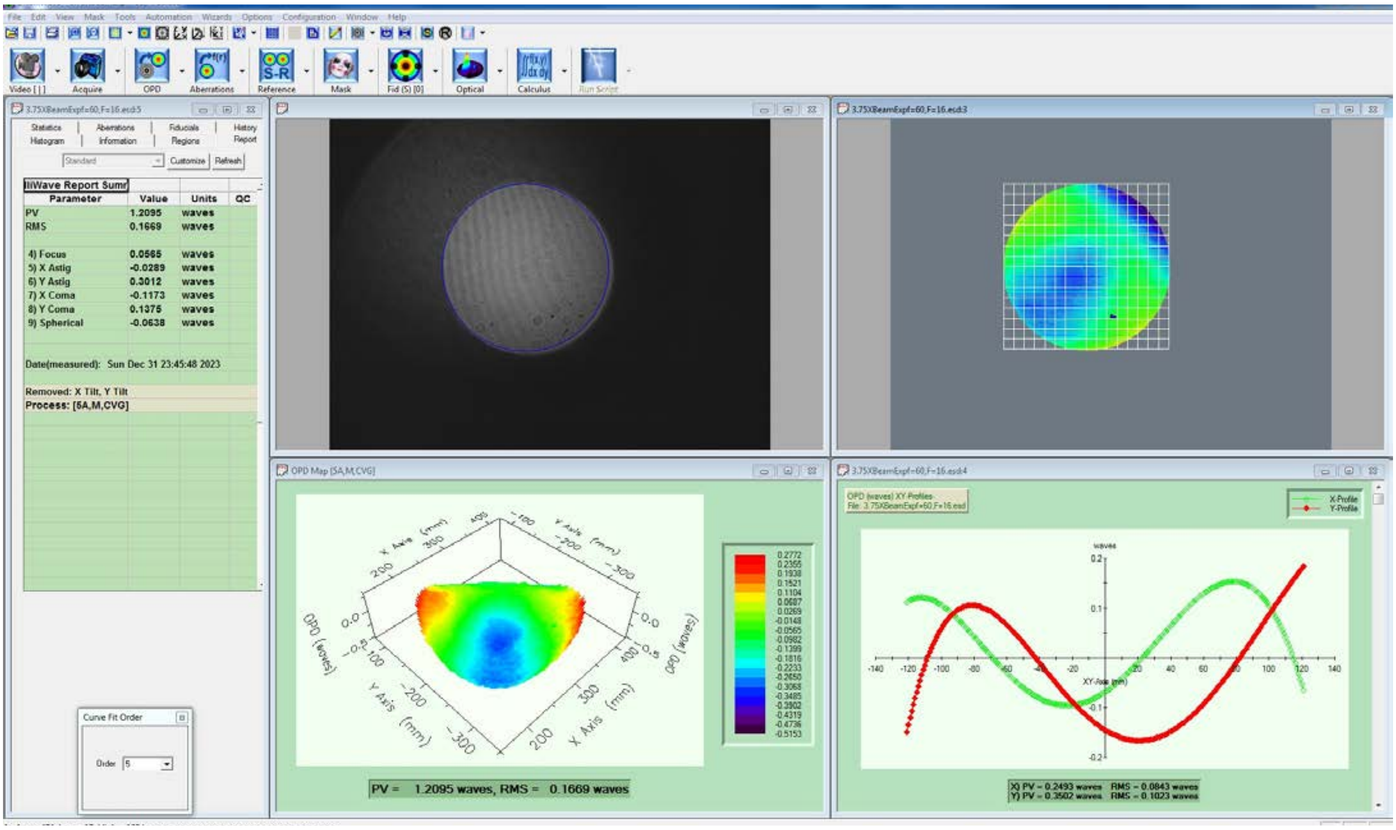
The f = 50 mm, CA = 21.4 mm Ø singlet lens test shows 11 waves field flatness. Wave length = 635 nm, Catalog N0. **20-120UV.** There looks to be an error in this setup.

Picking the Right Lenses to Build a Beam Expander

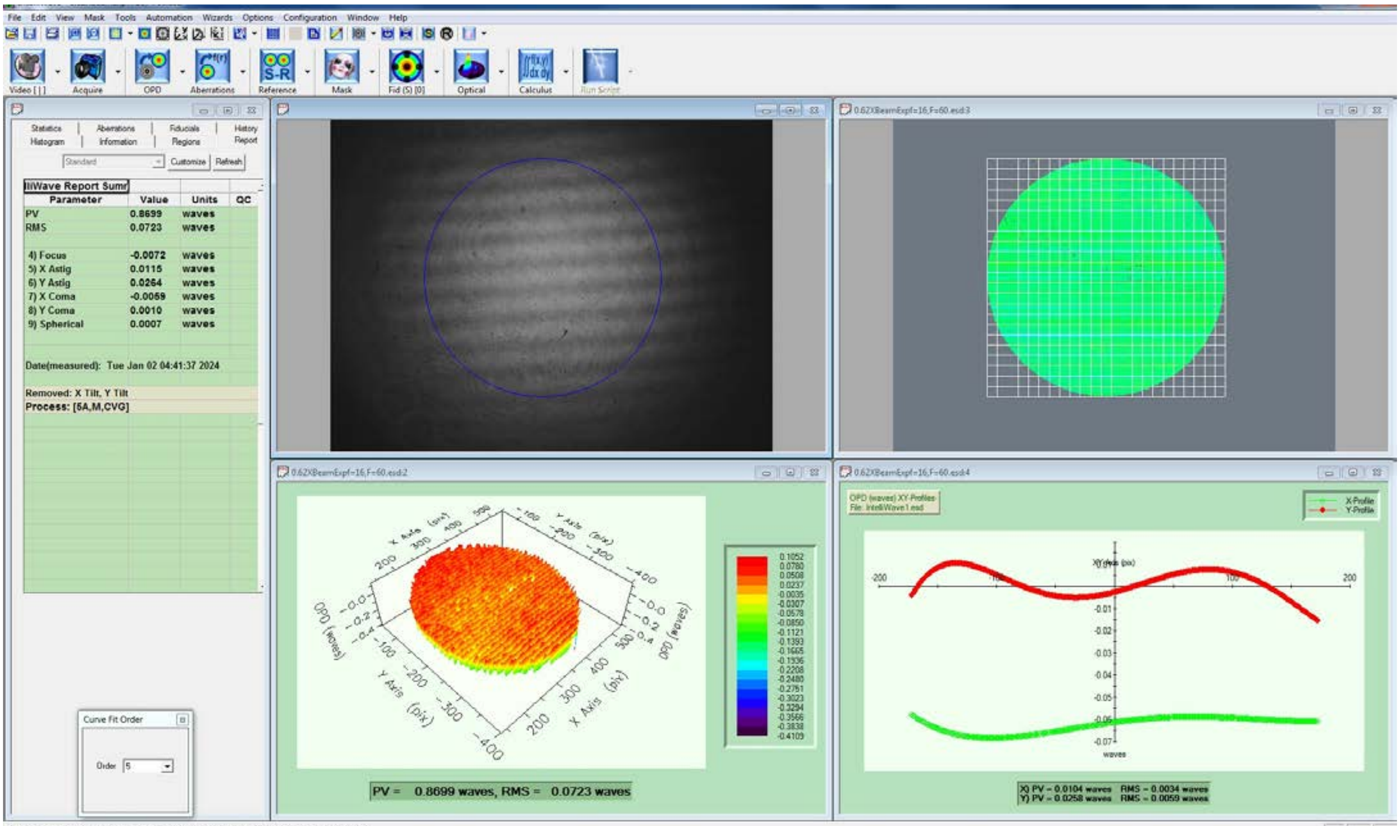
20-316 25-110 25-128 25-314 20-332

Above, the design can be built with Micromax 25 mounts: Reversing the beam expander optics above would create a beam reducer, and as you can see, a huge improvement on its wavefront flatness (opposite Page). One reason is the circular field of view of the beam expander (defined by F = 60 mm lens) is 21.4 mm whereas the field of view of the beam reducer (defined by F = 16 mm lens) is only 7 mm.



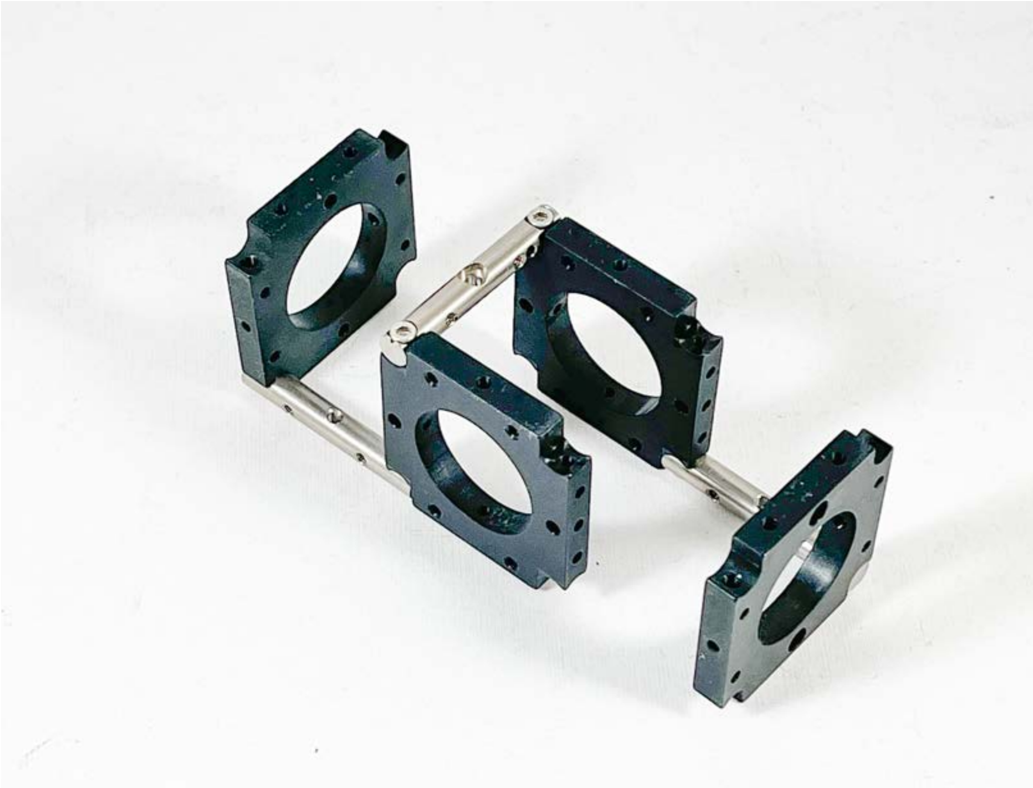


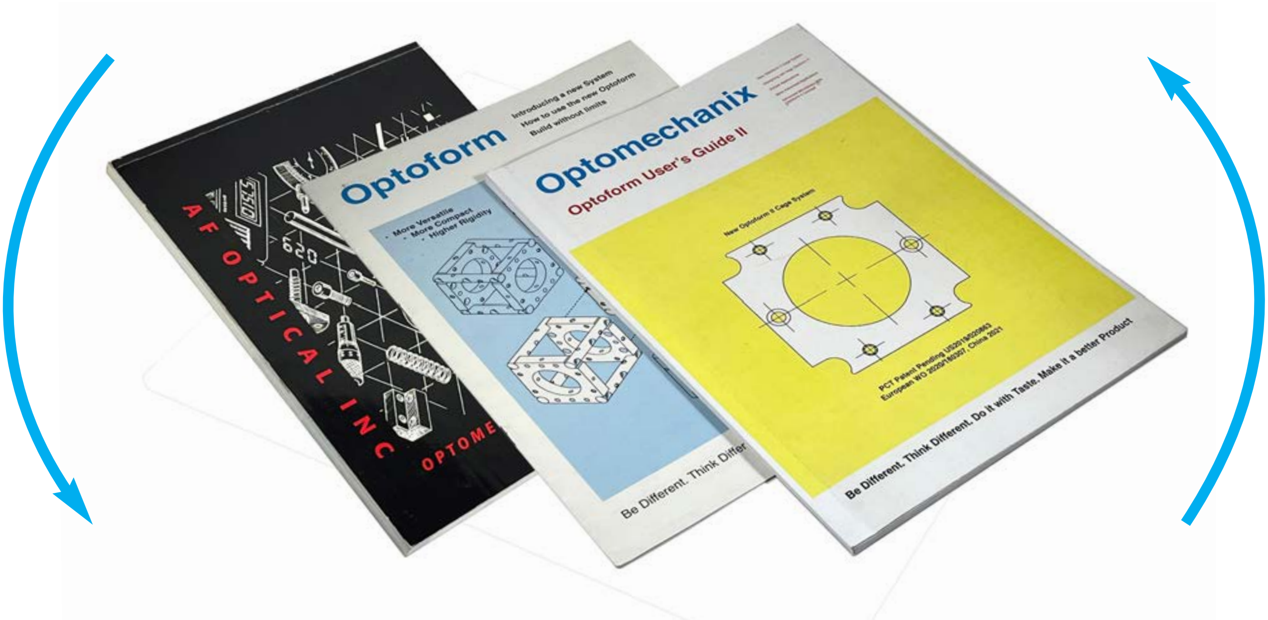
3.75X Beam Expander F = 16 mm + F = 60 mm



0.62X Beam Reducer F = 60 mm + F = 16 mm

The overall wavefront flatness of this design is 0.35 waves for the beam expander, and 0.05 waves for beam reducer. This is a lucky combination to achieve 1/20 wave performance out of the beam reducer we needed to inspect end of fiber polish. The only reason I could think of is the narrow field of view of the optics. You could get this performance from most of the optics tested here by narrowing their field of view to a small aperture.





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