SPACE OPTICS RESEARCH LABS

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Introduction

Space Optics Research Labs (SORL) reflective on and off axis optics and telescope assemblies offer you, the user, unique advantages. We provide complete achromatic performance which can be configured in compact, portable, and versatile systems for use in a variety of optical test and instrumentation applications. Unlike refractive optics and systems which operate only over a relatively narrow spectral region, reflective optics and systems can be used at any wavelength, or at a number of wavelengths simultaneously, without need to realign or refocus.

Optics and Materials

We manufacture on and off axis mirrors and telescope components from a wide variety of substrates, including low expansion glass-ceramics, most glasses, copper, and electro-less nickel-plated aluminum. Our components are designed to meet customers and environmental requirements while maintaining high quality and reliability.

Optical Design, Manufacture and Test

Space Optics Research Labs capability in design, manufacture and test of reflective on and off axis optics and telescope systems is a direct result of our leadership position among manufacturers of aspheric mirror components. Aspherics are required in telescopes to achieve unobscured system performance in compact designs. Our advancements in computer-directed asphérizing techniques have strengthened Space Optics Research Labs capability to produce an outstanding variety of aspheric surface geometries and standard products. State-of-the-art laser unequal pathlength interferometer (LUPI) interferometric and phase contrast testing provides the clearest view of optical figuring accuracy, and insures that every component meets stringent manufacturing specifications.

Mechanical Design

In addition to the quality of individual components, final telescope system performance is highly dependent on accuracy of alignment, stability and integrity of components and housing design. Every Space Optics Research Labs telescope is aligned interferometrically insuring that optimal performance is obtained. Our experience and extreme attention to detail results in stable, rugged designs and stress-free mounting provisions to meet most challenging requirements.

IR Visible and UV

SORL supplies quality optical components with coatings for any desired wavelength range. We provide optics and systems for standard use and original equipment manufacturers (OEM). We satisfy prototype and test applications in aerospace, defense, and commercial optics industries, and in university, government, and private research institutions throughout the world. We manufacture axially-symetric and other mirrors from 1 centimeter to more than 1 meter in diameter, and off-axis segments up to 1 meter in diameter for UV-VIS-IR use.

SORL's Credentials

- Satisfied users world wide
- Reliability of systems presently in use at test sites
- Competent engineering staff to propose solutions and assure meeting specifications
- Skilled opticians and hand-crafted optics expertly blended with computer assisted fabrication
- Quality assurance program approved by demanding industrial and government facilities
- Dedicated customer service
- References upon request

Applications

- Unobscured collimation
- Laser beam expansion
- Collimation and point source detection
- Target projection and simulation
- Satellite and missile telemetry
- LIDAR and laser range finders
- Radiometry and spectrometry
- Laser beam diagnostics
- Forward Looking Infrared (FLIR) testing and calibration
- Multi-channel signal processing
- Autocollimation and system alignment
- Beam expansion, diagnostics, propagation, reduction and steering
- Boresighting and divergence measurement

Whether your requirement can be satisfied by one of Space Optics Research Labs standard products, or requires a specialized approach, we are ready to serve you.

Technical Considerations and Design Notes

On and off axis mirrors offer significant advantages over lenses in meeting critical design requirements in many applications.

Achromatic Performance: Using lenses, material-light interactions invariably result in absorption within certain spectral regions. Over a narrow operational wavelength region, optical performance can vary significantly. Mirrors are spectrally limited only by the properties of their reflective coatings. These consist of a metallic layer. One or more layers of a protective (or enhanced) dielectric are often added. Performance is then limited only by surface accuracy and component quality. Mirrors and coatings providing excellent performance throughout the UV visible and IR are readily available. Most mirrors and systems allow optical alignment in the visible range since no refractive issues exist.

Compact Designs: Mirror system designs can utilize a folded light path, thus producing a smaller overall package size than a lens system of similar focal length. Aspheric designs yield equivalent or better optical performance and are more compact.

High System Transmission: Mirror coatings are very efficient, typically providing average reflectance of 90% over the visible and 95% over the IR wavelengths, and in excess of 98% at selected wavelengths. Coatings are relatively inexpensive; surfaces are more accessible to inspection and easier to clean.

High Power Applications: Since little incident energy is absorbed at a mirror surface, very high energy density can be used. Absorbed energy can be dissipated through high thermal-conductivity materials, silicon, aluminum, and copper. Liquid cooling can be introduced in very high power applications.

Scattering/Surface Finish: Mirror systems have fewer optical surfaces, and internal defects in material are of less consequence. Thus, scatter is less than in lens systems.

Large Apertures: Homogeneity of refractive index and material impurities are major concerns when using lenses. These are very difficult to control in large apertures. Reflective components such as mirrors solve these problems.

Since optical properties of substrates are of less concern, many materials can be used to manufacture mirrors, including most glasses, and metals. For high optical performance, low thermal expansion glass-ceramic materials are recommended.

Light-Weight Designs: In large diameters, the weight of the optical components is critical. Thickness of a mirror blank is simply a function of the required structural stability. Techniques for light-weighting both metal and glass-ceramic mirrors are available.

In summary, in telescope and off axis designs, mirror systems can be more flexible and less expensive than equivalent lens systems. Mirror systems can greatly minimize or eliminate some of the classical problems — obstructed light paths, requirement for complex baffles and generally small, curved fields of view.

SORL'S Quality Assurance

Complete Quality Control: A critical factor in determining the capacity to produce quality optics systems and Optical Test Station (OTS) is the ability to test and to verify compliance. Space Optics Research Labs prides itself in maintaining one of the most stringent quality assurance programs in the optics industry. From incoming material inspection to packaging for customer shipment, Space Optics Research Labs maintains the highest quality standards to ensure that our optics, components and systems meet or exceed all specified parameters.

In-Process Inspection: Following initial material inspection, an Optical Component Record is initiated and maintained throughout manufacturing from rough grind through polishing and final quality assurance testing. During the polishing procedure, surface accuracy is constantly monitored and recorded using surface contour scanners and Space Optics Research Labs Laser Unequal Pathlength Interferometers (LUPI's) and phase shift techniques.

Final Inspection: Before and after the specified coating is applied, the optical component is subjected to a final quality inspection. Critical parameters are measured and recorded. Adherence to specifications is reflected in a Final Quality Assurance Report which can be supplied with the component or system. For complex components and systems, in house final acceptance can be witnessed by our customers prior to shipment.

Optical Test Systems: The performance of all optics incorporated within an Optical Test System — such as a Telescope Off-Axis Newtonian (TOAN) Collimator, and the total system performance are measured and documented.

Custom Systems: Customers requirements are jointly screened and outline drawings and performance specifications are developed. If contracted as the supplier, design proposals are submitted for customer approval before production. Final weight and size are constant considerations. Preliminary and final design reviews are conducted.

Ordering Information

Placing an Order

You may place your order by. . .

Phone: 978-250-8640
800-552-SORL (Toll Free USA)

Fax: 978-256-5605

Email: SORL@sorl.com

Mail: Space Optics Research Labs (SORL)
7 Stuart Road
Chelmsford, MA 01824

Written Confirmation Required

All phone orders should be followed by a hard copy, clearly identified as a confirmation. Mail or fax the confirming purchase order(s) to the Sales Department at the address or fax number above.

Necessary Information

For efficient order processing the following information is required:

Your Purchase Order Number: This number should be clearly identified on written orders. If your requisition and purchase order numbers are different and you wish to have them both referenced, include your requisition number in the shipping address as an attention line. Use a different purchase order for each order.

Billing Address: This address must include the name of the company and person paying the invoice and the department or mail stop to which the invoice should be addressed.

Shipping Address: This is the address of the end user of the equipment, and should identify the department, mail stop, and name of the requisitioner, if appropriate.

Name of Contact: Include the full name and phone number of the person to contact regarding your order.

Method of Shipment (U.S. and Canada): If a carrier is not identified, we will use our best judgement in routing shipments.

Quantity: Include the quantity and units of each item.

Model Number: If available, please include the order number.

Description: A brief description of each item helps ensure that you receive the correct equipment.

Prices and Terms

All prices are F.O.B. warehouse, with title passing at such point. Prices are subject to change without notice.

Quantity discounts are available on qualifying orders.

Domestic Orders: With approved credit, terms of payment are "Net 30 Days".

Export Orders: Irrevocable L/C drawn on an acceptable United States bank valid for at least 6 months from date of issue.

Quotes

We provide written quote valid for 60 days. Please contact the Sales Department.

Credit Card Orders

We accept American Express, Master Charge and Visa.

Technical Information

SORL sales engineers are available to answer your technical questions or to help you design a system to meet your needs.

Change Orders

Changes or cancellations should be phoned in and followed by a written confirmation. The original purchase order number and order date are needed.

We cannot accept return of custom orders. Canceled custom orders are subject to a cancellation fee which covers materials and work already expended by Space Optics Research Labs.

All change orders are subject to a restocking fee of 20%

Warranty and Returns

Warranty

Space Optics Research Labs (SORL) warrants that each item produced and sold shall be free from any defects in material and workmanship. Should Space Optics Research Labs determine in our sole discretion that a product, with exception to electronics, is defective within ONE YEAR from date of shipment, Space Optics Research Labs will correct, either by repair or, at its option, by replacement, any said product. Electronics shall be free from defect for a period of ninety (90) days from the date of shipment. This warranty is contingent only to those products that are defective through no fault of the customer. This warranty does not apply to products which have been subject to improper usage, cleaning, handling or storage. This warranty does not apply to products which have been modified without the approval of Space Optics Research Labs, which have been removed or altered. This warranty does not include nonstandard coatings. Our liability under this warranty shall in any case be limited to the invoice value of the product sold and in no event shall Space Optics Research Labs be liable for any special or consequential damages. We make no warranty as to the merchantability of any goods, or that they are fit for any particular purpose or end application, nor do we make any warranty, either expressed or implied, other than as stated above.

Returning Goods

Warranty Returns: Obtain a Return Material Authorization (RMA) Number from Space Optics Research Labs (SORL). To simplify the processing of your return, have the original purchase date, the original purchase order number, and the SORL job number available when calling for an RMA number. The RMA should appear on the outside of the package and on all documents and packing slips, etc. A description of the problem and / or repairs needed should be enclosed.

Non-Warranty Returns: Obtain a Job number from SORL.

A purchase order for defect evaluation in the amount of $250.00 has to be issued. This should be done before making the return or the purchase order must accompany the return.

After completion of the evaluation, SORL will provide a quotation detailing the cost of needed repairs and shipping. The evaluation charge will be credited against this amount.

When a Purchase Order for the amount quoted is received, work will commence.

Glossary

ATS — Alignment Telescope

AW — Aperture Wheel

BBS — Black Body Source

TC — Cassegrain Telescope

CH — Chopper

CMA — Camera and Monitor (LUPI)

COAR — Off-Axis Laser Beam Expander

EP — Extension Plate

FOV — Field of View

FL — Focal Length

FLIR — Forward Looking Infrared

FX — Fourier System

GBS — "Glow-Bar" Radiation Source or Gray Body Source

HQ — High Quality

IRTS — Infrared Test Station

LUPI — Laser Unequal Pathlength Interferometer

MMA — Precision Mirror Mount

MMOA — Precision Mirror Mount with Alignment Flat

MPL — Plano Mirror (Flat Mirror)

MSP — Spherical Mirror

OAP — Off-Axis Parabolic Mirror

OC — Optical Correlator

OTS — Optical Test Station

PA — Precision Aperture

PS — Phase Shifting (LUPI)

SA — Slit Aperture

SF — Spatial Filtering

SSF — Star Simulator

TAC — Autocollimator

TC — Cassegrain Telescope

TCOM — Compact Cassegrain Collimator

TDK — Focusing Dall-Kirkham Telescope

TDKA — Afocal Dall-Kirkham Telescope

TLB — Light Collecting Telescope

TN — Newtonian Telescope

TOAN — Telescope Off-Axis Newtonian

TRC — Ritchey-Chretien Telescope

TSS — Schwarzchild Reflecting Objective

VCHQ — Vacuum Collimator

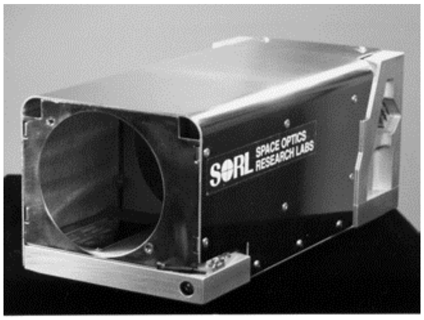
VF — Variable Focus

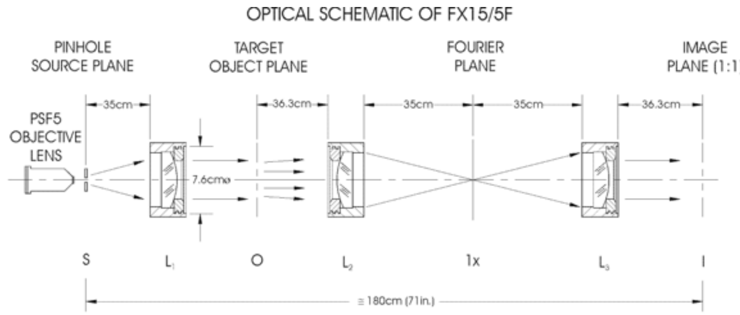
VMAG — Variable Magnification

WFOV — Wide Field of View

WHQ — Water-Cooled, High Quality

WVF — Water-Cooled Variable Focus





Our product line has Beam Expanders and Fourier Systems.

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SORL — outstanding expertise in optics

If we can help you, please contact us.

Call, Fax or Email. . .

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Email: SORL@sorl.com

STEVEN SEPVEST (Asian Market)
Phone: 703-209-2505
Fax: 703-891-9809
Email: sales@sepvest.com

Visit our Web Sites. . .

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SEPVEST
http://sepvest.com/Products/SORL.htm

Parabolic and Other Mirror Optics

SORL

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Aspheres for Unobstructed Beams

SORL has long recognized the advantages of compactness, quality and performance offered by aspheric components. For the last 25 years we have been working to improve our capability in designing, fabricating, and testing aspherics. Today we are acknowledged among the leaders in aspheric manufacturing technology, and are helping more of our customers to realize the full potential of their optical systems. Progress in the use of computer-directed aspherizing techniques has greatly strengthened and extended our capabilities, while helping us to hold the line on costs.

SORL doesn't just claim quality — with our modern testing facilities we prove it. Laser Unequal Path Interferometers (LUPI's) are used exclusively throughout the critical final production and quality assurance stages, assuring accurate figuring and a clear view of the final mirror surface. Surface accuracies to $\lambda/16$ at λ =0.6328 µ can be supplied. Our ability to produce quality spherical and flat mirror surfaces has grown as well. SORL can produce your desired surface on a wide variety of substrates, including most glasses, and metals such as nickel-plated aluminum and copper.

The end result to our customers is quality, reliability, and proof of compliance, as well as professional expertise and a unique capability to adapt and service your needs.

SORL supplies quality optical components and systems to the Commercial Optics, Aerospace and Defense industries. University, Government, and Research Institutions throughout the world use SORL optics for a variety of standard, OEM, and prototype applications.

Parabolic Mirrors

One of the best recognized aspheric surface geometries, the parabola, is most frequently used in collimation or target simulation applications.

Theoretically, concave parabolic surfaces focus incident collimated light, parallel to the axis of revolution (or light from an infinitely distant point source), to a perfectly corrected point image along that axis. Conversely, concave parabolic surfaces will form a highly collimated beam of light from a point source placed at the focus position. Concave spherical surfaces operate in a similar manner, but do not form perfect point images in collimated light, and therefore cannot form perfect collimated beams from a point source. Used as collimators, spherical mirrors limit the accuracy of the optical system.

As is the case with all reflective surfaces, performance is completely achromatic, and thus can be used at any wavelength without realigning or refocusing. This is an advantage over single component refractive systems that collimate only a narrow spectral range. Using an off-axis segment of a parabolic mirror offers the advantages of an unobstructed aperture and an easily accessible focus position.

Optical systems designed to contain parabolas collect images and detect point sources. They are ideally suited as collimators, or "Target Simulators". They serve to conveniently test system performance in the laboratory, and offer unparalleled accuracy, versatility, and economy.

Off-Axis Parabolic Mirrors (OAP)

In addition to the OAP's listed, SORL maintains an inventory of parent mirror blanks of varying focal lengths and diameters. Prices for special mirrors vary with angular portion of parent mirror subtended and surface accuracy required.

In the case of non-standards, it is generally necessary to manufacture the entire rotationally symmetric parent mirror to meet custom requirements. This approach is considered most cost effective in quantity orders. Requirements for parent mirrors up to 39.4 inches (1 meter) in diameter and f/numbers faster than f/1 can be accommodated.

Custom off-axis mirror requirements can be met via manufactured "Stand-Alones," allowing flexibility in off-axis distance and mirror diameter, to a maximum distance of 28 inches (700 mm) from true parabolic vertex to the outer edge. SORL's capability includes "Off-Aperture" mirrors, where the parabolic vertex lies slightly inside the mirror's edge. This can be a desirable feature for alignment purposes, made cost-effective by the "Stand-alone" manufacturing process.

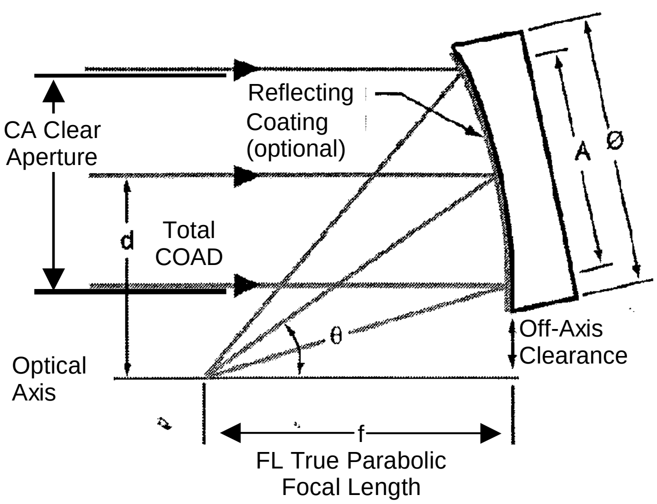
Off-Axis Parabolic Mirrors (OAP)

Standard mirrors are listed on the following pages. SORL has a considerable selection of off-axis and other versions that may prove suitable for your intended designs and systems.

Specifying an Off-Axis Parabolic Mirror (OAP) *(Also see the note and drawing below and on page 5.)*

Since not all our standard mirrors may fit a given application, we also supply custom made versions. When describing a custom made off-axis parabolic mirror, the following parameters should be specified.

1. **Material:** Zerodur® Zero thermal-expansion glass-ceramic is the most stable material and is our standard. Alternatives include Fused Silica, ULE glasses, conventional metals, and light weight substrates.
2. **Focal Length:** True parabolic or vertex focal length, measured along optical axis from the vertex to the focus should be specified. The apparent focal length, measured from the mirror center to the focal point, may also be specified if desired. (See note and drawing below.)
3. **Off-Axis Distance:** Specified along a perpendicular from optical axis to inner edge of mirror.
4. **Outer Diameter:** Size of mirror to outer edge, compatible with physical requirements.
5. **Clear Aperture:** The optically qualified and utilized area of the mirror surface.
6. **Edge Thickness:** To insure structural stability, a mirror will typically be made from a blank having a 6:1 diameter-to-thickness ratio. For stand-alone mirrors, this is approximately correct. Off-axis parabolic mirrors sectioned from a larger diameter parent mirror may be thicker.
7. **Optical Performance:** **Surface Accuracy** - Deviation from perfect parabolic shape can be specified in any unit used for the measurement of length. The wave-length of helium-neon laser light (typically 0.6328 μ) is most commonly employed in the optics industry.



NOTE:

Two quantities are usually given: (1) A "peak-to-peak" (peak-to-valley) value, specified in multiples (fractions) of the test wavelength, limiting maximum departure from true parabolic surface; and (2) A "slope error" figure (θ), measured in fractions of the test wavelengths per inch. Due to reflection at the surface, the interferometrically observed wavefront error is seen as twice the actual surface error for either "peak-to-peak" or "slope error" values.

Mirrors specified by surface accuracy must be measured interferometrically to guarantee compliance.

8. **Surface Quality of Finish:** A measure of the optical polish, specified by "scratch/dig" values denoting surface imperfections, as defined by Military specifications, MIL-M-13508C. Typical specifications:

Scratch/Dig: 80/50 Commercial or, standard IR quality
60/40 More optimum, visible region
40/20 Visible laser applications
20/10 High power laser and UV (VUV) components

9. **Optical Coatings:** May be selected from a variety of metals that can be evaporated and dielectric materials. Considerations include optimal performance in a wavelength region of interest, optical power level, and environment of intended operation.
   - Aluminum Silicon Oxide (AlSiO) is a most durable coating and has high reflectivity from Visible through the IR
   - Enhanced aluminum (Al) has higher average reflectivity, but is less durable
   - Enhanced silver (Ag) is better for higher power and has higher average reflectivity from visible through the IR, but is also less durable
   - Gold (Au) for IR and VUV. Also platinum (Pt); OSMIUM (Os); lawrencium Lr; tungsten (W)
   - Aluminum with magnesium fluoride (Al/Mgf2) overcoat for UV applications (see coating section)

We will help customers develop specifications from the following basic requirements:

- What size the collimated beam should have. This is given as CA (clear aperture)
- What apparent FL (Focal Length) you require. Focal length influences the F/number.
- In addition state desired angle μ or COAD (centric off axis distance).

Note that the D (diameter) normally exceeds the diameter of the CA (clear aperture). Since space for mirror mounting, etc., has to be provided, our listing of standard mirrors shows the typical oversize for given CA (clear aperture). Please do not hesitate to call with any questions. (see also page 5 drawing)

Ordering Information Example:

100 inch focal length

2.0 inch off-axis distanc

Off-Axis Parabolic Mirror

12 inch diam.

Order Number: OAP-100-02-12-Q

Standard OAP Features:
High Quality, λ/8 surface accuracy @ 0.63 μ, AlSiO coating,
Interferograms and data analysis supplied on request.

Standard Off-Axis Parabolic Mirrors

The off-axis parabolic mirror charts list SORL's broad range of standard OAPs. SORL meets both standard and specialized specifications. SORL's technical team is always available to provide assistance.

Our standard Off-Axis Parabolic Mirrors offer:

- Wide selection of focal lengths, diameters, and off-axis distances
- Zerodur®, a precision, low thermal-expansion glass-ceramic material for long term reliability and stability in performance
- High quality λ/8 surface accuracy best performance for IR, visible and UV applications.
- Highly reflective AlSiO coating is standard. Other coatings for high durability and UV through IR performance are available. (see coating section)

Quality Assurance

- Accurate measurements of all critical dimensions and param-eters
- Test and alignment procedures furnished if ordered with mount
- Interferograms and data analysis supplied on request

Order Number	Focal Length				Off-Axis Distance			Mirror Diameter		Clear Aperture		Outer Edge Thickness*		Optical Performance		Parent Mirror Usable Diameter	
	True Parabolic		Apparent		Inner Edge		Angle to Center							Standard Quality	High Quality "-Q"		
	in	mm	in	mm	in	mm	degree	in	mm	in	mm	in	mm	millirad.	Surface Accuracy	in	mm
OAP-100-04-24	100	2540	100.6	2555	4.0	102	9.1	24.0	610	23.5	597	4.00	102	…	λ/8	Stand Alone	
OAP-100-02-16	100	2540	100.3	2540	2.0	51	5.7	16.0	406	15.5	394	2.70	69	…	λ/8	Stand Alone	
OAP-100-16-16	100	2540	101.4	2565	16.0	406	13.7	16.0	406	15.5	394	2.70	69	…	λ/8	Stand Alone	
OAP-100-02-14	100	2540	100.2	2544	2.0	51	5.2	14.0	356	13.5	343	2.35	60	…	λ/8	Stand Alone	
OAP-100-02-12	100	2540	100.2	2544	2.0	51	4.6	12.0	305	11.5	292	2.00	51	…	λ/8	Stand Alone	
OAP-100-04-10	100	2540	100.2	2544	4.0	102	5.2	10.0	254	9.8	249	3.00	76	…	λ/8	28.0	711
OAP-100-02-10	100	2540	100.1	2543	2.0	51	4.0	10.0	254	9.6	244	1.67	42	…	λ/8	Stand Alone	
OAP-100-02-08	100	2540	100.1	2543	2.0	51	3.4	8.0	204	7.9	201	2.05	52	…	λ/8	24.0	610
OAP-100-04-08	100	2540	100.2	2544	4.0	102	4.6	8.0	204	7.9	201	2.16	55	…	λ/8	24.0	610
OAP-100-06-08	100	2540	100.3	2548	6.0	153	5.7.	8.0	204	7.9	201	2.96	75	…	λ/8	28.0	711
OAP-100-08-06	100	2540	100.3	2548	8.0	204	6.3	6.0	153	5.9	150	2.96	75	…	λ/8	28.0	711
OAP-100-06-06	100	2540	100.2	2544	6.0	153	5.2	6.0	153	5.9	150	2.16	55	…	λ/8	24.0	610
																Stand Alone	
OAP-80-02-12	80	2032	80.2	2037	2.0	51	5.8	12.0	305	11.8	300	3.00	76	…	λ/8	28.0	711
OAP-80-04-10	80	2032	80.3	2040	4.0	102	6.4	10.0	254	9.8	249	3.00	76	…	λ/8	28.0	711
OAP-80-02-10	80	2032	80.2	2037	2.0	51	5.0	10.0	254	9.8	249	2.20	56	…	λ/8	24.0	610
OAP-80-06-08	80	2032	80.3	2040	6.0	153	7.2	8.0	204	7.9	201	3.00	76	…	λ/8	28.0	711
OAP-80-04-08	80	2032	80.2	2037	4.0	102	5.7	8.0	204	7.9	201	2.20	56	…	λ/8	24.0	610
OAP-80-08-06	80	2032	80.4	2042	8.0	204	7.9	6.0	153	5.9	150	3.00	76	…	λ/8	28.0	711
OAP-80-04-06	80	2032	80.3	2040	6.0	153	6.4	6.0	153	5.9	150	2.16	55	…	λ/8	24.0	610
OAP-80-06-06	80	2032	80.3	2040	6.0	153	6.4	6.0	153	5.9	150	2.20	56	…	λ/8	24.0	610
OAP-80-08-04	80	2032	80.3	2040	8.0	204	7.1	4.0	102	3.9	99	2.20	56	…	λ/8	24.0	610

Order Number	Focal Length				Off-Axis Distance			Mirror Diameter		Clear Aperture		Outer Edge Thickness*		Optical Performance		Parent Mirror Usable Diameter	
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OAP-60-02-16	60	1524	60.4	1534	2.0	51	9.5	16.0	406	15.5	394	2.70	69	…	λ/8	Stand Alone	
OAP-60-02-12	60	1524	60.3	1532	2.0	51	7.6	12.0	305	11.5	292	2.00	51	…	λ/8	Stand Alone	
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OAP-60-06-08	60	1524	60.4	1534	6.0	153	9.5	8.0	204	7.9	201	2.94	75	…	λ/8	28.0	711
OAP-60-04-08	60	1524	60.3	1532	4.0	102	7.6	8.0	204	7.9	201	2.05	52	…	λ/8	24.0	610
OAP-60-08-06	60	1524	60.5	1537	8.0	204	10.5	6.0	153	5.9	150	2.94	75	…	λ/8	28.0	711
OAP-60-06-06	60	1524	60.3	1532	6.0	153	8.6	6.0	153	5.9	150	2.05	52	…	λ/8	24.0	610
OAP-60-04-06	60	1524	60.2	1529	4.0	102	6.7	6.0	153	5.9	150	1.87	47	…	λ/8	24.0	610
OAP-60-08-04	60	1524	60.4	1534	8.0	204	9.5	4.0	102	3.9	99	2.05	52	…	λ/8	24.0	610
OAP-60-10-04	60	1524	60.6	1539	10.0	254	11.4	4.0	102	3.9	99	2.94	75	…	λ/8	28.0	711
							11.4										
OAP-40-04-10	40	1016	40.5	1029	4.0	102	12.8	10.0	254	9.8	249	3.21	82	0.1	λ/8	28.0	711
OAP-40-06-08	40	1016	40.6	1031	6.0	153	14.3	8.0	204	7.9	201	3.21	82	0.1	λ/8	28.0	711
OAP-40-015-08	40	1016	40.2	1021	1.5	38	7.9	8.0	204	7.9	201	1.94	49	0.1	λ/8	19.0	483
OAP-40-08-06	40	1016	40.8	1036	8.0	203	15.7	6.0	152	5.9	150	3.21	82	0.1	λ/8	19.0	483
OAP-40-035-06	40	1016	40.3	1024	3.5	89	9.3	6.0	152	5.9	150	1.94	49	0.1	λ/8	19.0	483
OAP-40-055-04	40	1016	40.4	1026	5.5	140	10.7	4.0	102	3.9	99	1.94	49	0.1	λ/8	19.0	483
OAP-40-075-02	40	1016	40.5	1029	7.5	191	12.1	2.0	51	1.9	48	1.94	49	0.1	λ/8	19.0	483
OAP-40-025-02	40	1016	40.1	1019	2.5	64	5.0	2.0	51	1.9	48	1.51	38	0.1	λ/8	19.0	483
							13.3										
OAP-30-04-08	30	762	30.5	775	4.0	102	15.2	8.0	203	7.9	201	2.90	74	0.1	λ/8	24.0	61.0
OAP-30-015-08	30	762	30.3	770	1.5	38	10.5	8.0	203	7.9	201	1.82	56	0.1	λ/8	19.0	483
OAP-30-035-06	30	762	30.4	772	3.5	89	12.4	6.0	152	5.9	150	1.82	56	0.1	λ/8	19.0	483
OAP-30-055-04	30	762	30.5	775	5.5	140	14.3	4.0	102	3.9	99	1.82	56	0.1	λ/8	19.0	483
OAP-30-075-02	30	762	30.6	777	7.5	191	16.1	2.0	51	1.9	49	1.82	56	0.1	λ/8	19.0	483
OAP-30-025-02	30	762	30.1	765	2.5	64	6.7	2.0	51	1.9	49	1.41	36			19.0	48.3
							12.6										
OAP-25-035-06	25	635	25.4	645	3.5	89	14.8	6.0	152	5.9	150	1.90	56	0.1	λ/8	19.0	483
OAP-25-055-04	25	635	25.6	650	5.5	140	17.1	4.0	102	3.9	99	1.90	56	0.1	λ/8	19.0	483
OAP-25-075-02	25	635	25.7	653	7.5	191	19.3	2.0	51	1.9	49	1.90	56	0.1	λ/8	19.0	483
OAP-25-025-02	25	635	25.1	638	2.5	64	8.0	2.0	51	1.9	49	1.33	34	0.1		19.0	283
							8.6										
OAP-20-02-03	20	508	20.2	513	2.0	51	10.0	3.0	76	2.9	74	1.28	33	0.1	λ/8	10.0	25.4
OAP-20-03-02	20	508	20.2	513	3.0	76	11.4	2.0	51	1.9	49	1.28	33	0.1	λ/8	10.0	25.4

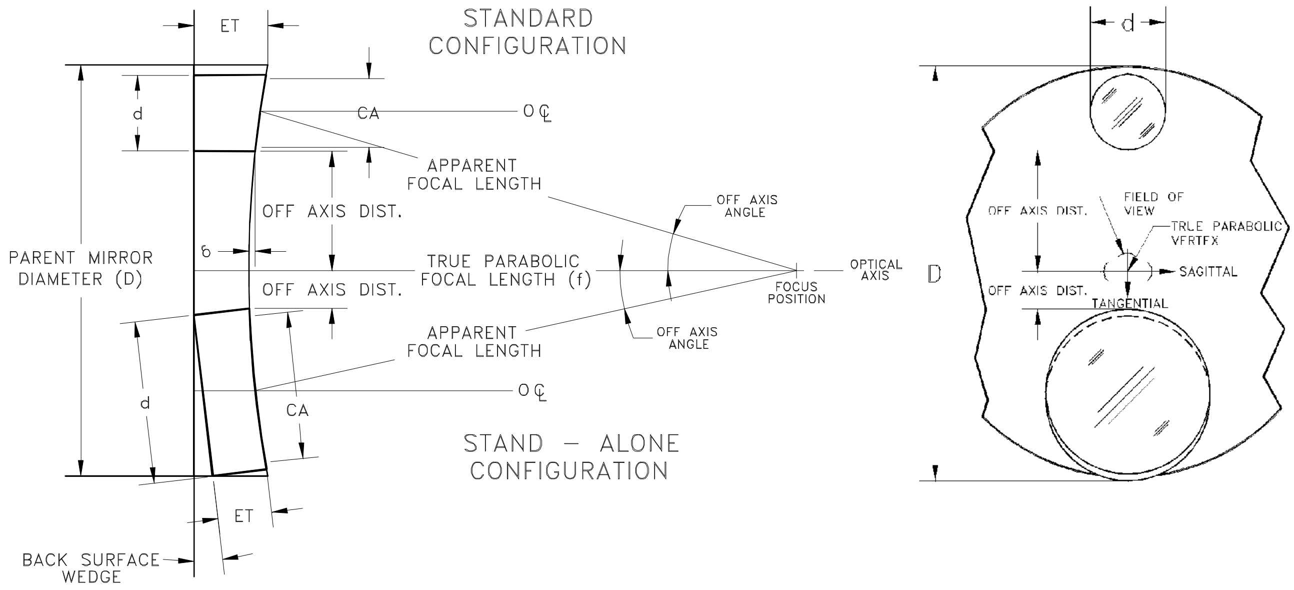
Order Number	Focal Length: True Parabolic		Focal Length: Apparent		Off-Axis Distance: Inner Edge		Off-Axis Distance: Angle to Center	Mirror Diameter		Clear Aperture		Outer Edge Thickness*		Optical Performance: Standard Quality	Optical Performance: High Quality "-Q"	Parent Mirror Usable Diameter	
	in	mm	in	mm	in	cm	degree	in	mm	in	mm	in	mm	millirad.	Surface Accuracy	in	mm
OAP-18-01-08	18	457	18.4	467	1.0	25	15.8	8.0	204	7.9	201	2.00	51	0.1	$\lambda/8$	18.0	457
OAP-18-03-06	18	457	18.5	470	3.0	76	18.9	6.0	152	5.9	150	2.00	51	0.1	$\lambda/8$	18.0	457
OAP-18-05-04	18	457	18.7	475	5.0	127	22.00	4.0	102	3.9	99	2.00	51	0.1	$\lambda/8$	18.0	457
OAP-18-06-03	18	45	18.8	478	6.0	153	23.5	3.0	76	2.9	74	2.01	51	0.1	$\lambda/8$	18.0	457
OAP-18-07-02	18	457	18.9	480	7.0	178	25.1	2.0	51	1.9	48	2.00	51	0.1	$\lambda/8$	18.0	457
OAP-12-017-04	12	305	12.3	312	1.7	43	17.5	4.0	102	3.9	99	1.88	48	0.1	$\lambda/8$	11.4	305
OAP-12-027-03	12	305	12.4	315	2.7	69	19.9	3.0	76	2.9	74	1.88	48	0.1	$\lambda/8$	11.4	305
OAP-12-037-02	12	305	12.5	318	3.7	94	22.2	2.0	51	1.9	48	1.88	48	0.1	$\lambda/8$	11.4	305
OAP-12-047-01	12	305	12.6	320	4.7	119	24.5	1.0	25	0.9	23	1.88	48	0.1	$\lambda/8$	11.4	305
OAP-06-02-03	6	152	6.5	165	2.0	51	32.5	3.0	76	2.9	74	1.66	41	0.2	$\lambda/5$	10.0	254
OAP-06-03-02	6	152	6.7	170	3.0	76	36.9	2.0	51	1.9	4.9	1.66	41	0.2	$\lambda/5$	10.0	254
OAP-06-04-01	6	152	6.8	173	4.0	102	41.1	1.0	25	0.9	2.3	1.66	41	0.2	$\lambda/5$	10.0	254
OAP-04-015-02	4	102	4.4	112	1.5	38	34.7	2.0	51	1.9	48	1.27	32	0.2	$\lambda/5$	7.0	178
OAP-04-025-01	4	102	4.6	117	2.5	64	41.1	1.0	25	0.9	23	1.27	32	0.2	$\lambda/5$	7.5	178
OAP-03-015-01	3	76	3.3	84	1.5	38	36.9	1.0	25	0.9	23	1.10	27	0.2	$\lambda/5$	5.0	127

Manufacturing Tolerances

- **Focal Length:** ±0.5%
- **Diameter:** +0.000" -0.010"
- **Off-Axis Distance:**
  ±0.02"(standard configuration)
  ±0.125" (stand-alone configuration)
- **Edge Thickness:**
  ±0.05" (12" focal length or less)
  ±0.10" (18" focal length or greater)
- **Surface Quality:** 60/40 (standard)

Surface Quality or Finish: A measure of the optical polish, specified by "scratch/dig" values denoting surface imperfections, as defined by Military Specifications, MIL-0-1383.

Scratch/Dig:
80/50 IR quality
60/40 Visible to IR (near UV)
40/20 UV to Visible Laser
20/10 UV and High Power Laser
Please note that 60/40 is standard for cataloged items.



NOTE: *What is a "Stand Alone" Aspheric Mirror?* If a rotationally symmetric "parent" cannot be manufactured because of size or material availability the aspheric section required has to be made as a sectional component. Asphericizing such Stand Alone components means the center point of an assumed sufficiently large rotational symmetric mirror has to be precisely simulated to assure the accuracy of the Stand Alone asphere. Shaping and precisely polishing such aspheres is a SORL specialty. SORL's precision of such difficult components is world famous.

- **Surface Accuracy:** Specified over 90% of the clear aperture area. (Typical Test Wavelength 0.6328 microns.) Deviation from perfect paraboloidal shape, specified as "peak to peak" (peak-to-valley) value in fractions of the interferometric test wavelength 0.6328 microns. Due to retro reflection at the surface, the interferometrically observable wavefront error is seen as twice the surface error. Therefore, the surface has twice the accuracy than interferometrically seen.

NOTE:

If you order by Order Number, you will receive an off-axis parabolic mirror with a surface accuracy of λ /8 or better.

The mirror will have an AlSiO coating for good reflectivity in the near IR and visible spectrum. For other coatings and wavelength ranges, consult page 13 and specify when ordering. Costs may differ from price list values.

Edge Thickness (ET): A mirror will typically be made from a blank having a 6:1 diameter-to-thickness ratio. For stand-alone mirrors, this is approximately correct. Standard OAPs sectioned from a larger diameter parent will be thicker. Edge thickness is given as reference only. Please clarify when ordering

On-Axis Parabolic Mirrors

Space Optics Research Labs (SORL) offers a complete manufacturing and test capability to produce on-axis mirrors up to 39.4 inches (1 meter) in diameter. Every requirement is handled on an individual basis and units are manufactured to customer specifications and supplied with or without center holes. Interferometric qualification of surface accuracy can be provided.

Focal lengths of 3 in (76 mm) to 100 in (2540 mm), as listed in the OAP section, will be quoted without extra tooling charge.

Spherical Mirrors (MSP)

Concave spherical mirrors are available with surface accuracies of $\lambda/10$ P-V at 0.6328 μ for use in the UV Visible and IR range. Accuracies to $\lambda/20$ P-V at 0.6328 μ are attainable for UV and applications such as Schlieren Photography.

- Radii (Rc) from 1 to 200 inches (25 to 5000 mm)
- Diameters to 1 meter
- Surface finish: 60/40 (others on request)
- Substrate: Zerodur® Zero-Expansion Glass-Ceramic and others
- Standard Coating: Aluminum silicon oxide (AlSiO) Other coatings, i.e., gold (Au) or aluminum with magnesium fluoride (Al/MgF2) available.
- Precision Mirror Mounts (optional)
- Applications: Light Collection
  Illumination
  Imaging

NOTE: For mounting see precision mirror mounts.

Ordering Information Example:

120 inch radius of curvature (Rc) (Customer insert desired radius when requesting price or ordering.)

Spherical Mirror

12 inch diameter

Order Number: MSP-120-12

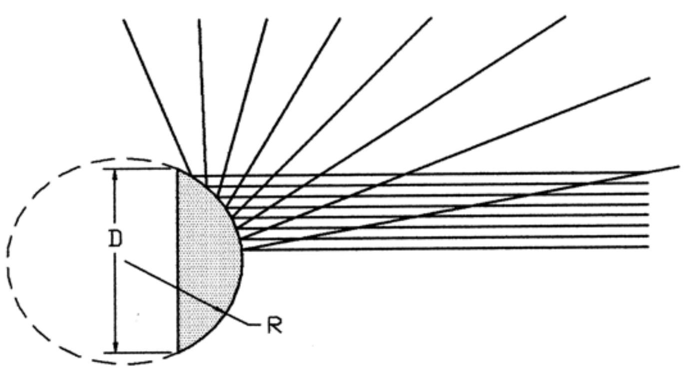
Standard Spherical Mirrors (MSP)

Order Number	Mirror Diameter		Clear Aperture		Edge Thickness	
	in	mm	in	mm	in	mm
MSP-Rc-10	10.0	254	9.7	246	1.67	42.4
MSP-Rc-12	12.00	305	11.5	292	2.00	50.8
MSP-Rc-16	16.0	406	15.5	394	2.67	67.8
MSP-Rc-18	18.0	457	17.5	444	3.00	76.2
MSP-Rc-20	20.0	508	19.5	495	3.33	84.6
MSP-Rc-24	24.0	610	23.0	584	4.00	101.6
MSP-Rc-26	26.0	660	25.0	635	4.33	110.0

If not otherwise specified, spherical mirrors listed are supplied having an accuracy of λ / 8; 60/40 finish and AlSiO coating.

Beam Expansion Spheres

On request we can supply convex spherical mirrors from 1" (25mm) to 3" (76 mm) diameter (D). Various curvatures (R) are available. Custom mounts can be provided. These components find use in Dall-Kirkham and other telescope designs.



Spherical Expanders

Off-Axis Machined and Post Polished Parabolas, Hyperbolas, and Ellipses

CNC precision machining and diamond turning operations shape these optical components. Prepolishing and stress relieving precede coating or final polishing. Finishes on bare metal and nickel coats are provided. SORL provides surface finishes and accuracies for UV-VIS-IR applications and subsequent suitable reflective coatings for given wavelength ranges.

On-axis and extreme off-axis components up to 1 m diameter or length can be manufactured in custom designs. Mounting and cooling provisions are available.

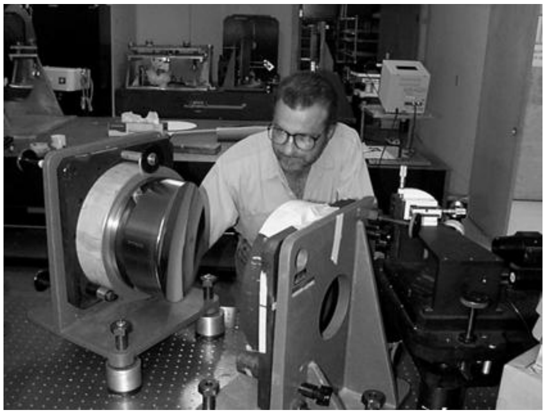
In the photograph at the right the top two mirrors are the Primary and Tertiary mirrors for a Space Optics designed Cryogenic collimator. The mirrors are post polished after diamond turning and ready for nickel plating and the next polishing cycle. The bottom mirror is a customer designed mirror that is already nickel plated and post polished.

Three examples of off-axis aluminum mirrors. (Primary, Tertiary and Customer Supplied)

Specifications for Three Aluminum Mirrors Pictured Above*

	SORL Primary	**SORL Tertiary**	**Customer Optic**
Type	Concave Ellipse	Concave Ellipse	Off-Axis Parabola
Diameter	11.37"	7.00"	10.236"
Radius of Curvature	38.00"	19.217"	18.454"
Conic Constant	-.91957	-.32230	-1.000 (parabola)
Off-Axis Distance	0.96"	0.88"	0.787"
P-V Wavefront	λ / 4	λ / 4	λ / 5

***Given as an example to reflect typical requirements for specifications to obtain SORL price quotations.



Post polishing of customer supplied diamond turned aluminum mirror from top picture.

The mirror above is being tested in an autocollimation null test with a LUPI interferometer. The null flat is in the mount closest to the camera. The focus of the mirror and the interferometer is behind the flat about 9 inches from the mirror. Like most optics at Space Optics, This mirror has a dedicated interferometric test set up while in fabrication.

Modified Gregorian Telescope Design

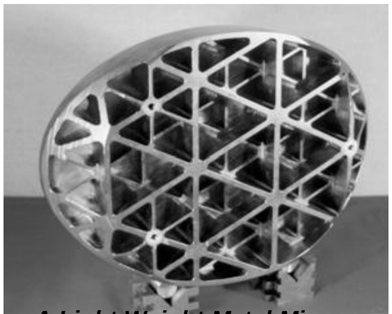
The optical layout above is of an all reflective off axis, wide field of view Cryogenic collimator. The design is a wide field variation on the Gregorian Telescope Design. The Secondary and Tertiary mirrors are shown in the picture above. The system is constructed of 6061-TT6 aluminum and is designed to operate in a Cryo-Vac environment. The field of view is 5° circular (full field angle).

SORL has profile measuring machines and twenty-two interferometer test stations equipped to tackle demanding manufacturing and testing tasks.

Light Weighted Mirrors

Spherical, Aspheric — On-Axis and Off-Axis — Glass, Glass-Ceramic, and Metal

SORL provides machined glass, glass-ceramic and metal mirrors to customer specifications.



A Light Weight Metal Mirror

Light Weight Metal Mirrors

Shown is an elliptical shaped optical flat with a major axis dimension of 13 inches in nickel plated aluminum 6061-T6. The substrate was designed for a 1/8 wave figure and is light weighted about 70% over the solid. This represents a very conservative mirror design. The mirror uses a three point mounting on the bolt pattern visible in this rear surface view.

Light Weight Glass Mirrors

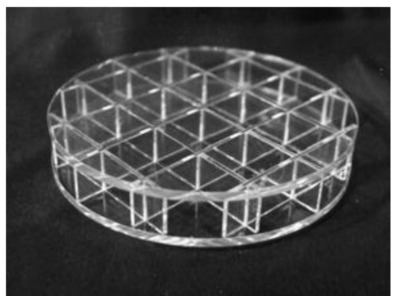
The light weight glass mirror pictured is a very transparent substrate — a Schott Zerodur® fused egg crate blank. (In this case an 8 inch optical flat.) It is shown without the reflective coatings.

Another technology we use is CNC machined mirrors from solid Zerodur® blanks.

A third technology is a bi-arch design machined blank with mounting bipods. This machined from block approach is easier than machining the pockets into Zerodur® mirrors but the weight removal is much lower.

SORL produces highly respected and functionally sound components and systems with weight concerns for airborne and rapid motion applications.

SORL's engineering and manufacturing staff stands ready to cooperate in the conceptual and design phases of customer projects.



A Light Weight Glass Mirror

Plano Mirrors (MPL)

High quality λ/10 P-V (λ = 0.6328 μ) surface flatness. More stringent surface accuracies are available upon request.

- Up to1 meter diameter capability
- Surface Finish: 60/40 (others on request)
- Substrate: Zerodur® Zero-Expansion Glass- ceramic
- Standard Coating: Aluminum silicon oxide (AlSiO)

Other coatings, i.e., gold (Au) or aluminum with magnesium fluoride (Al/MgF2) available.

- Precision Mirror Mount (optional)
- Applications: Beam Steering
  Autocollimation
  Telescope Configurations

Ordering Information Example:

Plano Mirror — 16 inch diameter

Order Number: MPL-16

Standard Plano Mirrors (MPL)

Order Number	Mirror Diameter		Clear Aperture		Edge Thickness	
	in	mm	in	mm	in	mm
MPL-4	4.00	102	3.8	96.5	0.67	17.0
MPL-6	6.00	132	5.8	147	1.00	25.4
MPL-8	8.00	203	7.8	198	1.33	33.9
MPL -10	10.0	254	9.7	246	1.67	42.4
MPL -12	12.00	305	11.5	292	2.00	50.8
MPL-16	16.0	406	15.5	394	2.67	67.8
MPL-18	18.0	457	17.5	444	3.00	76.2
MPL-20	20.0	508	19.5	495	3.33	84.6

Optical Coatings

Coatings may be selected from a variety of metals that can be evaporated. Considerations should include: optimal performance in the wavelength region of interest, coating thickness, optical power level, and the environment of intended operation. Following is general information regarding some typical coatings.

Aluminum (Al)

Aluminum is a versatile coating material. It is useful from below 200 nm through the IR. Aluminum quickly forms an oxide layer, which decreases reflectance at lower wavelengths. It is very soft and must be handled with extreme care. If this is done, the reflectance is somewhat superior to coated aluminum. There is, however, a dip in reflectance around 800 nm due to phonon absorption.

Protected Aluminum (AlSiO)

Overcoating the bare aluminum with a dielectric layer slows down the formation of the oxide layer, thus preserving the quality of reflectance. The AlSiO layer is very hard, which makes the mirror better suited for cleaning and handling. The reflectance dip near 800 nm that is intrinsic to aluminum remains.

Aluminum Magnesium Fluoride (AlMgF2)

This coating extends the usage of aluminum further into the UV, making it useful from 110 nm through the IR. Its somewhat harder surface makes handling easier and protects against the formation of the oxide layer.

Protected Silver

Since bare silver is extremely soft and susceptible to oxidation, a dielectric coating is added for durability. Silver has extremely high reflectivity in the visible region through the IR, with reflectance dropping off in the blue.

UV-Enhanced Silver

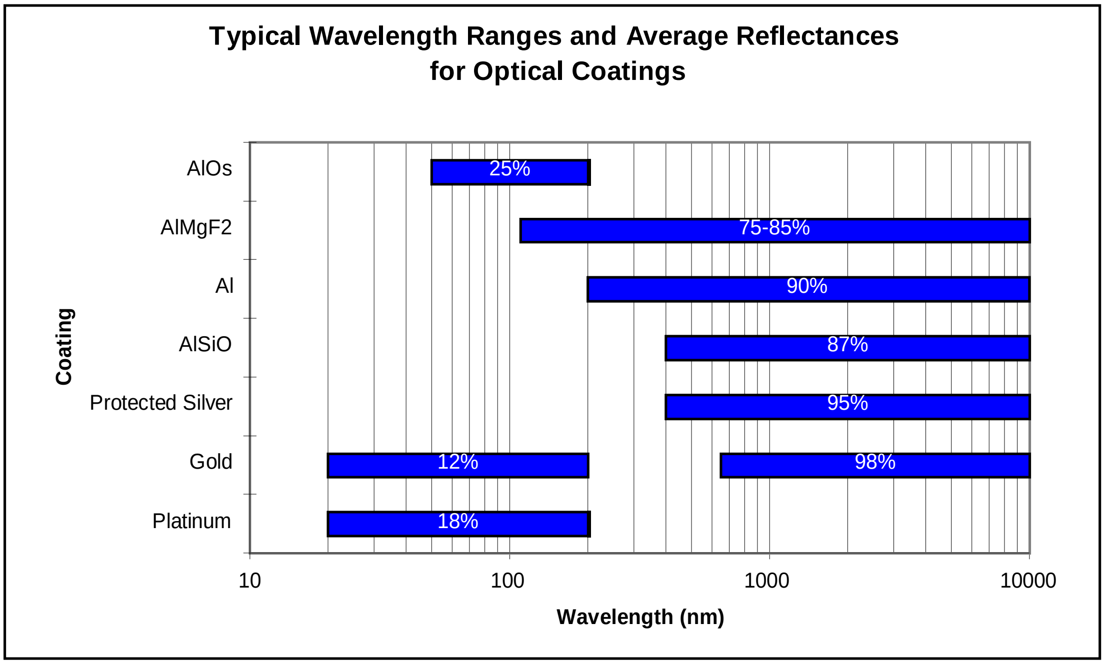
This efficient coating is protected silver with performance enhanced into the UV.

Protected Gold

Gold is the most efficient reflector in the IR. It is very soft, so a dielectric layer is added for durability. Gold is also used for some applications in the VUV.

Platinum

Platinum is very useful for VUV applications.



NOTE:
Please keep in mind that the reflectance of a coating not only depends on the wavelength of light used, but also on the thickness of the coating itself. SORL will assist you to select coatings for specific applications.

Precision Mirror Mounts

Precision Mirror Mount Features

Space Optics Research Labs (SORL) mirror mounts feature:

- Versatility to accept spherical, flat and parabolic mirrors
- Non-obscuring, custom mirror cell
- Orthogonal, tip-tilt adjustments
- Adjustable optical axis height, by mount feet
- Position locking adjustments
- Auxiliary reference flat to facilitate alignment (MMOA only)
- Vacuum compatibility of VIR versions. Prices quoted on request.

Precision Mirror Mount with Alignment Flat (MMOA)

Precision mirror mounts with reference flats are recommended when using off-axis parabolic mirrors (OAP). An autocollimating alignment flat, mounted on the circumference of off-axis parabolic mirror cell, serves as optical reference and aids in the alignment of the mount. This alignment flat is adjusted at SORL during final interferometric testing and is accurately perpendicular to the optical axis of the beam from the off-axis parabolic mirror.

Precision Mirror Mount (MMA)

Precision mirror mounts are typically utilized with Space Optics Research Labs plano (MPL) and spherical (MSP) mirrors. The design is basically the same as the precision mirror mounts with reference flats except for exclusion of alignment flat.

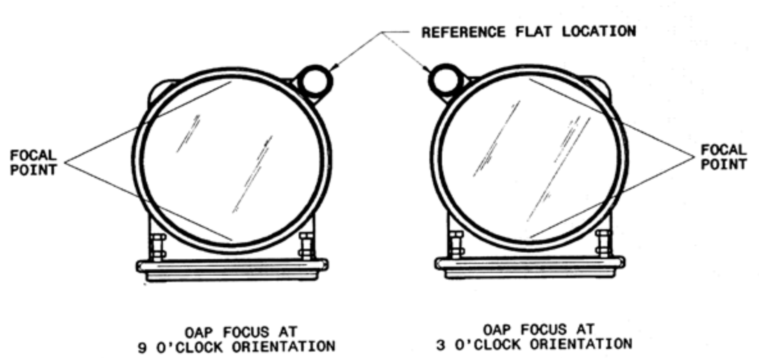
SORL Space Optics Research Labs
7 Stuart Road
Chelmsford, MA 01824
www.sorl.com
Phone: 978-250-8640
Fax: 978-256-5605

Precision Mirror Mounts —Note that vacuum versions(Inset) and reference flats are available and mounted to suit requirements.

Clocking Orientation

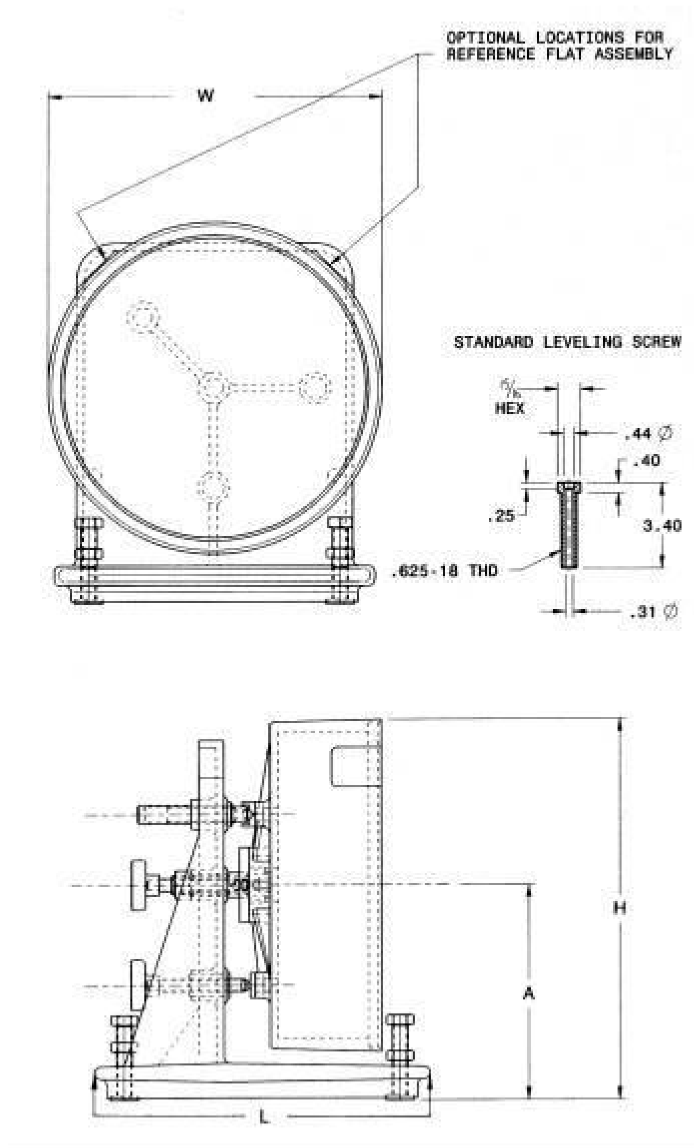
SORL Mounts identify the clocking orientation of your OAP, which specifies the OAP focus position and dictates location of the Reference Flat. Using the mirror at this correct rotational position will assure optimum wavefront performance. This is the position at which the mirror was fabricated and tested.

NOTE: Please include the clocking orientation on your order. Other orientations are possible, but may impact your final cost. Your SORL representative is always available to assist you with any clocking orientation questions you may have.



MMOA Mount Designed for use with SORL Off-Axis Parabolas

Exceptional optics are useless unless they are positioned with absolute precision. SORL designs and manufactures mounts specifically for use with SORL OAPs to optimize the performance of your optical system.



MMOA Series Mount Features

- **Adjustments:** These include elevation, azimuth, and vertical height. For small diameter mirrors, (MMOA-1, 2, and 3) fine rotation adjustment is provided.
- **Adjustment Locking:** After aligning, all adjustments can be locked in place for long-term stability.
- **Stability:** Designed to minimize vibration effects, withstand thermal variances, and eliminate potential mirror drift, MMOA mounts provide long-term stability and continued alignment of the OAP.
- **Stress-Free Mirror Mounting:** Designed to minimize mount-induced stress to the mirror front surface which can degrade surface accuracy and ultimately your system's performance.

Ordering Information Example:

Mirror Mount & Reference Flat — 16 inch diameter — Mirror Mount — 16 inch diameter

Order Number: MMOA-16 or MMA-16

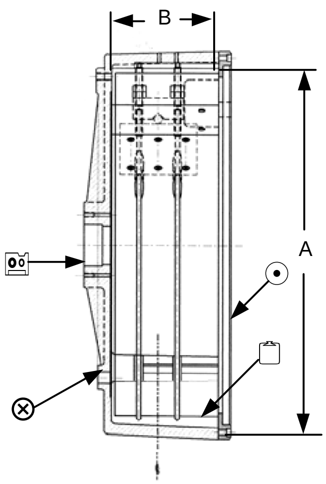
For Vacuum Versions add "Vacuum" to the order number.

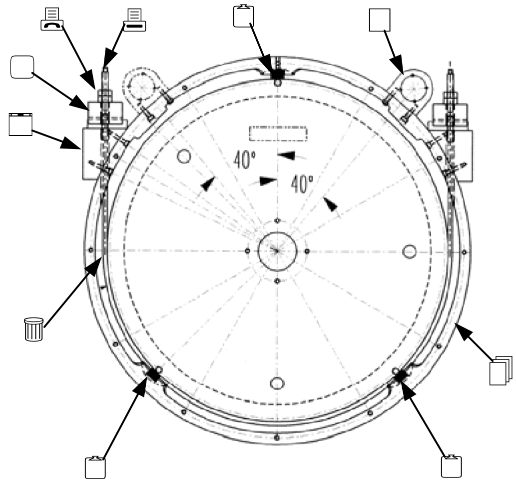
Mirror Mounts

Mirror Mount & Reference Flat Order Number	Mirror Diameter		Base to Mirror Center Height (A)		Dimensions Length (L)		Width (W)		Height (H)		(w/o optics) weight
	in	mm	in	mm	in	mm	in	mm	in	mm	lb.
MMOA-1	1	25	3.0	76	6.1	155	3.6	92	6.4	163	3.25
MMOA-2	2	51	3.0	76	6.1	155	3.6	92	6.4	163	3.00
MMOA-3	3	76	3.0	76	6.3	1.60	3.6	92	6.4	163	2.75
MMOA-4	4	102	5.0	127	9.0	229	6.3	159	8.4	213	9
MMOA-6	6	152	6.5	165	11.0	279	8.3	212	10.5	267	12
MMOA-8	8	203	6.5	165	11.0	279	9.6	244	11.4	289	17
MMOA-10	10	254	9.0	229	13.4	340	12.5	317	14.7	373	34
MMOA-12	12	305	9.0	229	13.4	340	13.3	338	15.3	387	37
MMOA-14	14	356	12.0	305	18.5	470	18.0	456	20.1	510	76
MMOA-16	16	406	12.0	305	18.5	470	18.0	456	21.1	535	82
MMOA-18	18	457	16.0	406	21.0	533	20.5	521	26.3	667	113
MMOA-20	20	508	16.0	406	21.0	533	22.5	571	27.3	692	120
MMOA-22	22	559	16.0	406	21.0	533	24.5	622	28.3	718	
MMOA-24	24	610	20.0	508	25.5	648	26.5	673	33.3	844	upon
MMOA-26	26	660	20.0	508	25.5	648	28.5	724	34.3	870	request
MMOA-28	28	711	20.0	508	25.5	648	30.5	775	35.3	895	
MMOA-30	30	762	20.0	508	25.5	648	32.5	825	36.3	9221	

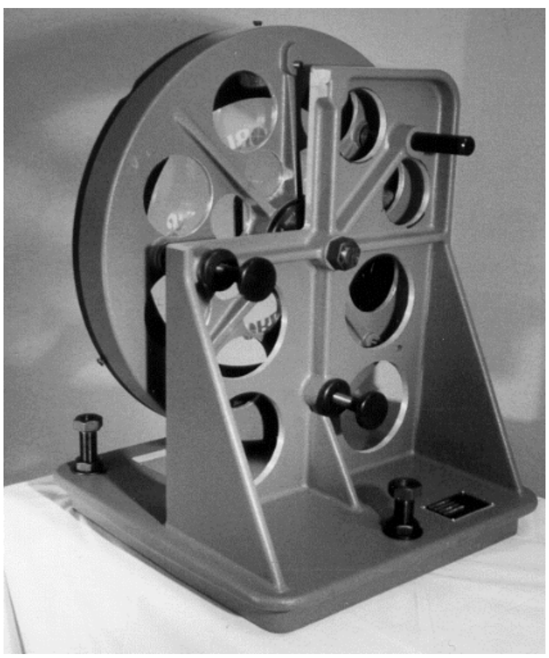
Sling Mirror Mounts

Text for sling mirror mount section.

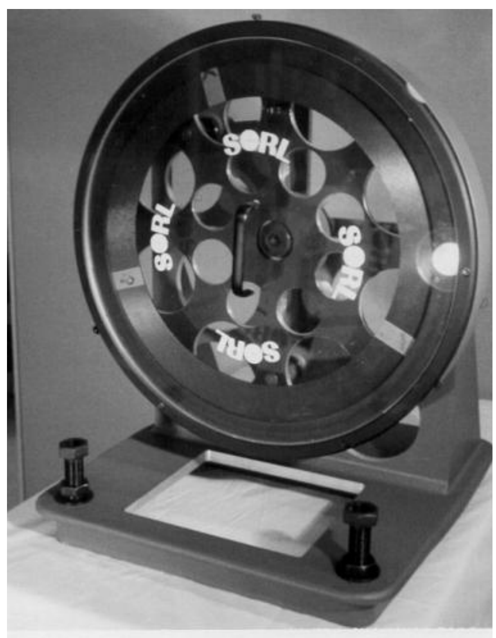




- ♍ Sling Mount Housing
- ♎ Support Blocks
- ♏ Sling Cable
- ♐ Lift Support
- ♑ Lift Block
- ♒ Lift Screws
- ♓ Lift Nuts
- er Cover Seat
- & Swivel Mount Bore
- ● Pitch Adjustment Receptical (Yaw not shown)
- ♌ Reference Flat (Optional) Indicate desired location when ordering.



Rear view of a SORL sling mount is shown above.



Front view of a SORL sling mount is shown above.

Beam Expanders, Collimators, Target Projectors and Telescopes

SORL

SPACE OPTICS RESEARCH LABS

7 Stuart Road • Chelmsford, MA 01824 USA

PHONE: 978-250-8640 **FAX:** 978-256-5605 **EMAIL:** SORL@sorl.com **www:** http://www.sorl.com

IR-VIS-UV Achromatic Performance Without Refractive Components

Space Optics Research Labs (SORL) reflective on and off axis optics and telescope assemblies offer the user unique advantages. SORL provides complete achromatic performance that can be configured in compact, portable, and versatile systems for use in a variety of optical test and instrumentation applications. Unlike refractive optics and systems that operate only over a relatively narrow spectral region, reflective optics and systems can be used at any wavelength, or at a number of wavelengths simultaneously, without need to realign or refocus.

Optics and Materials

On and off axis mirrors and telescope components are manufactured from a wide variety of substrates, including low expansion glass-ceramics, most glasses, copper, and electro-less nickel-plated aluminum, etc. Components are designed to meet extreme environmental requirements while maintaining high quality and reliability.

Optical Design, Manufacture and Test

SORL's capability in design, manufacture and test of reflective on and off axis optics and telescope systems is outstanding and reflects SORL's leading position among manufacturers of aspheric mirror components. SORL's aspheric components, as required in unobscured telescopes, achieve unsurpassed system performance in compact designs. Our advancements in computer-directed asphering techniques have strengthened SORL's capability to produce custom configured aspheric surface geometries and standard products. State-of-the-art laser unequal pathlength interferometric (LUPI) and phase contrast testing assures optical figuring accuracy, and insures that components meet state-of-the-art manufacturing specifications.

Mechanical Design

In addition to the quality of individual components, final telescope system performance is highly dependent on accuracy and stability of alignment. Integrity of components and structural design of every SORL telescope is interferometrically and technically tested to assure optimal performance. SORL's experience and extreme attention to detail result in stable and reliable instruments that meet most challenging requirements.

IR Visible and UV

SORL supplies quality telescope systems and optical components with coatings for any required wavelength range. We provide optics and systems for standard and OEM use. SORL offers answers for prototype and test applications in aerospace, defense, and commercial optics industries, and applications in university, government, and private research institutions throughout the world. SORL manufactures axially symmetric and off-axis mirrors from 1 centimeter to more than 1 meter in diameter, and off-axis segments up to 1 meter in diameter for UV-VIS-IR use.

SORL's Credentials

- Satisfied users world wide
- Reliability of systems widely in use
- Competent engineering staff to discuss applications and to assure specifications can be met
- Skilled optical craftsmen and master opticians to produce expertly crafted optics
- Quality assurance programs meeting industrial and government requirements
- References upon request

Applications

- Unobscured collimation
- Laser beam expansion
- Collimation and point source detection
- Target projection and simulation
- Satellite and missile telemetry
- LIDAR and laser range finders
- Radiometry and spectrometry
- Laser beam diagnostics
- Forward Looking Infrared (FLIR) testing and calibration
- Multi-channel signal processing
- Autocollimation and system alignment
- Beam expansion, diagnostics, propagation, reduction and steering
- Boresighting and divergence measurement

SORL is ready to serve you whether requirements can be satisfied by standard products, or a specialized approach.

Off-Axis Reflective Blackbody and Spectral Collimators Series (TOAN)

Concave parabolic mirrors are frequently used to accurately collimate point sources of visible and IR radiation. Precise alignment is required to obtain optimal performance, and lengthy set-up times may be encountered, especially if the mirror is frequently moved.

Space Optics Research Labs off-axis collimators incorporate one of our precision, zero thermal-expansion, off-axis parabolic mirrors, interferometrically aligned in a rugged and compact housing. Twenty-one models are offered, providing unobstructed apertures from 4 to 14 inches, a variety of f-numbers, and two wavefront accuracy specifications.

Applications

- Target Simulation
- OTF, MTF, and MRT Testing
- FLIR Test and Calibration
- IR Target Projection

Off-Axis Reflective Blackbody Collimators

Standard IR Quality

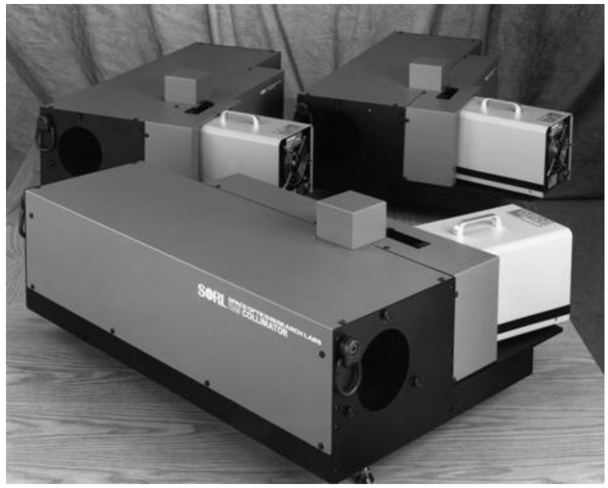
Incorporating one of our standard quality, 0.1 mrad resolution, off-axis parabolic mirrors, these models are designed to provide diffraction limited performance beyond 3 µ. Protected aluminum coatings provide 95% average transmission through the IR. Standard IR Quality systems mainly supply the larger systems. (TOAN 8.5-12 and larger) Quantity builds of smaller systems could be a savings with the reduced surface accuracy of the mirrors but SORL doesn't normally stock material for this quality level.

High Quality (HQ)

For applications in the visible and near infrared, these systems provide a $\lambda/4$ wavefront, as tested at 0.6328 µ. Enhanced aluminum coatings to improve visible transmission and complete interferometric data are supplied.

Custom Requirements

SORL will be happy to quote systems to meet specialized applications.



Off-Axis Reflective Collimators

Accessories

Aperture Wheel and Pinhole Aperture (AW-)

Our six-position focal plane aperture wheel with 0.05, 0.1, 0.25, 0.5, 1.0, and 5.0 mrad pinhole apertures is a frequently desired option.. Additional interchangeable aperture wheels and targets may be purchased separately.

"Glow-Bar" Radiation Source (GBS-01)

High temperature (1500°K) "Grey" body source for broadband radiation requirements.

Chopper (CH-01)

Variable frequency focal plane modulator for above.

Customized Focal Plane Equipment

A variety of application requirements can be satisfied including remotely-selectable apertures, four bar targets, spatial frequency sweep targets, multi-channel illumination systems, and microprocessor compatible systems. Please contact Space Optics Research Labs to discuss your requirements.

Monochromatic Light Accessory

Variable UV-VIS-IR illuminators available on request.

BB Sources

Micron 360x
High temperature

Ordering Information Example:

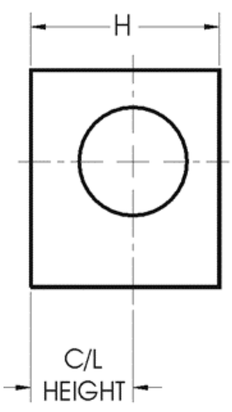
Order Number: TOAN-7.5-8QAW

- TOAN — Telescope Off-Axis Newtonian
- 7.5 — f/#
- 8 — Clear Aperture Diameter
- Q — High Quality
- AW — Aperture Wheel, 6 Pinhole Apertures (Optional)

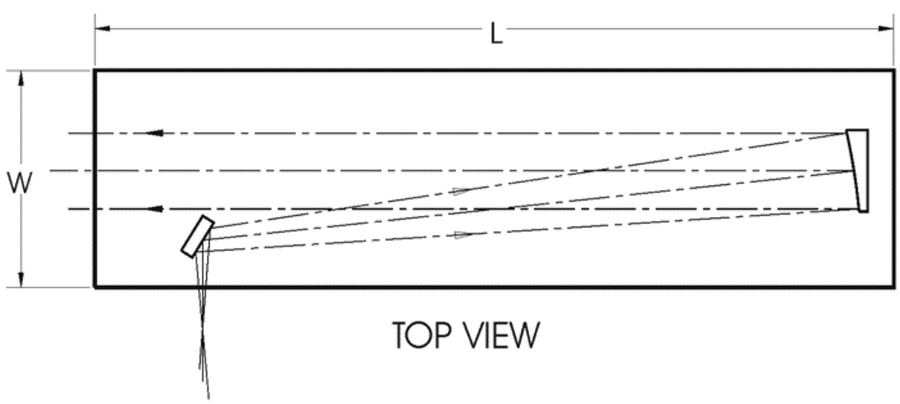
SORL Space Optics Research Labs
7 Stuart Road
Chelmsford, MA 01824
www.sorl.com
Phone: 978-250-8640
Fax: 978-256-5605

Telescope Off-Axis Newtonians

Order Number	f/#	Clear Aperture		Length (L)		Width (W)		Height (H)		Optical Centerline Height		Weight	
		in	mm	in	mm	in	mm	in	mm	in	mm	lb	kg
TOAN-4.5-4	4.5	4.0	102	21.5	546	12.3	312	10.0	254	6.0	15	30	14
TOAN-6-4	6	4.0	102	28.0	711	10.3	262	10.2	259	6.0	152	50	23
TOAN-5-5	5	5.0	127	28.0	711	10.3	262	10.2	259	6.0	15	50	23
TOAN-6-5	6	5.0	127	34.0	864	12.3	312	10.2	259	6.0	152	55	25
TOAN-3-6	3	6.0	152	21.5	546	12.3	312	10.0	254	6.0	152	30	14
TOAN-4-6	4	6.0	152	28.0	711	10.3	262	10.2	259	6.0	152	50	23
TOAN-5-6	5	6.0	152	34.0	864	12.3	312	10.2	259	6.0	152	55	25
TOAN-6.7-6	6.7	6.0	152	46.4	1179	12.3	312	11.4	290	6.0	152	75	34
TOAN-5-8	5	8.0	203	46.4	1179	12.0	305	11.4	290	6.0	152	75	34
TOAN-7.5-8	7.5	8.0	203	65.5	1664	14.0	356	11.5	292	6.0	152	110	50
TOAN-6-10	6	10.0	254	65.5	1664	14.0	356	14.5	368	8.0	203	130	59
TOAN-5-12	5	12.0	305	68.2	1732	14.7	373	16.0	406	8.8	224	165	75
TOAN-8.3-12	8.3	12.0	305	108.0	2743	16.0	406	20.1	511	12.3	312	340	154
TOAN-5-14	5	14.0	356	81.6	2073	19.1	485	20.8	528	10.8	274	300	136
TOAN-7.14 - 14	7.14	14.0	256										
TOAN-5.6-18	5.6	18	457										
TOAN-5-20	5	20	508										



OUTPUT



TOP VIEW

Off-Axis Reflective Laser Beam Expanders (COAR)

Features

Every off-axis reflective laser beam expander features an ultra-low thermal expansion ceramic primary mirror, and a ceramic or metal secondary mirror. External focusing control of the secondary mirror and tilt adjust of the primary allow controlled focusing of either the input or output beams and fine tuning of the wavefront profile. The convex secondary eliminates internal focusing, a common concern in high power applications. All optical components are coated with Protected Aluminum. Other coatings can be added for improved transmission and/or laser damage threshold.

Off-Axis Reflective Laser Beam Expanders

Air Cooled, Variable Focus (VF)

Our standard, air-cooled, variable focus line provides a 1λ system wavefront (tested at $\lambda = .6328\ \mu$), and is designed to provide diffraction limited performance at all wavelengths beyond 3 µ. Glass-ceramic optics, with high efficiency optical coatings, are designed to withstand a maximum of 50 watts/cm^2 CW Laser energy density at 10.6 µ.

High Quality, Air Cooled Models (HQ)

For applications involving visible and near infrared lasers in which high wavefront integrity is desired, Space Optics Research Labs offers a high quality version of each model in our standard line. Here the primary mirror is figured at a λ/10 surface accuracy ($\lambda = .6328\ \mu$), and interferometrically aligned to a high quality secondary mirror to provide a λ/5 system wavefront. Focusing and tilt adjust control are provided. Complete interferometric data is supplied with each unit.

Water-Cooled, Variable Focus (WVF)

Thermal considerations and laser damage are critical in applications requiring energy densities greater than 50 watts/cm^2 CW at 10.6 µ. To meet these requirements, Space Optics Research Labs replaces the ceramic secondary mirror of our air-cooled line with a water-cooled copper mirror. High thermal conductivity of copper allows medium power CO_2 lasers to be operated without concern, the absorbed energy being dissipated through the housing. For high power applications, i.e., energy densities greater than 200 watts/cm^2 or extended operating conditions, the water cooling further extends the units application. These units provide a 1λ wavefront ($\lambda = .6328\ \mu$), and focus/tilt adjustments.

Water Cooled, High Quality (WHQ)

For high powered applications requiring high wave-front integrity, a high quality λ/5 system wavefront (tested at .6328 µ) is offered in our water-cooled models. Interferograms are supplied with every unit.

Options

Variable Magnification (VMAG)

By introducing additional secondary mirrors with the appropriate focal length, magnification of a given unit may be adjusted within a small range of its designed ratio. For example, an off-axis reflective laser beam expander 10x10 may be modified in this fashion to provide 5 and 15 power expansion ratios. A decrease in system wavefront accuracy will be observed when employing this option, but it is often a desirable feature when "fine-tuning" the energy density of your beam.

Spatial Filtering (SF)

For applications employing unfiltered beams, a limited line of spatially filtered Off-Axis Reflective Expanders are provided. A concave secondary is used to produce an internal focus, and a pinhole is placed at this point to improve uniformity of the output beam.

Four models are offered. Ceramic optics, precision mounting and micrometer adjustments are provided for fine-tune focusing.

COAR-10X05SF-HQ
Spatially Filtered Off-Axis Reflective Expanders

Ordering Information Example:

10X expansion, 10 mm input ϕ max, 100 mm output ϕ max

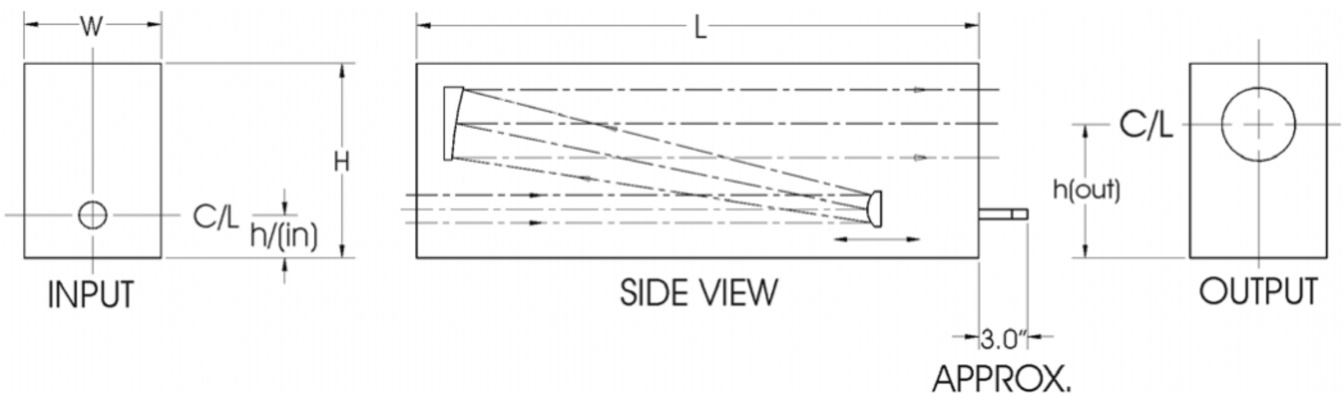
Off-Axis Reflective Laser Beam Expander

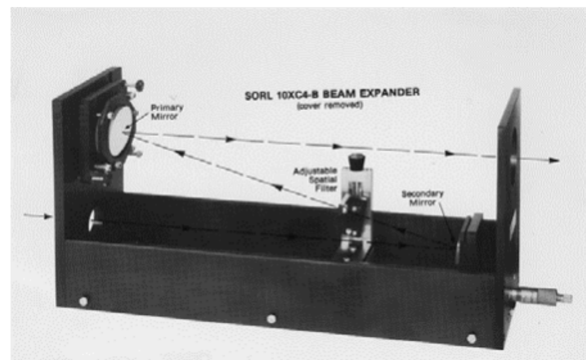
High Quality λ / 5 @ 0.63 µ

Order Number: COAR-10 X 10-HQ

Off-Axis Reflective Laser Beam Expanders

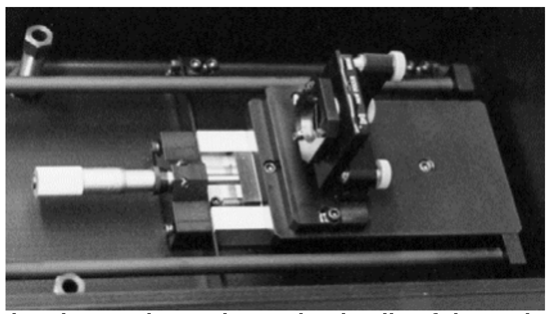
Order Number	Expansion Ratio	Max. Input (mm) Diameter	Max. Output (mm) Diameter	Invar Metered Y, N, O*	Length (L) Air Cooled		Width (W)		Height (H)		Input Beam h (in)		Output Beam h (out)		Weight		Micrometer
					in	mm	in	mm	in	mm	in	mm	in	mm	lbs	kg	Position
COAR-2 X 25	2X	25	50	N	18.4	467	4.2	107	6.5	165	2.6	66	4.3	109	15	7	EXT
COAR-2 X 50	2X	50	100	N	34.5	877	6.3	160	10.8	274	3.6	91	7.3	185	33	15	INT
COAR-2 X 75	2X	75	150	Y	36.8	935	8.3	211	12.5	320	3.50	89	8.5	216	44	20	INT
COAR-3 X 33	3X	33.3	100	N	32.5	877	6.3	160	10.8	274	3.6	91	7.3	185	33	15	EXT
COAR-3X50	3X	50	150	Y	36.8	935	8.3	211	11.7	297	3.25	83	7.75	197	41	19	INT
COAR-3.3 X	3.3X	5	16.5	N	14.0	356	3.3	84	4.0	102	2.1	53	3.2	81	5	2	EXT
COAR-3.57 X	3.57X	42	150	Y	36.8	935	8.3	211	11.7	297	3.25	83	7.75	197	41	19	INT
COAR-4 X 25	4X	25	100	O	21.6	549	6.3	160	8.9	226	3.25	83	6.0	152	20	9	INT
COAR-4 X 37	4X	37	150	Y	36.8	935	8.3	211	11.7	297	3.25	83	7.9	201	35	16	INT
COAR-5 X 20	5X	20	100	O	21.6	549	6.3	160	8.9	226	3.1	79	6.0	152	20	9	INT
COAR-5 X 30	5X	30	150	Y	36.8	935	8.3	211	11.7	297	3.25	83	7.75	197	41	19	INT
COAR-6 X 25	6X	25	150	Y	44.3	1125	8.3	211	11.7	297	3.25	83	7.75	197	44	20	INT
COAR-7.5 X	7.5X	20	150	Y	44.3	1125	8.3	211	11.7	297	3.25	83	7.75	197	44	20	INT
COAR-10 X 10	10X	10	100	O	28.6	726	6.3	160	8.9	226	3.2	81	5.9	150	30	14	INT
COAR-10 X 15	10X	15	150	Y	44.3	1125	8.3	211	11.7	297	3.25	83	7.75	197	40	18	INT
COAR-10 X 20	10X	20	200	O	60.2	1530	11.75	298	14.75	375	3.2	81	8.83	224	155	70	INT
COAR-10 X 25	10X	25	250	Y	65.6	1670	16.0	406	18.25	464	3.75	95	10.5	267	190	86	INT
COAR-10 X 30	10X	30	300	Y	62.5	1590	16.0	406	18.25	464	3.375	86	10.25	26.0	200	91	INT
COAR-10X40	10X	40	400	Y	84.0	2130	22.5	570	25.9	660	5.5	140	15.0	381	360	164	INT
COAR-15 X 10	15X	10	150	Y	44.3	1125	8.3	211	11.7	297	3.25	83	7.75	197	40	18	INT





COAR-35 x 04-HG
Off-Axis Reflective Laser Beam Expander

Order Number	Expansion Ratio	Max. Input (mm) Diameter	Max. Output (mm) Diameter	Invar Metered Y, N, O*	Length (L) Air Cooled		Width (W)		Height (H)		Input Beam h (in)		Output Beam h (out)		Weight		Micrometer
					in	mm	in	mm	in	mm	in	mm	in	cm	lb	kg	Position
COAR-20 X 05	20X	5	100	O	26	660	6.3	160	8.9	226	2.9	74	6.0	153	30	14	INT
COAR-20 X 7.5	20X	7.5	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-20 X 10	20X	10	200	O	64	1630	11.75	298	14.7	373	3.375	86	10.	260	155	70	INT
COAR-20 X 20	20X	20.0	400	Y	96.38	2300	22.5	570	25.9	660	5.5	140	15.	381	360	164	INT
COAR-25 X 04	25X	4	100	O	26	660	6.3	160	8.9	226	2.9	74	6.0	153	30	14	INT
COAR-25 X 06	25X	6	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-25 X 10	25X	10	250	Y	65.6	1670	16.0	406	18.25	463	3.375	86	10.	267	190	86	INT
COAR-30 X 03	30X	3.33	100	O	26	660	6.3	160	8.9	226	2.9	74	6.0	153	30	14	INT
COAR-30 X 05	30X	5	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-30 X 10	30X	10	300	Y	65.5	1660	16.0	406	18.25	463	3.375	86	10.	260	200	91	INT
COAR-35 X 04.3	35X	4.3	150	Y	40.0	1016	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-40 X 02.5	40X	2.5	100	O	26	660	6.3	160	8.9	226	2.9	74	6.0	153	30	14	INT
COAR-40 X 3.75	40X	3.75	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-40 X 05	40X	5	200	O	64	1630	11.75	298	14.7	372	3.375	86	10.	260	155	70	INT
COAR-40 X 10	40X	10	400	Y	90.38	2300	22.5	570	25.9	660	5.5	140	15.	381	360	164	INT
COAR-50 X 03	50X	3	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-50 X 05	50X	5	250	Y	65.6	1670	16.0	406	18.25	463	3.375	86	10.	267	190	86	INT
COAR-75 X 02	75X	2	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
COAR-100X01.5	100X	1.5	150	Y	46.4	1179	8.3	211	11.7	297	3.25	83	7.7	197	45	20.	INT
Spatially Filtered																	
COAR-5 X 20SF	5X	20	100	N	29.5	749	8.3	211	10.6	269	3.2	81	7.5	191	35	16	EXT
COAR-10 X 10SF	10X	10	100	N	33.4	848	8.3	211	9.9	251	3.6	91	6.8	173	35	16	EXT
COAR-10X15SF	10X	15	150	Y	50	1270	8.3	211	12.75	324	3.25	83	8.7	222	55	25	INT
COAR-20X05SF	20X	5	100	N	30.9	785	8.3	211	9.7	246	3.6	91	6.7	170	35	16	EXT



The picture above shows the details of the optional invar metering system in the 100 mm diameter COAR series.

The construction of the metering system shown above is similar to the larger systems' metering.

The metering system is important when your optics must operate in a wide range of temperatures with a high wavefront accuracy

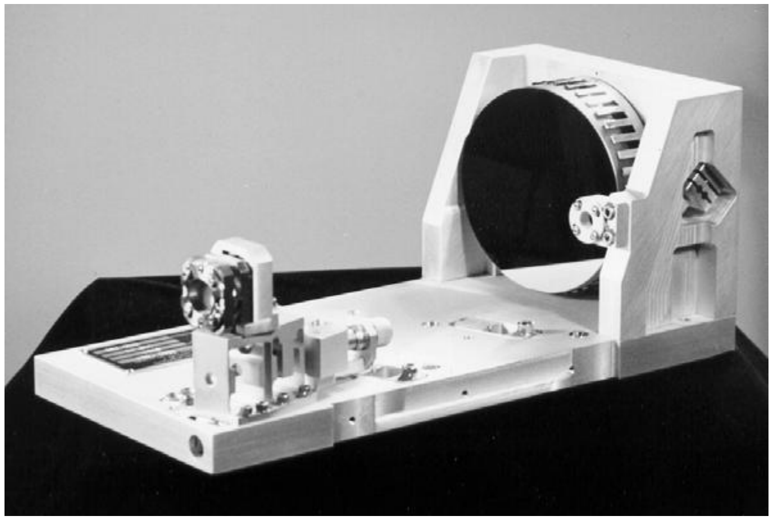
Beam Expanders, Collimators, Target Projectors and Telescopes Built to Order

COAR 32 x 03Q

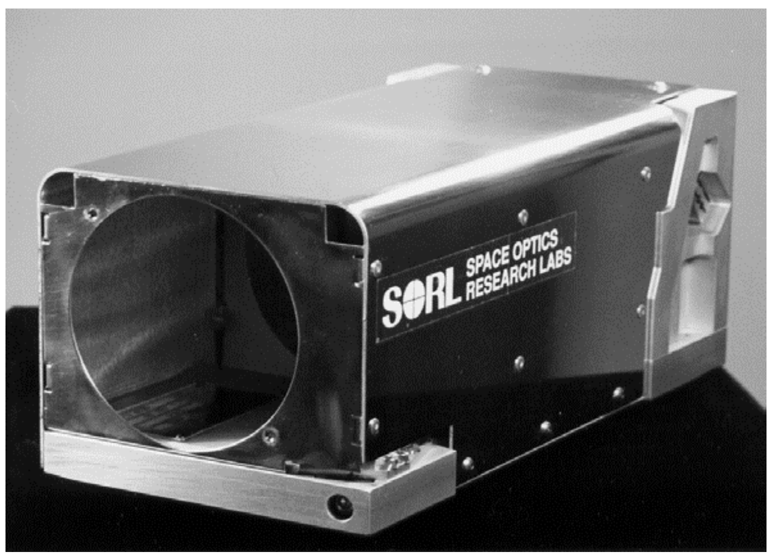
This small 4" aperture telescope has a very high magnification afocal design. Designed for narrow fields of view and a high vibration environment. The system has an extremely stiff optomechanical design for operating in a typical airborne environment. The complete optical and optomechanical design was performed at Space Optics, including the Finite Element analysis of the structure. Finger flexure design on the Primary Mount provides greater stiffness than is possible with tangent bars, bi-pod or RTV potted mirror designs.

Specifications:

- 4" Clear Aperture
- 9.50" Focal Length Primary Mirror
- 32x Magnification
- 2 Mirror Off Axis Dall-Kirkham Design with an Additional Fold Mirror
- Zerodur® Mirrors with Protected Gold Coatings
- Better than $\lambda/16$ Wave Surface Accuracy @ 632.8 nm
- Aluminum 6061-T6 Structure
- Invar Metering Rod System to Control Separation of Primary and Secondary Optics
- -40° to 40°C Operating Range
- Flexure Supported Secondary Mirror with Focus Adjustment
- First Mode of Vibration is Above 700 Hz with Covers Off



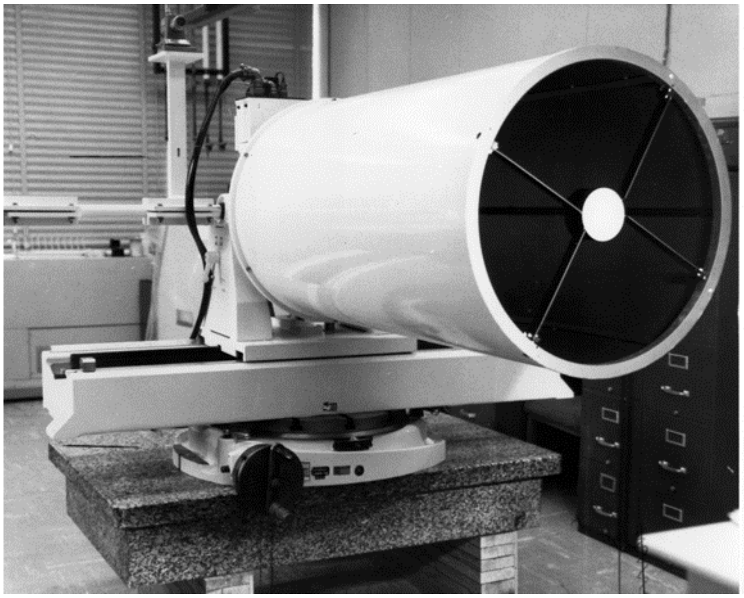
COAR 32 X 03Q Without the Covers to Show Opto-Mechanical Construction Details



COAR 32 X 03 with Covers Fitted

On-Axis Reflective Telescopes

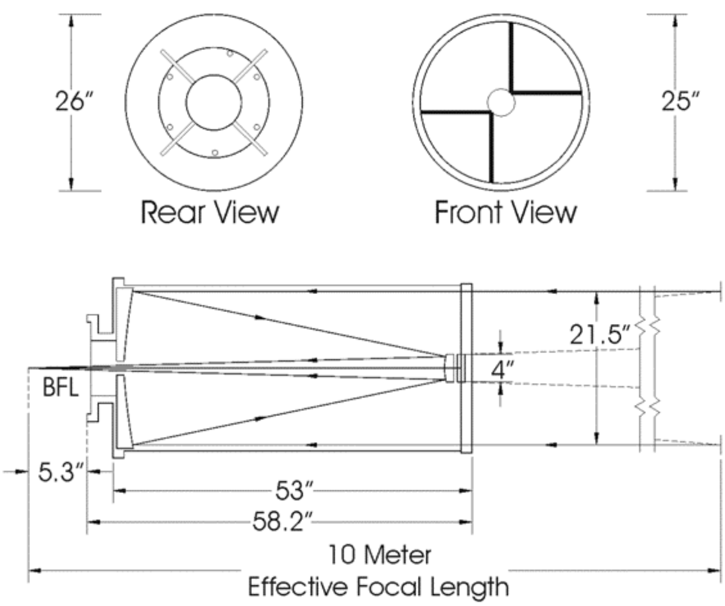
Dall-Kirkham (TDK-9) ⌘ Cassegrain



Dall-Kirkham (TDK-9) Telescope

Focusing Dall-Kirkham Telescope (TDK-9)

- **Primary Diameter:** 22" (560 mm)
- **Focal Length:** 10 meters
- **Obscuration:** 5% area
- **Outline Dimensions:** 26" ϕ X 58.5" length (66 mm ϕ X 149 mm length)
- **System Wavefront:** 1 λ at 0.63 μ
- High Quality black body calibration collimator system design, for 3 to 15 micron region
- Aluminum Housing



Dall-Kirkham (TDK-9) Outline Drawing

Afocal Dall-Kirkham Telescope (TDKA-10)

- 10 X magnification
- **Primary (Output) Mirror Aperture:** 10.5" (267 mm)
- **System Wavefront:** λ / 6 Peak-to-Peak (λ = 0.6328 μ)
- **Central Obscuration:** <4% Area
- **Outline Dimensions**
  Diameter: 13" (330 mm)
  Length: 28" (710 mm)
- **Weight:** 75 lbs. (34 kg)

Cassegrain Telescope (TC-5.6)

Narrow field of view, all-reflective, IR telescope designed for low scatter and diffraction limited performance @ 3.5 microns.

- **Primary Diameter:** 6.8" (172 mm)
- **EFL Telescope:** 37.8" (960 mm)
- **BFL from Primary:** 5.1" (129 mm)
- f/5.6 central obscuration < 15% area
- 40/20 mirror surface finish
- **Mirror Surface Accuracy:** λ / 2 @ 0.63 μ
- **Temperature Range:** 25° ± 10° C
- **Coatings:** 99% reflectivity, enhanced silver
- **Outline Dimensions:** 9.1" ϕ X 12.32" length (230 mm ϕ X 310 mm length)
- Blur Circle Diameter @ 0.63 μ (80% energy)
  1) **On-Axis:** 40 μ
  2) **½ field (4 minutes):** 40 μ
  3) **Full Field (8 minutes):** 60 μ
- Baffled Housing to reduce scattering for entrance angles up to 10° off-axis

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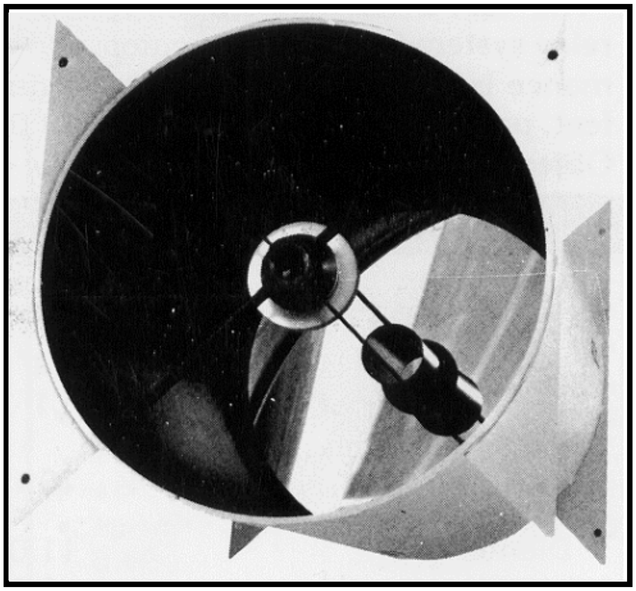
Large Aperture Telescope

Light Collecting Telescope (TLB 8.3-36)

The large aperture light collecting telescope is an economical solution to your LIDAR needs. This large aperture "Light Bucket" is extremely lightweight, compact and efficient, providing broadband performance over the UV, Visible, and IR range in a laboratory / outdoor environment. Durable coatings may be peaked for specified wavelengths.



Light Collecting Telescope

Specifications

System f/#: f/8.3

Primary (Input) Mirror Aperture: 36" (910 mm)

Blur Spot Diameter: 1" (25 mm)

Effective Focal Length: 300" (7620 mm)

Back Working Distance: 11" (280 mm)

Central Obscuration: 6% Area

Mirror Coating: Protected Aluminum

Outline Dimensions

Diameter: 39" (990 mm)

Length: 60" (1520 mm)

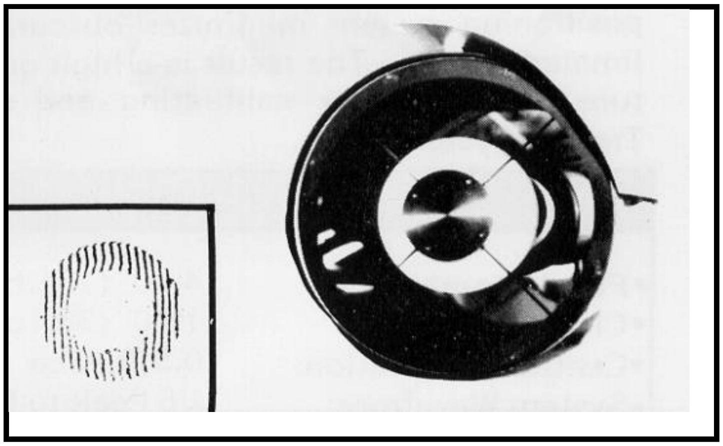
Weight: 230 lbs. (104 kg)

Shipping Weight: 300 lbs. (136 kg)

Wide Field of View Telescope

Ritchey-Chretien Telescope (TRC-3)

The wide field of view focusing telescope is a large aperture telescope that employs two hyperboloid mirrors for increased field-of-view. The Ritchey-Chretien design corrects for spherical aberration and coma. Internal stray-light baffles, durable broadband mirror coatings, and detachable thermal shield enhance the TRC-3's laboratory and field applications.



Ritchey-Chretien Telescope

Specifications

System f/#: f/3

Aperture: 11.7" (297 mm)

Back Working Distance: 4.4" (112 mm)

Central Obscuration: 36% Area

Full Field Of View: 0.8°

Wavefront Accuracy: λ/2 P-P at 63 μ

Coating: Protected Aluminum, 0.45 - 20.0 μ

Outline Dimensions

Diameter: 14.5" (368 mm)

Length: 17.4" (442 mm)

Weight: 61 lbs. (28 kg)

Shipping Weight: 91 lbs. (41 kg)

Ritchey-Chretien Telescope Performance

Wave-length (μ)	Blur Spot (%)	Blur Spot Diameter					
		On-Axis		Half-Field		Full-field	
		10^{-3} in	μ	10^{-3} in	μ	10^{-3} in	μ
4.0	80	2.5	63.5	2.6	66.0	3.3	83.8
	90	3.9	99.1	4.4	111.8	5.4	137.2
10.6	80	6.3	160.0	6.3	160.0	6.5	165.1
	90	9.8	248.9	9.9	251.4	10.4	264.2

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4 Mirror Afocal Telescope

This is an all reflective afocal telescope for an airborne application. It was designed as the front end telescope for an imaging spectrometer. The system is shown with the transport covers over the optics.

Specifications:

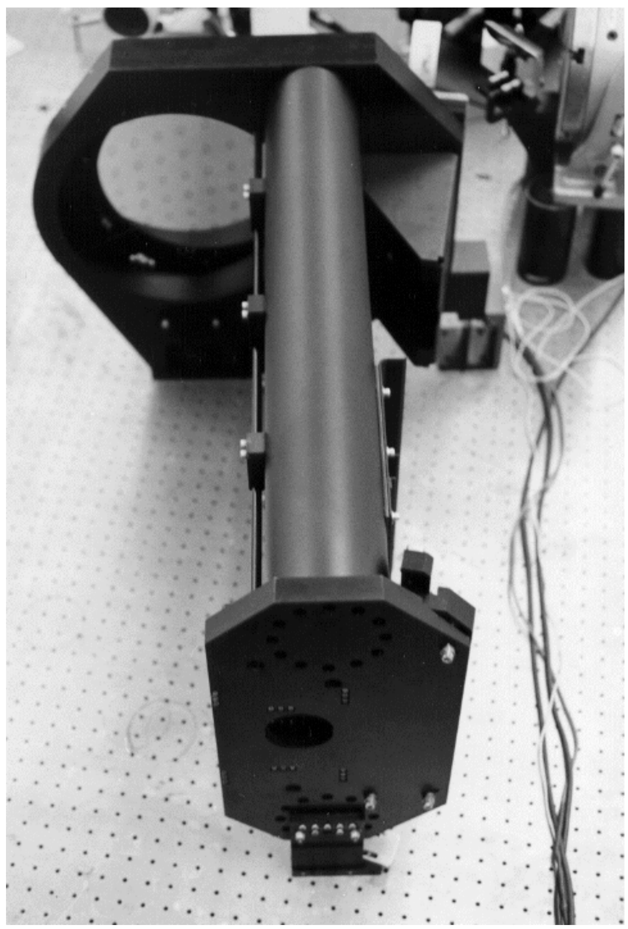
- 10" Clear Aperture
- 10x Magnification
- Capable of Multi-Spectral Operation from Visible to Far Infrared
- Wide FOV Design
- 4 Mirror Off Axis Unobscured Design (four powered optics)
- Zerodur® Mirrors with Protected Gold Coatings
- $\lambda/10$ Wave Surface Accuracy @ 632.8 nm
- Aluminum 6061-T6 Structure
- Invar Metering Rod System to Control Separation of Primary and Secondary Optics
- -40º to +40ºC Operating Range

In the picture on the right, the upper Invar metering rod is visible next to the main support tube. The Invar rods provide the athermalization for this system. The system is undergoing final interferometric test in this photo and some of the test equipment is visible behind the system. This is being picked up by a fold mirror on a rotary stage to feed into the LUPI (Laser Unequal Pathlength Interferometer). This is necessary to allow testing of the large field of view angles.

All the optics are aspheric except for the convex spherical Tertiary. The entrance pupil and exit pupil are a fair distance from the optics in this system.

A Ray Trace of the 4 Mirror Afocal Telescope System

4 Mirror Afocal Telescope shown with the Protective Covers Over the Primary and Tertiary Mirrors



4 Mirror Afocal Telescope Shown Without the Covers

Infrared Relay Objective

Schwarzschild Reflecting Objective (TSS-2)

The all-reflective objective is a point-to-point relay system for the 3.5 μ region. On-axis system performance is nearly constant at object distances of 15 to 40 feet, providing an image diameter of 0.25 inch, full-field. Object size scales in proportion to the magnifications.

Specifications

System f/#: f/1.8

Aperture: 9.7" (246 mm)

Effective Focal Length: 5.4" (137 mm)

Secondary Mirror Obscuration: 3.1" (79 mm)

System Transmission, Including Obscuration: 70%

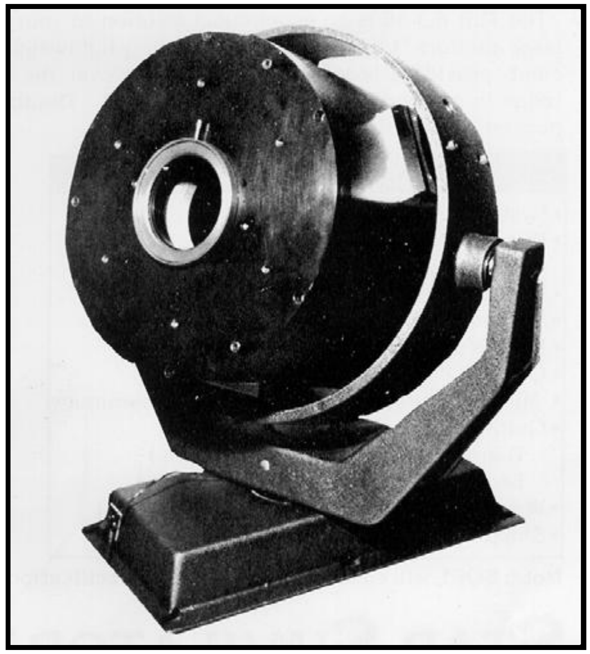
Outline Dimensions

Diameter: 11.0" (279 mm)

Length: 10.3" (262 mm)

Weight: 30 lbs. (14 kg)

Shipping Weight: 60 lbs. (28 kg)



Schwarzschild Reflecting Objective

Schwarzchild Reflecting Objective Performance in the 3-5 μ Region

Object Distance		Image Distance		Magnification	Image Height from Optic Axis		Blur Spot Diameter			
							80% Energy		90% Energy	
in	mm	in	mm		in	mm	10^{-3} in	μ	10^{-3} in	μ
171	4340	9.3	236	-1 / 30	0	0	1.5	38.1	2.2	55.9
					0.125	3.18	1.7	43.2	2.7	68.6
207	5260	9.2	234	-1 / 40	0	0	1.5	38.1	2.3	58.4
					0.125	3.18	1.6	40.6	2.6	66.0
471	11960	9.2	234	-1 / 89	0	0	1.7	43.2	2.6	66.0
					0.125	3.18	1.6	40.6	2.5	63.5

Schwarzchild Reflecting Objective

Schwarzchild Reflecting Objective

Schwarzchild Reflecting Objective

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Star Simulator

with Fiber Optic Star Source (SSF 40-15)

The star simulator with fiber optic star source is a 15-inch aperture star simulator that duplicates a single star of varying magnitudes. Light is relayed to the collimating mirror via a fiber optic light guide, which simulates the star source. A unique fiber positioning system minimizes obscuration of the collimated output. The result is a high quality, large aperture instrument for calibrating and qualifying star tracker systems.

Specifications

Focal Length: 40.0" (1016 mm)

Clear Aperture: 15.0" (381 mm)

Central Obscuration: 0.5% Area

System Wavefront: λ / 6 Peak-to-Peak (λ=0.6328 μ)

Source Diameter: 8 Arc Seconds

Spectral Characteristics: AOV Stellar Class

Star Brightness Range: -2 to +6 Magnitudes, in ½ Magnitude Increments

Angular Adjustment
Azimuth: ±5°

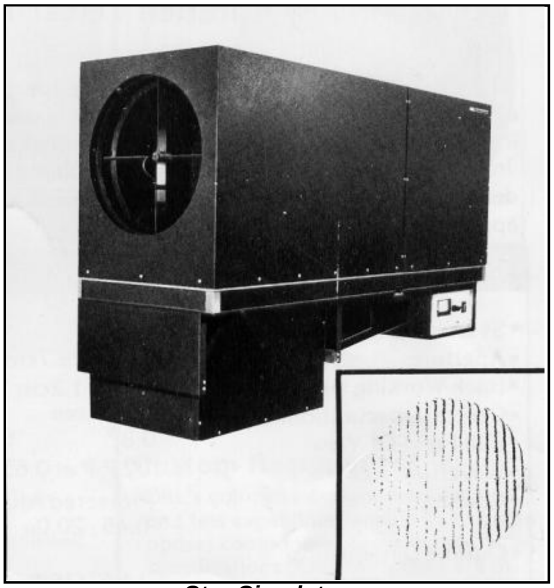
Elevation: ±5°

Electrical Requirements: 110-120 volts AC Single Phase

Outline Dimensions
Length: 60" (1520 mm)

Width: 20" (510 mm)

Height: 38" (970 mm)



Star Simulator

Common Telescope Systems

Numerous designs exist for a wide variety of applications. Two basic families of telescope designs emerge when described by the characteristics of their operation.

1. **Afocal Systems:** Incident light emerges collimated.
2. **Focal Systems:** Incident light is brought directly to a real image.

Within each family, various methods for producing desired results are possible, providing the potential user guidance in selecting an approach.

Afocal Systems

Many applications involving lasers require the use of optical systems that operate between infinite conjugates. Such systems, commonly referred to as Beam Expanders, are, in fact, telescopes. They are used in controlling the energy of laser beams, correcting beam divergence, LIDAR systems, beam propagation studies, and in reducing the field of view and increasing the magnification of FLIR systems.

The most common, the classical Cassegrain, (sometimes known as Merseinne Telescope) employs two confocal paraboloids (see Figure 1a). The expansion ration is given simply by the ratio of the focal lengths of the mirrors. The energy density varies with the square of this ratio.

A less expensive version is obtained using a Dall-Kirkham design comprised of elliptical primary and convex spherical secondary giving good on-axis performance.

A Gregorian telescope, employing a concave parabolic secondary mirror, (Figure 2c) is sometimes used in combination with a pinhole placed at the common focus to "spatially filter" the laser beam.

Off-Axis versions of the above are illustrated in Figure 3.

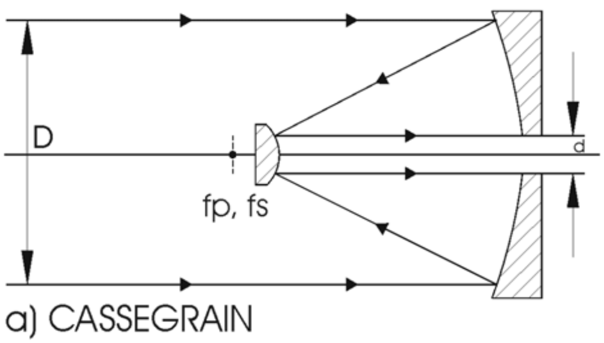


Figure 1 Afocal Telescope Designs. Expansion Ratio (D/d) = fp/fs.

Focal Systems

In most telescope applications, it is desired that light from a distant object or source be brought to focus where it may be detected, photographed, or measured. Conversely, these systems are often used as collimators or target projectors, where a target or source placed in the focal plane is imaged to some distant point. Designs commonly used for this purpose are described in the text that follows.

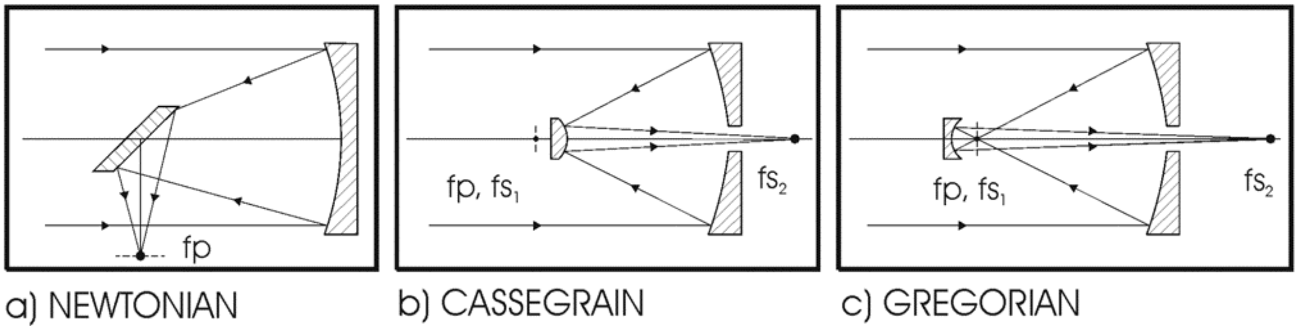


Figure 2 Focal Telescope Designs

Single Mirror Designs: In many cases, one-mirror optical designs provide an ideal solution. Conic surfaces of revolution possess two focal points between which perfect on-axis imaging can be obtained. In the case of the paraboloid, light from an infinitely distant point source is brought to a perfect, on-axis point image. Ellipsoids focus light similarly between two finite conjugate positions.

In the Newtonian Telescope (see Figure 2a), a small diagonal mirror is inserted in the focusing beam to bring it out at a right angle to the incoming beam. This yields a more accessible focused spot, but produces a central obscuration in the aperture which increases the system diffraction spot size.

To eliminate obscuration effects, an off-axis section of the primary mirror can be used in the configuration illustrated in Figure 3b. Known as a Herschelian Telescope, this design is common in collimation and target projection systems.

Space Optics Research Labs offers three On-Axis Newtonian designs and a complete line of 19 Off-Axis Newtonian Series Collimators**,** as well as full custom capabilities to meet your requirements.

Two Mirror Focusing Designs: The addition of a second mirror to the optical design allows the designer to improve the system field-of-view, increase the system focal length within a given package size, or reduce the package size while maintaining a given focal length and performance characteristics.

The Classical Cassegrain Telescope (Figure 2b) employs a parabolic primary mirror, and a hyperbolic secondary positioned such that the parabolic and virtual hyperbolic focuses (fp and fs_1) coincide. In this configuration, the on-axis image produced at the real hyperbolic focus (fs_2) is perfect, but off-axis performance suffers.

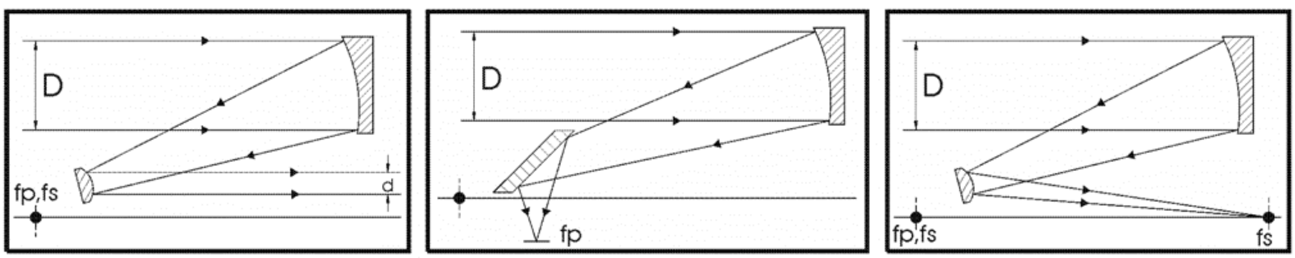
An increased field-of-view can be obtained by using two hyperboloids in a similar configuration. This is known as a Ritchey-Chretien design, which is completely corrected for spherical aberration and coma.

A less expensive design than either the Cassegrain or Ritchey-Chretien — the Dall-Kirkham — uses an ellipsoid primary mirror and a spherical secondary mirror. Here the paraxial focii of the two mirrors are slightly separated, and spherical abberation is corrected by the ellipse. On-axis performance of this system is quite good, but degrades rapidly off-axis. For infrared applications, however, off-axis performance is often adequate.

Using a concave elliptical secondary mirror and parabolic primary results in a Gregorian Telescope (Figure 2c). Designs of this nature, however, are not frequently encountered.

Off-axis versions of each of the above are possible (see Figure 3c), but only the Off-Axis Dall-Kirkham is common.

SORL offers a variety of standard telescope models employing these designs, or will manufacture a system to your specifications. Every model in the Space Optics Research Lab off-axis laser beam expander series offers focusing control to cover application requirements fulfilled by an off-axis Dall-Kirkham design.



a) Off-Axis Dall-Kirkham SORL COAR Series

b) Off-Axis Newtonian SORL TOAN Series

c) Off-Axis Focusing Dall-Kirkham SORL COAR Series

Figure 3 Off-Axis Telescope Designs

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Catadioptric Systems

The introduction of refractive elements to the optical design can, in large part, eliminate the off-axis aberration and field curvature characteristics of reflective telescopes. This is achieved at the expense of the all-reflective broad band spectral and achromatic performance advantages, but is often justified in systems where good imaging over a wide field and discrete wavelength band is desired. The combinations here are limitless, but include such familiar designs as the Schmidt, Schmidt-Cassegrain, and Bouwers-Maksutov. Such designs are often employed in astronomical and reconnaissance applications.

Designing a Telescope

Several parameters must be defined when designing a telescope. Some of these will be determined by the system performance requirements; others must be defined within practical limits such as the available space and operating environment. Here we will discuss some of these factors.

1. **Resolution:** As with any optical system, resolution is perhaps the single most important design consideration. For a telescope, on-axis resolution will depend on the figuring and alignment accuracy of the optical components, atmospheric turbulence, and diffraction. Diffraction effects arise from both the limiting primary mirror aperture and the central obscuration, as described in reference 6. Off-axis resolution over a given field-of-view will further depend on the design adopted.

2. **Mirror Apertures:** The relative size of the primary and secondary mirror apertures are main considerations in the light collecting power and diffraction characteristics of the system. Light collection varies directly with the unobscured primary aperture area. Diffraction depends both on primary mirror aperture and size of secondary obscuration.

3. **Effective Focal Length:** Effective focal length of the telescope system will determine its geometrical imaging properties. Effective f-number will affect image quality. Since effective focal length is determined by the degree to which the primary mirror focal length is magnified by the secondary, flexibility between these focal lengths and the overall required package size is possible. Back focal length should be chosen convenient to the application.

4. **Materials:** As discussed earlier, a wide range of choices are possible including glass, glass-ceramics, and metals. Environment, weight, and accuracy requirements must be considered.

5. **Optical Coatings:** These may be selected from a variety of evaporated metals and dielectric materials for optimal performance in the wavelength region, optical power level, and environment of intended operation.

6. **Housing Design and Mounting Provisions:** Careful consideration must be given to thermal and mechanical stresses, which may affect the optical components directly or their relative alignment.

7. **Manufacturing Difficulty:** A number of design/cost trade-offs are available to the designer of a telescope system: Within the practical limits of structural stability, the cost of a typical system will vary directly with number, accuracy, type and speed of the aspheric components required to meet design specifications. "Asphericity" (Δ) of a conic mirror is given by the relation:

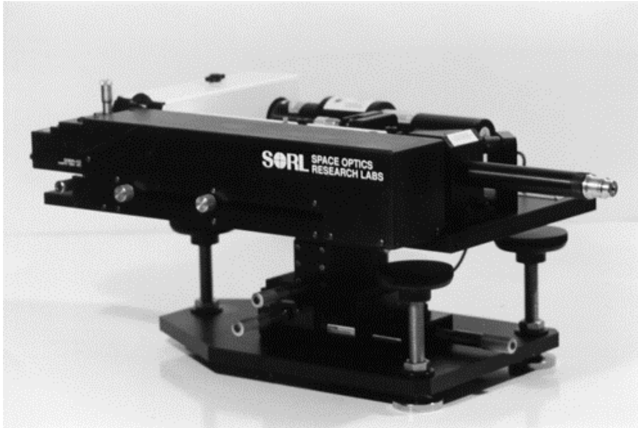
$$\Delta = \frac{kD^4}{4096f^3}$$

where k is the conic constant, D is the diameter, and f is the paraxial focal length. This indicates the amount of material to be removed from " best-fit- sphere" when generating that surface. As the asphericity increases, so does the cost in manufacturing. When testing requirements are also considered, it is found that spherical components are least expensive, followed by parabolics, ellipsoids, hyperboloids, and generalized aspherics, in that order.

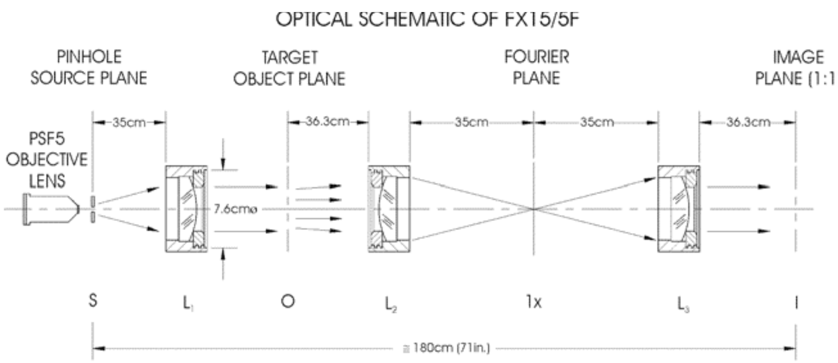
Alignment tolerances become very critical and difficult to maintain in extremely fast systems, and in systems involving two or more aspherics. Thus, it is recommended that reasonable space be allowed for length of system; that apertures of the components be kept at a minimum to meet light collection and resolution requirements; and that operational wavelength region be considered when specifying the figuring accuracy of components and field-of-view performance of the system. In the infrared, it is often found that the least expensive available Newtonian or Dall-Kirkham design is adequate for performance requirements.

References

1. Ingalls, Albert G. ed., **Amateur Telescope Making**, Scientific American, Inc., 1980.
2. Kingslake, Rudolf, **Lens Design Fundamentals**, Academic Press, 1978.
3. Shannon, Robert R., "Aspheric Surfaces", in **Applied Optics and Optical Engineering,** Volume VIII, Chapter 3. Edited by R. R. Shannon & J. C. Wyant, Academic Press, 1980.
4. Smith, Warren J., **Modern Optical Engineering,** McGraw-Hill, 1966.
5. Walker, Bruce H., "Reflectors", in **The Optical Industry and Systems Purchasing Directory,** McGraw-Hill, 1966.
6. Wetherell, William B., "The Calculation of Image Quality", in **Applied Optics and Optical Engineering,** Volume VIII, Chapter 6. Edited by R. R. Shannon and J. C. Wyant, Academic Press, 1980.
7. MIL-HDBK- 141, Optical Design, 1962.



We have Laser Unequal Pathlength Interferometer (LUPI-II™) Systems and Fourier Systems in our product line.



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Laser Unequal Pathlength Interferometer (LUPI-II™) Systems

Test and Align Optics and Systems

The laser unequal pathlength interferometer is a portable, precision instrument for testing and aligning optical components and systems. It can serve as the primary inspection tool for in-process optical fabrication and final quality certification. It is very compact and portable, yet extremely stable and is adaptable to most component or system tests, including coated and uncoated optics in reflection or transmission.

A POWERFUL TOOL FOR TESTING IN APPLICATION AND RESEARCH AND DEVELOPMENT LABORATORIES AND FOR OPTICS FABRICATAOR SHOPS. SIMPLE AND PRECISE OPERATION PROVIDES FOR FAST VISUAL CHECKING OF INTERFEROGRAMS BY EYE, VIDEO CAMERA DISPLAY OR VIA FRINGE ANALYSIS.

The SORL LUPI Interferometer can easily be modified for phase shifting. For such an application a piezo operated flat can simply be placed and mounted in front of the permanent reference flat. The piezo induced phase shift in conjunction with the appropriate camera provides fringe analysis and interferogram interpretation.

This software supported fringe analysis system is available as an option. It permits mapping and averaging, wavefront scanning, fringe fitting, and subtraction of aberrations and polynomials.

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Laser Unequal Pathlength Interferometer

The LUPI is a Twyman-Green type interferometer. In this type of instrument, light coming from the laser source is spatially filtered, collimated and passed through a beam splitter. Half of the light is reflected by the beam splitter and directed to a reference flat. The other half of the light passes through the beam splitter and is tightly focused. This focal point is also the focal point of an object being tested, such as a lens or a mirror.

After reflecting off the mirror being tested and reaching the reference flat, light is retro reflected. It retraces its path through the focal point and back to the beam splitter. In lens testing, beams collimated from the focal point also reach the reference flat and retrace their paths back to the beam splitter

At the beam splitter, the two beams of light recombine. Through constructive and destructive interference of the light waves, a pattern of light and dark fringes are formed. These are observed by the camera and fed to a video screen. The fringe pattern reveals the shape of the test piece and any errors that may be present. It can also be used to determine the focal length and off axis conditions.

The SORL LUPI Interferometer can easily be modified for phase shifting. For such an application a piezo operated flat can simply be placed and mounted in front of the permanent reference flat. The piezo induced phase shift in conjunction with the appropriate camera provides fringe analysis and interferogram interpretation.

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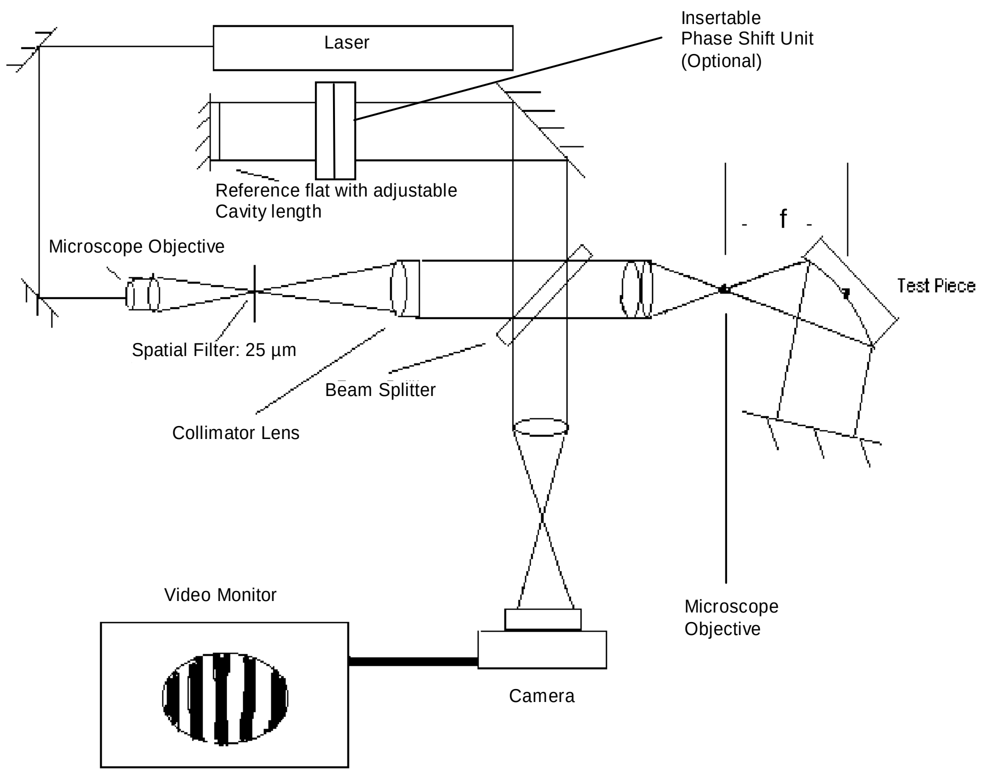
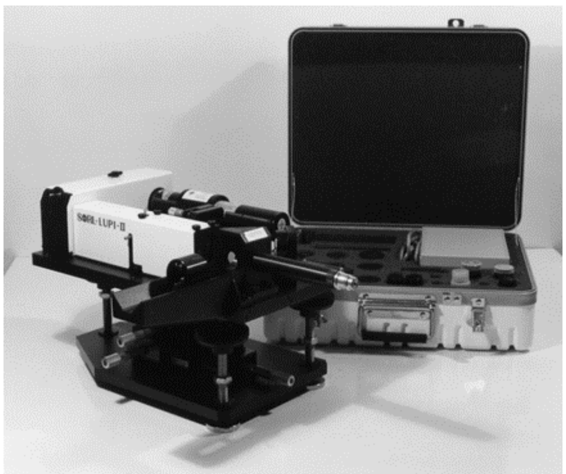


Laser Unequal Pathlength Interferometer

LUPI-II™ Systems

Features

- 2 mW laser, 0.6328 micron wavelength, polarized
- Fully adjustable x-y-z control — precise micrometer positioning
- Tests both focal and afocal telescope systems
- Compact, portable: 18" L x 10.1" W x 10.1" H (460 mm L x 260 mm W x 260 mm H)
- Weight: 47 lbs. (23 kg)
- Cone Angle Range: f/2 - f/8 Stand, (f/1 - f/20 optional)
- Microscope Objective Lens: 10X, V2, 0.25 N.A.
- Imaging Lens, Matched to Objective
- Objective Lens Extension Tube, 6" (150 mm) Long
- Eyepiece
- Complete—Custom Instrument and Accessory Cases



Laser Unequal Pathlength Interferometer (LUPI)
Custom Instrument and Accessory Case

Accessory Kit (AK-I™)

Permits measurement of cone angles from f/2 to f/20

- Microscope objectives (3), including interferograms
- Matching imaging lenses (5)
- Objective extension tubes, 4/10" (10 mm) to 3" (75 mm) long (4)
- Eyepieces*

* Space Optics Research Labs does not recommend this classic approach. Possible eye damage may occur when using an eyepiece with the interferometer. Observe proper laser safety practices. Eye pieces are supplied for image projection not visual use.

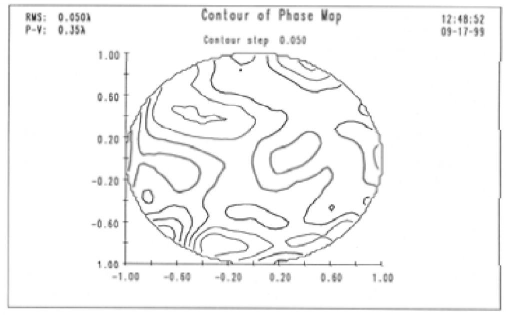
Calibration Sphere with Mount (CSP™)

For calibrating the laser unequal pathlength interferometer:

- 2.5" (75 mm) Diameter, 2.5" (64 mm) Radius of Curvature, λ / 20 P-V (λ = 0.6328 microns) Surface Accuracy
- Cell-Type Mount, Adjustable Tip and Tilt

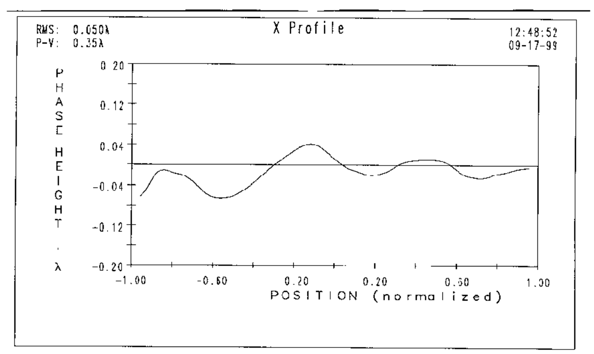
Fringe Analysis System

A powerful tool for testing in Application and Research and Development Laboratories and for Optics Fabricator Shops. Its simple and precise operation provides for fast fringe analysis.



Contour of Phase Map

Permits quality control of most demanding optical components. Phase shift analysis can be routinely performed.



Ph***ase Height***

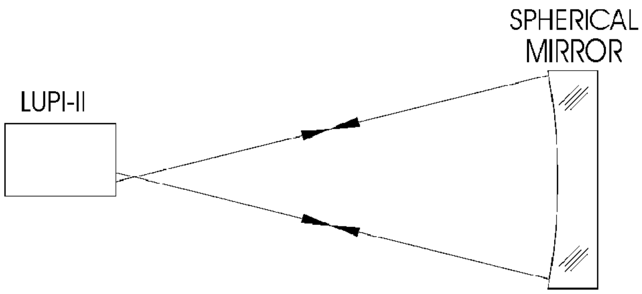
The contour map and phase height profile shown depict typical phase shift data obtained with a LUPI operating with a Fringe analysis system.

Sample Tests with a LUPI

Concave Spherical Mirror Test: Concave spherical mirrors (MSP Series) from 4/10" (10 mm) to 6 ½ feet (2 meters) in diameter may be tested using the laser unequal pathlength interferometer with the proper diverging objective lens.

1. The focal point of the laser unequal pathlength interferometer objective is located at a distance coincident with the radius-of-curvature (rc) of the spherical mirror.
2. The resultant diverging wavefront from the laser unequal pathlength interferometer reflects off the spherical mirror back into the laser unequal pathlength interferometer, where the interference pattern is observed in the image plane, either:
   - Through an eyepiece*
   - On a ground glass screen
   - On a video monitor (LUPI-IIA™ CM)

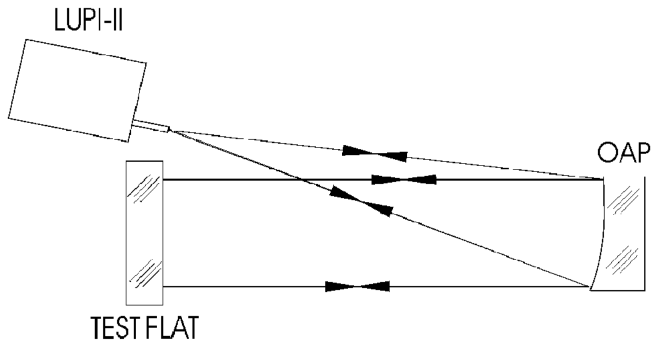
One fringe of deviation indicates λ/2 peak-to valley (p-v) surface accuracy at 0.6328 microns, Helium-Neon laser light.



Off-Axis Parabolic Mirror Test: Interferometric analysis of an off-axis parabolic mirror is achieved using the laser unequal pathlength interferometer and a high quality test flat.

1. The laser unequal pathlength interferometer objective focal point is placed at a distance coincident with the focal length (fl) of the off-axis parabolic mirror.
2. The laser unequal pathlength interferometer objective projects a diverging point source to the off-axis parabolic mirror under test.
3. The off-axis parabolic mirror collimates the point source and projects it to the test flat.
4. The flat mirror autocollimates the light back to the off-axis parabolic mirror that then focuses the light back into the laser unequal pathlength interferometer.
5. Minimal fine tuning of the laser unequal pathlength interferometer, off-axis parabolic mirror and test flat results in optimum interferometric analysis of the parabolic mirror surface (as the laser unequal pathlength interferometer and test flat are of known, calibrated quality).

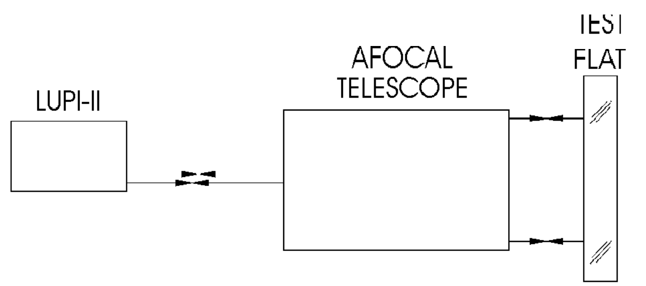
Test configuration is conventionally known as double-pass autocollimation test.



Afocal Optical System Test: An afocal optical system, is analyzed for system wavefront using the laser unequal pathlength interferometer and a precision flat mirror. This double-pass autocollimation test is performed as follows:

1. The laser unequal pathlength interferometer(minus objective diverger) and test flat are oriented such that the collimated laser unequal pathlength interferometer output strikes the test so that the collimated laser unequal pathlength interferometer output flat at normal incidence.
2. T'he afocal system, in this case a telescope, is placed in the optical path and aligned so that the collimated LUPI-IIA™ output transmits through the telescope to the flat. The flat then reflects the beam back through the telescope to the laser unequal pathlength interferometer.

The interferogram produced by the laser unequal pathlength interferometer is examined, with one fringe of deviation equal to λ/2 P-V system wavefront error.



* Space Optics Research Labs does not recommend this classic approach. Possible eye damage may occur when using an eyepiece with the interferometer. Observe proper laser safety practices. Eye pieces are supplied for image projection not visual use.

Fourier System (FX)

The Fourier System (FX) meets the needs of the experimentalist on a very limited budget with a unique combination of hardware and software for a wide variety of applications.*

Fourier System (FX15/5)

- Three 15 in (380 mm) focal length; f/5 lenses — 1 collimating and 2 Fourier) — mounted in cells

Fourier System (FX15/5F)

- Three 15 in (380 mm) focal length; f/5 lenses (1 collimating and 2 Fourier), mounted in cells; plus spatial filter (PSF5) with 40x objective and 10 micron pinhole (F indicates Spatial Filter.)

Fourier System (FX15/5FM)

- Three 15 in (380 mm) focal length; f/5 lenses (1 collimating and 2 Fourier), mounted in cells; plus spatial filter (PSF5) with 40x objective and 10 micron pinhole (F indicates Spatial Filter.) n cells; plus spatial filter PSF5) with 40x objective and 10 micron pinhole (F indicates Spatial Filter and M indicates upright-mounted with "Boys Point" Alignment Technique.)

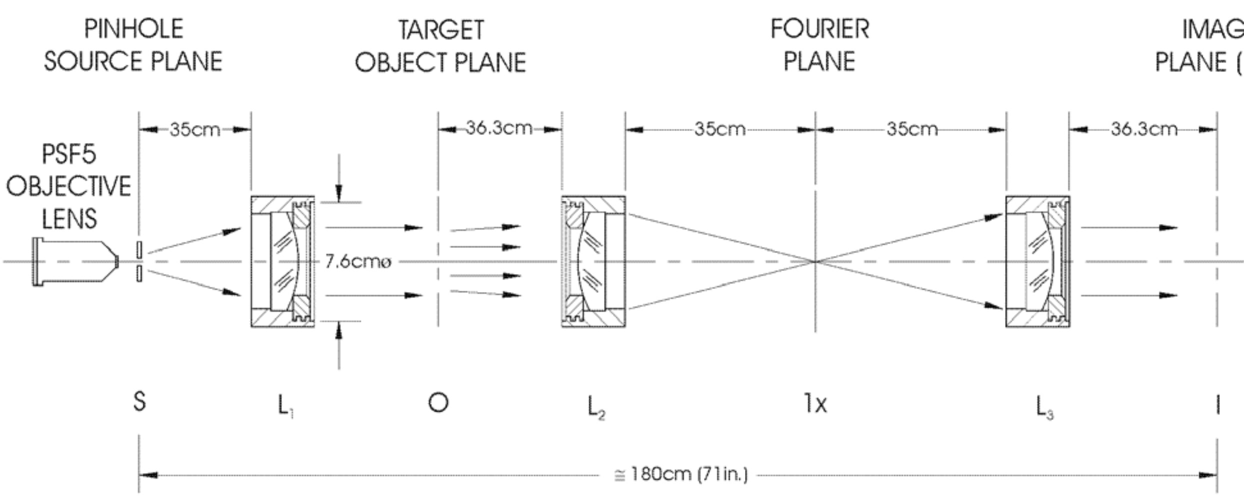
Fourier System (FX15/5FS)

Three 15 in (380 mm) focal length; f/5 lenses (1 collimating and 2 Fourier) , mounted in cells; plus spatial filter (PSF5) with 40x objective and 10 micron pinhole (F indicates Spatial Filter and S indicates basic 3-meter rack and pinion optical rail system.)

Applications

- Computer generated holography
- Hybrid computer-controlled optical correlator for multiple target recognition
- Optical-data processing/liquid crystal television spatial light modulator
- Acouso-optic space integrating correlator
- Color encoding of holographic interferometric fringe patterns with white-light processing
- Coherent optical implementation of generalized two-dimensional transforms

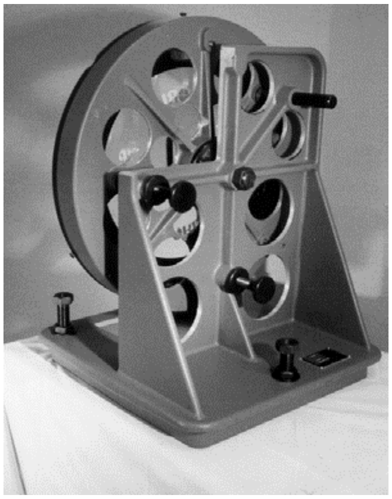
OPTICAL SCHEMATIC OF FX15/5F

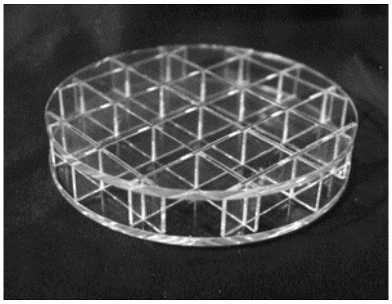


System Operation

Pinhole Spatial Filter takes collimated laser beam and provides diverging output cone via precision X, Y, and Z micrometers, which align 40X objective lens precisely with 10 μ pinhole. Pinhole becomes noise-free source plane[1], S. Collimator Lens, L_1, and two Fourier Lenses, L_2 and L_3, are of achromatic-doublet design, selectively tested for performance at 0.6328 μ, helium-neon, with even higher resolution at 0.4880 μ, argon. Optimum system performance results when all lenses are precisely aligned[2]. The Collimator L_1, located a focal length distance from the pinhole, S, presents a parallel light bundle to the object/target[3], O to be transformed. Fourier Lens, L_2 then transforms the object information at the Fourier transform plane, 1x. The selection and use of an appropriate filter[4] retransforms the filtered object through lens, L_3, to the image plane, I essentially the recording plane.

*For a reference text on the applications of Fourier optics, we recommend "The New Physical Optics Notebook" published by SPIE.





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