Opto-Alignment Technology
Solutions for Optical Systems Manufacturing
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REDUCE COST OF OPTICS AND FINAL ASSEMBLY:

THE BENEFITS OF LASER-REFLECTION BASED ULTRA-PRECISION ACTIVE ALIGNMENT

By Steve Bohuczky and Sasha Perlman

Aligning and centering lenses for cementing or positioning in an optical system poses different challenges depending on the final precision requirements and the methods used during alignment. Desired quality, efficiency, cost of components and capital investment all play important roles in selecting the correct assembly method. The LASER ALIGNMENT AND ASSEMBLY STATION™ (LAS) is a dynamic laser reflection based, non-contact, real-time optical centration and angular measurement instrument, designed for aligning lenses in a multi-element optical system, such as a telescope, microscope objective or microlithography stepper. The LAS's optical module provides strong, clear reflections by which the user can easily measure and record sub-micron Total Indicated Runout (TIR) for spheric, aspheric, parabolic, cylindric, coated, or uncoated optics with radius of curvatures from 2.0mm to infinity, without changing objectives.

Transmission and Reflection Based Alignment:
Most optical labs are familiar with TRANSMISSION based alignment instruments, such as autocollimators, and alignment telescopes used for measuring parallelism and lens alignment. Autocollimators have been used in land surveying, for measuring slope and topography and in other industries for over sixty years. They are also valuable for taking optical alignment measurements but they have some limitations. First, their use is not effective on aspheric, cylindric and parabolic lenses. In contrast, dynamic laser reflection systems can be utilized on any optical surface. Second, autocollimator based aligners require frequent changing of objectives and investment into an expensive set of them. Standard autocollimators use low intensity white light sources that do not reflect well from most AR coated optics, especially from V-coatings. This can be improved somewhat by installing high energy halogen bulbs, but these generate heat and have short lives.

Autocollimator based systems may seem relatively inexpensive when considering a base unit but they require costly accessories and maintenance to perform more demanding tasks. Once they have been accessorized to a specific task, the cost is high and they still remain limited in performance. Most experts would agree that laser reflection combined with active alignment method is the most accurate way to align lenses, but before we review laser reflection in more detail let's understand the basics of active alignment.

The Benefits of Active Alignment and Design:

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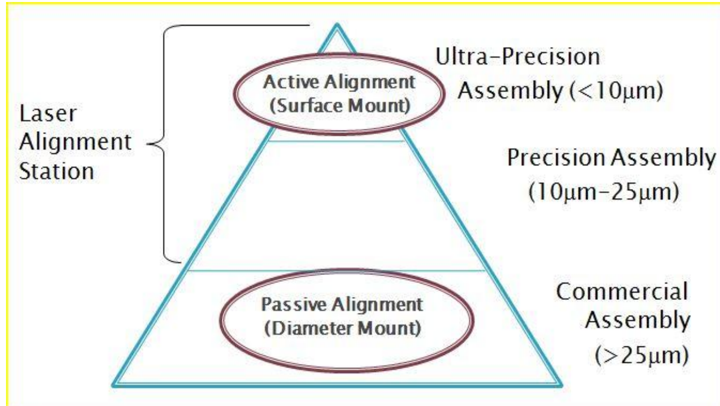
<td>Ultra precision active alignment references the spherical or rotationally symmetric surfaces of lens elements such that their radius or axes of curvatures are aligned to a mechanical or common axis to 0.2 - 10 µm TIR.

Precision and commercial grade assembly techniques usually rely on diameter mounting, requiring that the dimensions of the lens elements and hardware be machined very accurately, making components expensive. Despite accurate machining, differences in the coefficient of expansion of glasses vs. metals as well as clearances required to enable assembly mean that alignment accuracies are much poorer than with active alignment, usually in a range from10 to 25 microns TIR or even greater.</td>
<td>

TIR tolerances for high and lower grade optical systems</td>
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Diameter mounting requires a gap between the OD of the glass and the ID of the metal housing. This gap represents slop that the element is free to move within. This slop can easily be 10 µm or more and lead to 10 µm or more of wedge (TIR) between the two optical surfaces. Active alignment and potting allows a non-uniform gap around the element so any wedge in the element can be manifest as runout of the OD (which doesn't matter) instead of runout of the polished surface(s).

Comparison of Active and Passive Alignment

Active Alignment (Surface Mount)	Passive Alignment (Diameter Mount)
• Lower costs of optical and mechanical components and assemblies via: o More relaxed tolerances o Lower cost of quality via higher component and assembly yields	• Higher costs of optical and mechanical components, and assemblies via: o Tighter tolerances o Higher cost of quality via lower component and assembly yields
• Higher optical alignment accuracies o Active alignment is the only technique that can consistently meet the alignment tolerances for most precision and ultra precision systems.	• Lower optical alignment accuracies o For most precision and ultra precision optical systems, passive mounting techniques will simply not meet the required tolerances.
• Optical assemblies are relatively insensitive to environment conditions such as temperature change and mechanical shock, making active alignment appropriate for many high and ultra precision applications including: o Medical o Military o Airborne	• Optical assemblies are sensitive to environment conditions such as temperature change and mechanical shock *
• High degree of control over lens alignment accuracy during assembly o Optical alignment quality is under the control of the assembly technician during the assembly process.	• Almost no control over lens alignment accuracy during assembly o Assembly technician has little or no control over the optical alignment during the assembly process.

* (As you reduce the gap (slop) between the OD of the glass and the ID of the metal the assembly becomes more sensitive to temperature extremes. Both glass and metal will shrink as the temperature is lowered (to the low ship temperature, for example), but they shrink at different rates. The metal generally shrinks more than the glass so if the nominal gap isn't large enough the metal & glass will reach the same diameter at some temperature and the glass will start to be compressed as the temperature is lowered further. This is hoop stress. If it becomes too great, the glass will break. It's a fine line to walk between making a diameter mounted system a close fit so the alignment is good (the slop is low) and being too tight and making it hard to survive shipment. Potting glass into the metal housing minimizes this problem while still keeping the elements well aligned with the mechanical axis.)

Laser Reflection Method Developed by Opto-Alignment Technology

Active alignment combined with the Laser Reflection Method provides the optimum in ultra precision alignment.

In this Laser Reflection Method, lens elements are aligned by reflecting a laser beam from the top surface while the lens is resting on its bottom surface curvature. (The alignment of a bottom surface can also be verified using the reflected laser beam).

Industry experts agree that the laser REFLECTION method is the most accurate way to measure and align optical elements. This is why Opto-Alignment Technology developed its proprietary laser reflection based technology and has incorporated it in its Laser Alignment and Assembly Station™, satisfying the most demanding alignment applications.

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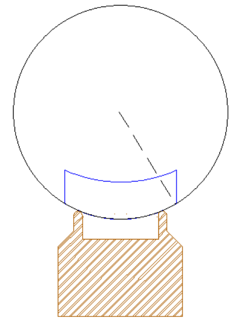
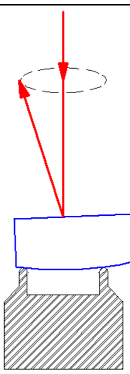




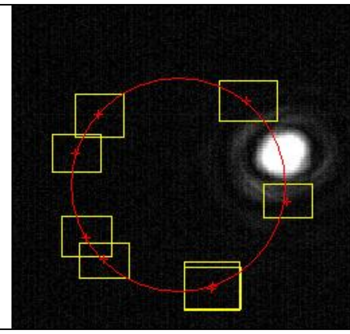
Opto-Alignment Technology Laser Alignment Systems
In response to the demands of customers manufacturing high precision night vision equipment, in 2009, OAT expanded the working wavelength of its LAS by developing mid and long IR (MWIR, LWIR) alignment systems. The modulated design of OAT's LAS allows for many different configurations, which can efficiently accommodate a variety of optical system manufacturing applications. Customers can choose from four wavelengths (532nm 633nm, MWIR and LWIR), five different air bearing diameters(4 to 12inch), each with x-y tip-tilt platform, vertical stages up to 36 inches, linear and angular encoders with manual or motorized operation with vibration controlled workstations. OAT provides an easy-to-use LAS module selection chart to facilitate choosing the best configuration. The LAS workstation can be ordered with vacuum lens pick-up tools (RotoWand™) to stack or inspect lenses from 1mm to 150mm diameter.

Common Mistakes Made in Accessorizing Alignment Systems:
If production time is critical some motorized linear movements and encoders are very useful. In conjunction with CalcuLens software the LAS's servo controlled active linear encoder is definitely a great accessory for establishing and recording the location of each lens surface on the Z-axis. The encoder improves repeatability and reduces cycle times. These are sufficient accessories for efficient precision alignment. Rotation of the air-bearing can be done efficiently by hand. If needed a rotary encoder may help establishing reference points, but not necessary.
Additional bench-top robotics that deliver bonding syringes, aligning pins and other tools to the lens assembly are not necessarily practical or cost effective investments for precision optical alignment. They require constant supervision and have limited intelligence with unreliable accuracy. And, the lenses still have to be loaded by hand by the operating technician. In the end, more equipment has to be maintained, production time and labor costs are not reduced. When used to produce low margin, commercial grade assemblies the return on investment is very long. When used to produce high cost assemblies, the risk of potential damage to the optics considerable.

Opto-Alignment Technology Alignment Software, Calculens™ :

Smart machines are all around us; almost every modern tool has microchips in it. For over eighteen years, Opto-Alignment's ongoing product improvement philosophy has been: submicron accuracy, repeatability, efficiency, operator safety, and high quality final products. The alignment software is an important element of that philosophy. LAS users can align, cement and bond lenses confidently with the user-friendly optical centration measurement software Calculens™ that is integrated into the turnkey LAS system. Simple to use. Practical. Reliable.

The 2009 update of Calculens™ 2.1 software introduced **automatic centroid detection** and tolerance zone marking, that improves speed and repeatability of TIR measuring.
For faster data input, the user can import ZEMAX® files into CalcuLens™.

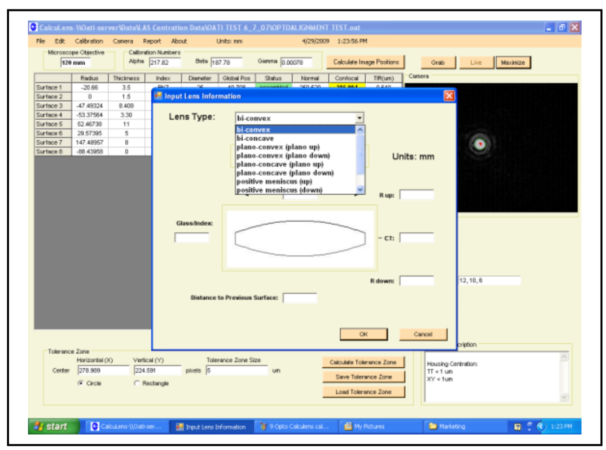


CalcuLens provides the user with non-contact and instant sub-micron measurements for any lens surface, including cylindrical, aspheric and parabolic lenses with coated or uncoated surfaces. It accommodates radius of curvatures from ±2.0mm to infinity. CalcuLens allows assembly personnel to download and forward alignment results to design or engineering personnel at any time during assembly. It comes with a customizable index of refraction library, converts between English, metric and ISO/DIN units and generates QA reports on demand.

Conversion from Linear to Angular TIR (per 100mm)

Linear (mm)	Linear (µm)	Angular
0.0005	0.5	1.031 arc sec.
0.001	1.0	2.062 arc sec.
0.002	2.0	4.125 arc sec.
0.005	5.0	10.313 arc sec.

Tgt⁻¹ [(½TIR) / (½Ø)]



Steve Bohuczky is Executive Director of Business Development, Sasha Pearlman is President and Founder of Opto-Alignment Technology. To sign up for our next precision alignment seminar please send your enquiry to the contact below.

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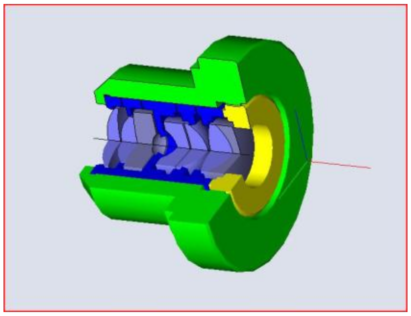

Opto-Alignment Technology is a leading manufacturer of optical alignment and assembly instruments for ultra precision optical systems manufacturing. Our products and services aid in the assembly, alignment, inspection, cleaning, and handling of precision optics.

Opto-Alignment Technology also offers high quality, precision alignment and assembly services of optical systems from UV to IR wavelengths. Assemblies produced by Opto-Alignment Technology include Doublets (Achromats), Triplets, & Quadruplets, Aerospace & Airborne optical systems, Telescopes & Vision applications, Microscope Objectives from UV to IR, Night Vision Goggles and Fire control Optics.

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