



Where Passion Meets Precision™

Catalog of Standard and Custom  
Optical Components





## Try Our New Optical Designer

Our new Optical Designer brings everything you need for custom optics calculations to one place. You can purchase catalog optics or design custom optics that Esco can quote and manufacture.

<http://calc.EscoOptics.com>



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# Introduction

Can I use N-BK7/S-BSL7 or does my application require fused silica? What are the consequences of using a bi-convex lens instead of a plano-convex lens? Which type of neutral density filter best suits my application, metallic coated or solid glass? Do I need  $\lambda/10$ , or will  $\lambda/2$  be precise enough?

Questions such as these are not uncommon in the high tech field of optical design and manufacturing. Today's engineers are faced with a staggering array of available components and configurations to make their designs a reality. From the development of aspheric surface contours, to the more complex thin film coatings, to the formulation of new and more exotic materials, modern fabrication techniques now allow for previously impossible optical designs to become feasible.

*Esco Optics is proud to be at the forefront of this challenging field and offers one of the most comprehensive lines of standard and custom optical elements in the world today.*

Our goal is to ensure our customers easily locate the parts they need, have access to the expertise of our sales and engineering teams, as well as, receive timely and accurate answers to their technical questions.

But wait! It doesn't stop there! Our opticians possess all the skills that are necessary to produce high accuracy elements in low quantities. We also have the capacity to produce high volume, American made components at competitive prices.

Our reputation precedes us. Esco is a proven manufacturing leader of fused silica and quartz, standard optical glasses, low expansion materials, absorptive filters, and a host of others to suit a wide portfolio of custom requests. Whether windows, lenses, prisms, cylinders, or aspheres, all including the application of thin film coatings, Esco Optics is the go to choice for high precision optical components.

We are pleased that you have looked to us as a reliable supplier of your optical needs. We hope that this catalog demonstrates our commitment to excellence, answers many of your questions, and gives you a clearer understanding of why Esco Optics is an industry leader.



Esco Optics new home at 95 Chamberlain Road in Oak Ridge, New Jersey.

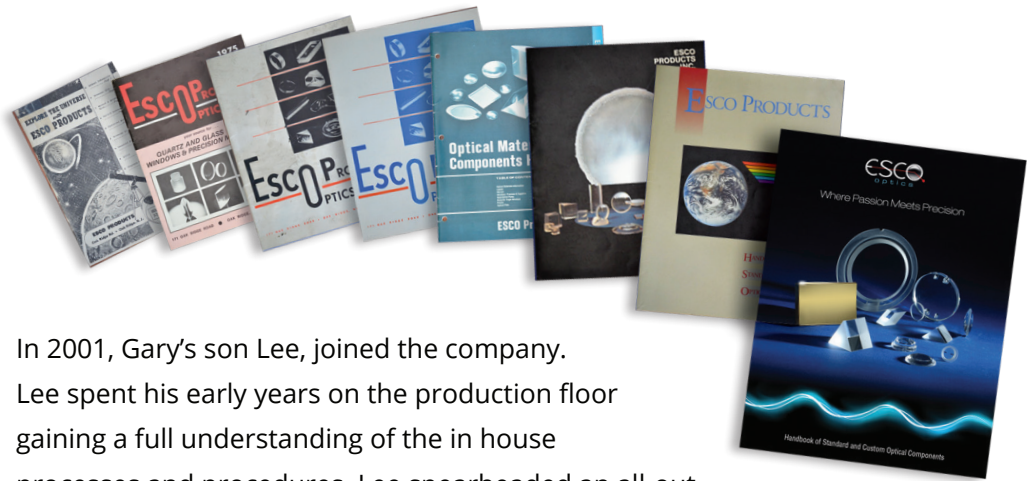


# 60 Years of Optics

## The Foundation of the Past

Esco Optics was founded in the late 1950's in Hoboken, New Jersey. Back then the company was operating under the name Esco Products and was exclusively a supplier of telescope kits for aspiring astronomers.

Fueled by the commitment to quality, Esco's precision component of the business quickly grew to require additional space. Property was purchased at 171 Oak Ridge Road in Oak Ridge, New Jersey. The custom optics business continued to thrive in the 1970's. It was during this time that Gary Steneken, a graduate of Stevens Institute of Technology, joined the company. Gary rose to the position of General Manager in the 1980's and eventually purchased the business to become the sole owner of Esco Products.



In 2001, Gary's son Lee, joined the company. Lee spent his early years on the production floor gaining a full understanding of the in house processes and procedures. Lee spearheaded an all-out effort to refine and optimize the processes by incorporating state of the art fabrication and metrology equipment. The business continued to grow under his direction. In 2011, Lee became a partner in Esco Products and was appointed as President and CEO. The company continued to expand and in 2012 adopted a new name and a new philosophy. Esco Optics was born!

## The Challenges of the Present

On August 10, 2014, disaster struck. A fire raged through the shop at 171 Oak Ridge Road destroying everything. While no one was hurt, the entire facility experienced varying degrees of damage and ultimately culminated in a total loss. While most would think all was lost, Esco rose to the challenge and within a weeks time had a plan to satisfy current and future in house order commitments to its customers. Failure was never an option! All members of the Esco team banded together and began rebuilding the "new" Esco Optics. The fire spawned the image and philosophy of a phoenix rising from the ashes and the mantra of "Rising Above".

Most recently, in 2015, Lee bought the business from his father and became the sole owner of Esco Optics!

### **The Rise of the Future**

The “new” Esco Optics is moving to a 27,000 square foot facility at 95 Chamberlin Road in Oak Ridge, New Jersey. The company will be expanding the building for increased production capabilities and adding a second floor to accommodate the administrative offices. With these renovations, the total square footage will equal 32,000 square feet! Esco has had the unique opportunity to re-invent the organization from the ground up. The manufacturing flow is based on lean manufacturing principals, in addition to, the optimization of the fabrication processes. Since the fire, Esco Optics has doubled its lens manufacturing capacity for both the spherical, aspherical, acylindrical, and free form elements. Moreover, Esco has tripled its plano capacity and metrology and coating equipment have been greatly improved upon.



## ITAR Registered and Compliant

As the leader for military and defense optics in the United States, Esco Optics adheres to the International Traffic in Arms Regulations (ITAR), a set of government regulations that controls the manufacturing and exporting activities of defense services.

ITAR registered and compliant, Esco manufactures ITAR optics with the strictest confidentiality. ITAR regulations dictate that information and materials pertaining to defense and military-related technologies may only be shared with U.S. Persons unless authorization from the Department of State is received.

***Your order information will be kept confidential  
when you purchase optical components from Esco.***

We take great precautions in securing our manufacturing plant as well as all sensitive documents and prints. As an ITAR registered and compliant manufacturer, you will have peace of mind knowing all federal rules and regulations will be followed in order to manufacture your optical components.



Esco applies the ITAR regulation to all its customers. Whether you are purchasing catalog optics or custom precision optical components, your information and usage will remain classified.



## Products and Capabilities

Our top priority is to provide customers with the highest quality and most accurate optics in the industry. From catalog optics to custom optical components, we are committed to manufacturing optical components that meet or exceed your specifications.

The majority of our staff has been with the company for over 20 years, demonstrating their expertise and delivering products you will be completely satisfied with. We strive to maintain an elevated level of customer service, where you are always treated with respect and in a timely manner.

Our process begins and ends with quality control. Every order we receive is reviewed and confirmed. We encourage open lines of communication throughout the manufacturing and delivery of your optical components.

# Products and Capabilities

| Products                                          | Capabilities                              |
|---------------------------------------------------|-------------------------------------------|
| Spherical, Cylindrical, and Aspherical lenses     | Scratch Dig: $\leq 5-2$ per MIL-PRF-13830 |
| Precision Flats and Wedges                        | Flatness: $\leq \lambda/10$               |
| Plano and Spherical Mirrors                       | Wedge: $\leq 1$ arc sec                   |
| Commercial Windows and Wafers                     | Centering TIR: $\leq 30$ arc sec          |
| Beamsplitters Cubes and Plates                    | Parallelism: $\leq 1$ arc sec             |
| Colored Filters, ND Filters, and Bandpass Filters | Max Diameter: 16" (406 mm)                |
| Sapphire Components                               | Min Thickness: 0.004" (0.10 mm)           |
| Complete in-house coating capabilities            | Precision Bevels: $\pm 0.001$ "           |
| Fused Silica, BK-7, and Substrate Blanks          | Surface Roughness: $\leq 5 \text{ \AA}$   |

## Why Should You Choose Esco Optics?

- Esco Optics is vertically integrated, creating lower pricing and shorter lead times
- Esco incorporates a tenured work force with state of the art CNC machinery and metrology
- Esco stocks all optical materials for UV, Visible, and IR applications
- Esco maintains an extensive OEM catalog as well as the ability to manufacture custom optical elements
- Double-Sided and CP polishing centers allow Esco to achieve high accuracy surface flatness and parallelism
- Spherical and Aspherical lenses are produced on OptiPro and OptoTech CNC machine centers, which ensure precision and repeatability
- Optipro OptiTrace and Mahr LD150 3D profilometers provide accurate and precise metrology of all lenses
- An in-house coating facility provides standard and custom coatings including: Metallic Reflectors, Anti-Reflective Coatings, Beamsplitter Coatings, and Bandpass Filters
- Esco's philosophy is to treat every customer with the utmost respect, as Esco's success is measured by the success of their customers



## Conversion Tables

The following conversion tables are for your understanding and calculations in making better decisions for your specific needs. If you have any questions please contact us at 1-800-922-ESCO (3726) or email [sales@EscoOptics.com](mailto:sales@EscoOptics.com)

# Conversion Tables

| Conversion Table                    | * Interference Fringes @632.8 nm | Inches (in) | Micro Inches (µin) | Millimeters (mm) | Microns (µ) | Nanometers (nm) | Angstroms (Å) |
|-------------------------------------|----------------------------------|-------------|--------------------|------------------|-------------|-----------------|---------------|
|                                     | 0.05                             | 6.2283E-07  | 0.62               | 0.0000158        | 0.0158200   | 15.82           | 158           |
|                                     | 0.1                              | 1.2457E-06  | 1.25               | 0.0000316        | 0.0316400   | 31.64           | 316           |
|                                     | 0.25                             | 3.1142E-06  | 3.11               | 0.0000791        | 0.0791000   | 79.10           | 791           |
|                                     | 0.3                              | 3.7370E-06  | 3.74               | 0.0000949        | 0.0949200   | 94.92           | 949           |
|                                     | 0.4                              | 4.9827E-06  | 4.98               | 0.0001266        | 0.1265600   | 126.56          | 1266          |
|                                     | 0.5                              | 6.2283E-06  | 6.23               | 0.0001582        | 0.1582000   | 158.20          | 1582          |
|                                     | 0.6                              | 7.4740E-06  | 7.47               | 0.0001898        | 0.1898400   | 189.84          | 1898          |
|                                     | 0.7                              | 8.7197E-06  | 8.72               | 0.0002215        | 0.2214799   | 221.48          | 2215          |
|                                     | 0.8                              | 9.9654E-06  | 9.97               | 0.0002531        | 0.2531199   | 253.12          | 2531          |
|                                     | 0.9                              | 0.0000112   | 11.21              | 0.0002848        | 0.2847599   | 284.76          | 2848          |
|                                     | 1                                | 0.0000125   | 12.46              | 0.0003164        | 0.3163999   | 316.40          | 3164          |
|                                     | 2                                | 0.0000249   | 24.91              | 0.0006328        | 0.6327999   | 632.80          | 6328          |
|                                     | 3                                | 0.0000374   | 37.37              | 0.0009492        | 0.9491998   | 949.20          | 9492          |
|                                     | 4                                | 0.0000498   | 49.83              | 0.0012656        | 1.2655997   | 1265.60         | 12656         |
|                                     | 5                                | 0.0000623   | 62.28              | 0.0015820        | 1.5819996   | 1582.00         | 15820         |
|                                     | 6                                | 0.0000747   | 74.74              | 0.0018984        | 1.8983996   | 1898.40         | 18984         |
|                                     | 7                                | 0.0000872   | 87.20              | 0.0022148        | 2.2147995   | 2214.80         | 22148         |
|                                     | 8                                | 0.0000997   | 99.65              | 0.0025312        | 2.5311994   | 2531.20         | 25312         |
|                                     | 9                                | 0.0001121   | 112.11             | 0.0028476        | 2.8475993   | 2847.60         | 28476         |
|                                     | 10                               | 0.0001246   | 124.57             | 0.0031640        | 3.1639993   | 3164.00         | 31640         |
| * Values assume that 2 fringes = 1λ |                                  |             |                    |                  |             |                 |               |

| Metrology Terms | Prefix | Symbol | Scientific Value      |  | Prefix | Symbol | Scientific Value     |
|-----------------|--------|--------|-----------------------|--|--------|--------|----------------------|
|                 | femto  | f      | 1 x 10 <sup>-15</sup> |  | hecto  | h      | 1 x 10 <sup>2</sup>  |
|                 | pico   | p      | 1 x 10 <sup>-12</sup> |  | kilo   | k      | 1 x 10 <sup>3</sup>  |
|                 | nano   | n      | 1 x 10 <sup>-9</sup>  |  | mega   | M      | 1 x 10 <sup>6</sup>  |
|                 | micro  | µ      | 1 x 10 <sup>-6</sup>  |  | giga   | G      | 1 x 10 <sup>9</sup>  |
|                 | milli  | m      | 1 x 10 <sup>-3</sup>  |  | tera   | T      | 1 x 10 <sup>12</sup> |
|                 | centi  | c      | 1 x 10 <sup>-2</sup>  |  | peta   | P      | 1 x 10 <sup>15</sup> |

| Angles to Linear Measurement | Angle      | Per Inch | Per mm    | Per 10 mm | Per 25 mm | Per 50 mm | Per 100 mm |
|------------------------------|------------|----------|-----------|-----------|-----------|-----------|------------|
|                              | 1 arc sec  | 0.000050 | 0.0000020 | 0.000020  | 0.000049  | 0.000098  | 0.000197   |
|                              | 5 arc sec  | 0.000024 | 0.0000009 | 0.000009  | 0.000024  | 0.000047  | 0.000094   |
|                              | 10 arc sec | 0.000048 | 0.0000019 | 0.000019  | 0.000047  | 0.000094  | 0.000189   |
|                              | 30 arc sec | 0.000145 | 0.0000057 | 0.000057  | 0.000143  | 0.000285  | 0.000571   |
|                              | 1 arc min  | 0.000291 | 0.0000115 | 0.000115  | 0.000286  | 0.000573  | 0.001146   |
|                              | 5 arc min  | 0.001455 | 0.0000573 | 0.000573  | 0.001432  | 0.002864  | 0.005728   |
|                              | 10 arc min | 0.002910 | 0.0001146 | 0.001146  | 0.002864  | 0.005728  | 0.011457   |
|                              | 30 arc min | 0.008730 | 0.0003437 | 0.003437  | 0.008593  | 0.017185  | 0.034370   |

# Conversion Tables

| Flatness Conversion Table                                                                     | Number of Bands | Microinches<br>(Millionths of an Inch) | Inches    | Millimeters |
|-----------------------------------------------------------------------------------------------|-----------------|----------------------------------------|-----------|-------------|
|                                                                                               | 0.1             | 1.2                                    | 0.0000012 | 0.000032    |
|                                                                                               | 0.2             | 2.5                                    | 0.0000025 | 0.000063    |
|                                                                                               | 0.3             | 3.7                                    | 0.0000037 | 0.000095    |
|                                                                                               | 0.4             | 5                                      | 0.0000050 | 0.000127    |
|                                                                                               | 0.5             | 6.2                                    | 0.0000062 | 0.000158    |
|                                                                                               | 0.6             | 7.5                                    | 0.0000075 | 0.000190    |
|                                                                                               | 0.7             | 8.7                                    | 0.0000087 | 0.000221    |
|                                                                                               | 0.8             | 10                                     | 0.0000100 | 0.000253    |
|                                                                                               | 0.9             | 11.2                                   | 0.0000112 | 0.000285    |
|                                                                                               | 1.0             | 12.5                                   | 0.0000125 | 0.000316    |
|                                                                                               | 2.0             | 24.9                                   | 0.0000249 | 0.000633    |
|                                                                                               | 3.0             | 37.4                                   | 0.0000374 | 0.000949    |
|                                                                                               | 4.0             | 49.8                                   | 0.0000498 | 0.001266    |
|                                                                                               | 5.0             | 62.3                                   | 0.0000623 | 0.001582    |
|                                                                                               | 6.0             | 74.7                                   | 0.0000747 | 0.001898    |
|                                                                                               | 7.0             | 87.2                                   | 0.0000872 | 0.002215    |
|                                                                                               | 8.0             | 99.7                                   | 0.0000997 | 0.002531    |
|                                                                                               | 9.0             | 112.1                                  | 0.0001121 | 0.002848    |
|                                                                                               | 10.0            | 124.6                                  | 0.0001246 | 0.003164    |
|                                                                                               | 11.0            | 137                                    | 0.0001370 | 0.003480    |
|                                                                                               | 12.0            | 149.5                                  | 0.0001495 | 0.003797    |
|                                                                                               | 13.0            | 161.9                                  | 0.0001619 | 0.004113    |
|                                                                                               | 14.0            | 174.4                                  | 0.0001744 | 0.004430    |
|                                                                                               | 15.0            | 186.9                                  | 0.0001869 | 0.004746    |
|                                                                                               | 16.0            | 199.3                                  | 0.0001993 | 0.005062    |
|                                                                                               | 17.0            | 211.8                                  | 0.0002118 | 0.005379    |
|                                                                                               | 18.0            | 224.2                                  | 0.0002242 | 0.005695    |
|                                                                                               | 19.0            | 236.7                                  | 0.0002367 | 0.006012    |
|                                                                                               | 20.0            | 249.1                                  | 0.0002491 | 0.006328    |
| Millimeters or inches is wavelength dependent. Assumes reference $\lambda = 632.8 \text{ nm}$ |                 |                                        |           |             |



A bank of Speed Fam 16 B double sided polishers ready for service in Esco's new facility.

## Glass Reference Chart

The following chart lists the glass types according to their industry standard glass codes. The first three numbers represent the refractive index and the last three numbers are the dispersion. For example, the first glass code 471673 represents an index of 1.471 and a dispersion of 67.3. The codes are listed in order of increasing refractive index.

# Glass Reference Chart

| Code    | Schott         | Code    | Ohara          | Code    | Hoya          | Code    | CDGM          |
|---------|----------------|---------|----------------|---------|---------------|---------|---------------|
| ---     | ---            | 439 950 | <b>S-FPL53</b> | ---     | ---           | ---     | ---           |
| ---     | ---            | ---     | ---            | 457 903 | <b>FCD10</b>  | 457 903 | <b>H-FK71</b> |
| 471 673 | <b>FK1</b>     | 471 674 | <b>FSL1</b>    | 471 673 | <b>FC1</b>    | 470 668 | <b>H-QK1</b>  |
| 487 704 | <b>N-FK5</b>   | 487 702 | <b>S-FSL5</b>  | 487 704 | <b>FC5</b>    | 487 704 | <b>H-QK3L</b> |
| 487 845 | <b>N-FK51A</b> | ---     | ---            | ---     | ---           | ---     | ---           |
| 497 816 | <b>N-PK52A</b> | 497 816 | <b>S-FPL51</b> | 497 816 | <b>FCD1</b>   | 497 816 | <b>H-FK61</b> |
| 498 670 | <b>N-BK10</b>  | ---     | ---            | ---     | ---           | ---     | ---           |
| 500 658 | <b>BK4</b>     | 500 660 | <b>BSL4</b>    | 500 660 | <b>BSC4</b>   | 500 660 | <b>H-K2</b>   |
| 501 564 | <b>K10</b>     | ---     | ---            | ---     | ---           | ---     | ---           |
| ---     | ---            | ---     | ---            | 505 650 | <b>BK5</b>    | 505 647 | <b>H-K3</b>   |
| 508 612 | <b>N-ZK7</b>   | 508 608 | <b>ZSL7</b>    | 508 613 | <b>ZNC7</b>   | 508 611 | <b>K4A</b>    |
| 510 635 | <b>BK1</b>     | 510 636 | <b>BSL1</b>    | 510 634 | <b>BSC1</b>   | 510 634 | <b>H-K5</b>   |
| 511 604 | <b>K7</b>      | 511 605 | <b>NSL7</b>    | 511 605 | <b>C7</b>     | 511 605 | <b>H-K6</b>   |
| ---     | ---            | ---     | ---            | ---     | ---           | 515 606 | <b>H-K7</b>   |
| 517 642 | <b>N-BK7</b>   | 516 641 | <b>S-BSL7</b>  | 517 642 | <b>BSC7</b>   | 517 642 | <b>H-K9L</b>  |
| ---     | ---            | 517 524 | <b>S-NSL36</b> | 517 522 | <b>E-CF6</b>  | 517 522 | <b>H-KF6</b>  |
| ---     | ---            | 518 590 | <b>S-NSL3</b>  | 518 590 | <b>E-C3</b>   | 518 590 | <b>H-K10</b>  |
| ---     | ---            | ---     | ---            | ---     | ---           | 518 635 | <b>D-K59</b>  |
| 522 595 | <b>N-K5</b>    | 522 598 | <b>S-NSL5</b>  | 522 595 | <b>C5</b>     | 522 592 | <b>H-K50</b>  |
| 523 515 | <b>N-KF9</b>   | ---     | ---            | ---     | ---           | ---     | ---           |
| ---     | ---            | 523 585 | <b>NSL51</b>   | 523 586 | <b>C12</b>    | 523 586 | <b>H-K51</b>  |
| ---     | ---            | ---     | ---            | ---     | ---           | 525 704 | <b>D-PK3</b>  |
| 526 600 | <b>BALK1</b>   | 526 600 | <b>NSL21</b>   | 526 601 | <b>BACL1</b>  | 526 602 | <b>H-K11</b>  |
| 529 770 | <b>N-PK51</b>  | ---     | ---            | ---     | ---           | ---     | ---           |
| ---     | ---            | ---     | ---            | ---     | ---           | 530 605 | <b>H-BaK1</b> |
| 531 488 | <b>LLF6</b>    | 532 489 | <b>PBL6</b>    | 532 488 | <b>FEL6</b>   | 532 488 | <b>QF6</b>    |
| 532 489 | <b>N-LLF6</b>  | 532 489 | <b>S-TIL6</b>  | 532 488 | <b>E-FEL6</b> | 532 488 | <b>H-QF6A</b> |
| 540 597 | <b>N-BAK2</b>  | 540 595 | <b>S-BAL12</b> | 540 597 | <b>BAC2</b>   | 540 597 | <b>H-BaK2</b> |
| 541 472 | <b>LLF2</b>    | 541 472 | <b>PBL2</b>    | 541 472 | <b>FEL2</b>   | 541 472 | <b>QF8</b>    |
| ---     | ---            | 541 472 | <b>S-TIL2</b>  | 541 472 | <b>E-FEL2</b> | 541 472 | <b>H-QF8</b>  |
| 547 536 | <b>N-BALF5</b> | ---     | ---            | ---     | ---           | ---     | ---           |
| 548 458 | <b>N-FEL1</b>  | 548 458 | <b>S-TIL1</b>  | 548 458 | <b>E-FEL1</b> | 548 458 | <b>H-QF1</b>  |
| 548 458 | <b>LLF1</b>    | 548 458 | <b>PBL1</b>    | 548 458 | <b>FEL1</b>   | 548 459 | <b>QF1</b>    |
| ---     | ---            | ---     | ---            | 548 628 | <b>BAL21</b>  | 547 628 | <b>H-BaK3</b> |
| 552 635 | <b>N-PSK3</b>  | 552 638 | <b>BAL23</b>   | 552 634 | <b>PCD3</b>   | 552 634 | <b>H-BaK4</b> |

# Glass Reference Chart

| Code    | Schott         | Code    | Ohara          | Code    | Hoya            | Code    | CDGM          |
|---------|----------------|---------|----------------|---------|-----------------|---------|---------------|
| 558 540 | <b>N-KZFS2</b> | ---     | ---            | ---     | ---             | ---     | ---           |
| ---     | ---            | ---     | ---            | ---     | ---             | 561 583 | <b>H-BaK5</b> |
| 564 608 | <b>N-SK11</b>  | 564 607 | <b>S-BAL41</b> | 564 608 | <b>BACD11</b>   | 564 608 | <b>H-BaK6</b> |
| ---     | ---            | 567 428 | <b>S-TIL26</b> | 567 428 | <b>E-FL6</b>    | 567 428 | <b>H-QF56</b> |
| 569 560 | <b>N-BAK4</b>  | 569 563 | <b>S-BAL14</b> | 569 560 | <b>BAC4</b>     | 569 560 | <b>H-BaK7</b> |
| 569 631 | <b>PSK2</b>    | 569 631 | <b>BAL22</b>   | 569 631 | <b>PCD2</b>     | 569 629 | <b>H-ZK1</b>  |
| 570 494 | <b>BAF2</b>    | 570 493 | <b>BAM2</b>    | 570 492 | <b>BAF2</b>     | 570 495 | <b>BaF2</b>   |
| ---     | ---            | 571 508 | <b>S-BAL2</b>  | ---     | ---             | ---     | ---           |
| ---     | ---            | 571 530 | <b>S-BAL3</b>  | ---     | ---             | ---     | ---           |
| 573 576 | <b>N-BAK1</b>  | 573 575 | <b>S-BAL11</b> | 573 575 | <b>BAC1</b>     | 573 575 | <b>H-BaK8</b> |
| 575 415 | <b>LF7</b>     | 575 415 | <b>PBL27</b>   | 575 413 | <b>FL7</b>      | 575 413 | <b>QF3</b>    |
| ---     | ---            | 575 415 | <b>S-TIL27</b> | ---     | ---             | 575 415 | <b>H-QF3</b>  |
| 580 539 | <b>N-BALF4</b> | ---     | ---            | 580 539 | <b>N-BALF4</b>  | 580 537 | <b>H-BaF3</b> |
| 581 409 | <b>LF5</b>     | 581 407 | <b>PBL25</b>   | 581 409 | <b>FL5</b>      | 581 409 | <b>QF50</b>   |
| 581 409 | <b>N-LF5</b>   | 581 407 | <b>S-TIL25</b> | 581 409 | <b>E-FL5</b>    | 581 409 | <b>H-QF50</b> |
| 582 421 | <b>LF3</b>     | 582 421 | <b>PBL23</b>   | 582 420 | <b>FL3</b>      | 582 420 | <b>QF5</b>    |
| ---     | ---            | 583 464 | <b>S-BAM3</b>  | ---     | ---             | ---     | ---           |
| 583 595 | <b>SK12</b>    | 583 594 | <b>S-BAL42</b> | 583 595 | <b>BACD12</b>   | 583 595 | <b>H-ZK2</b>  |
| ---     | ---            | 583 594 | <b>L-BAL42</b> | 583 595 | <b>M-BACD12</b> | 583 594 | <b>D-ZK2</b>  |
| 589 613 | <b>N-SK5</b>   | 589 612 | <b>S-BAL35</b> | 589 613 | <b>BACD5</b>    | 589 613 | <b>H-ZK3</b>  |
| 589 612 | <b>P-SK58A</b> | 589 612 | <b>L-BAL35</b> | 589 613 | <b>M-BACD5N</b> | 589 612 | <b>D-ZK3</b>  |
| ---     | ---            | 593 353 | <b>S-FTM16</b> | 593 355 | <b>FF5</b>      | ---     | ---           |
| ---     | ---            | 595 677 | <b>S-FPM2</b>  | ---     | ---             | ---     | ---           |
| ---     | ---            | 596 392 | <b>S-TIM8</b>  | 596 392 | <b>E-F8</b>     | 596 392 | <b>H-QF14</b> |
| 603 380 | <b>F5</b>      | 603 380 | <b>PBM5</b>    | 603 380 | <b>F5</b>       | 603 380 | <b>F1</b>     |
| ---     | ---            | 603 380 | <b>S-TIM5</b>  | 603 380 | <b>E-F5</b>     | 603 380 | <b>H-F1</b>   |
| 603 606 | <b>N-SK14</b>  | 603 607 | <b>S-BSM14</b> | 603 607 | <b>BACD14</b>   | 603 606 | <b>H-ZK14</b> |
| ---     | ---            | 603 655 | <b>S-PHM53</b> | ---     | ---             | 603 655 | <b>H-ZPK2</b> |
| 606 437 | <b>BAF4</b>    | 606 437 | <b>BAM4</b>    | 606 439 | <b>BAF4</b>     | 606 439 | <b>BaF5</b>   |
| 606 437 | <b>N-BAF4</b>  | 606 437 | <b>S-BAM4</b>  | ---     | ---             | ---     | ---           |
| ---     | ---            | ---     | ---            | 606 637 | <b>LBC3N</b>    | ---     | ---           |
| 607 567 | <b>N-SK2</b>   | 607 568 | <b>BSM2</b>    | 607 567 | <b>BACD2</b>    | 607 567 | <b>H-ZK50</b> |
| ---     | ---            | 607 568 | <b>S-BSM2</b>  | ---     | ---             | ---     | ---           |
| ---     | ---            | ---     | ---            | 608 462 | <b>BAF7</b>     | 608 462 | <b>H-BaF6</b> |
| 609 466 | <b>N-BAF52</b> | ---     | ---            | ---     | ---             | ---     | ---           |

# Glass Reference Chart

| Code    | Schott          | Code    | Ohara          | Code    | Hoya            | Code    | CDGM           |
|---------|-----------------|---------|----------------|---------|-----------------|---------|----------------|
| ---     | ---             | ---     | ---            | ---     | ---             | 609 579 | <b>D-ZK79</b>  |
| 609 589 | <b>SK3</b>      | 609 590 | <b>BSM3</b>    | 609 589 | <b>BACD3</b>    | 609 589 | <b>H-ZK4</b>   |
| 611 559 | <b>SK8</b>      | 611 559 | <b>BSM8</b>    | 611 558 | <b>BACD8</b>    | 611 558 | <b>H-ZK5</b>   |
| 613 370 | <b>F3</b>       | 613 370 | <b>PBM3</b>    | 613 370 | <b>F3</b>       | 613 370 | <b>F2</b>      |
| ---     | ---             | 613 370 | <b>S-TIM3</b>  | 613 370 | <b>E-F3</b>     | 613 370 | <b>H-F2</b>    |
| 613 443 | <b>KZFS4</b>    | 613 442 | <b>BPM51</b>   | 613 443 | <b>ADF40</b>    | 612 441 | <b>TF3</b>     |
| ---     | ---             | 613 443 | <b>S-NBM51</b> | ---     | ---             | 613 441 | <b>H-TF3L</b>  |
| 613 445 | <b>N-KZFS4</b>  | ---     | ---            | ---     | ---             | ---     | ---            |
| 613 586 | <b>N-SK4</b>    | 613 587 | <b>S-BSM4</b>  | 613 586 | <b>BACD4</b>    | 613 586 | <b>H-ZK6</b>   |
| ---     | ---             | ---     | ---            | ---     | ---             | 613 606 | <b>H-ZK7</b>   |
| ---     | ---             | ---     | ---            | ---     | ---             | 614 400 | <b>BaF7</b>    |
| ---     | ---             | ---     | ---            | 613 444 | <b>E-ADF10</b>  | ---     | ---            |
| 614 552 | <b>SK9</b>      | 614 550 | <b>S-BSM9</b>  | 614 551 | <b>BACD9</b>    | 614 551 | <b>H-ZK8</b>   |
| 617 366 | <b>F4</b>       | 617 366 | <b>PBM4</b>    | 617 366 | <b>F4</b>       | 617 366 | <b>F3</b>      |
| 617 539 | <b>SSK1</b>     | 617 540 | <b>BSM21</b>   | 617 539 | <b>BACED1</b>   | 617 539 | <b>H-ZK20</b>  |
| 618 498 | <b>N-SSK8</b>   | 618 498 | <b>S-BSM28</b> | ---     | ---             | ---     | ---            |
| 618 634 | <b>N-PSK53A</b> | 618 634 | <b>S-PHM52</b> | 618 634 | <b>PCD4</b>     | 618 634 | <b>H-ZPK1</b>  |
| 620 364 | <b>F2</b>       | 620 363 | <b>PBM2</b>    | 620 363 | <b>F2</b>       | 620 364 | <b>F4</b>      |
| 620 364 | <b>N-F2</b>     | 620 363 | <b>S-TIM2</b>  | 620 363 | <b>E-F2</b>     | 620 364 | <b>H-F4</b>    |
| 620 603 | <b>N-SK16</b>   | 620 603 | <b>S-BSM16</b> | 620 603 | <b>BACD16</b>   | 620 603 | <b>H-ZK9B</b>  |
| ---     | ---             | ---     | ---            | 620 622 | <b>ADC1</b>     | ---     | ---            |
| ---     | ---             | ---     | ---            | 621 359 | <b>PBM11</b>    | 624 359 | <b>F5</b>      |
| 622 533 | <b>N-SSK2</b>   | 622 532 | <b>S-BSM22</b> | ---     | ---             | 622 532 | <b>H-ZBaF1</b> |
| ---     | ---             | ---     | ---            | ---     | ---             | 622 567 | <b>H-ZK10</b>  |
| 622 570 | <b>N-SK10</b>   | 623 570 | <b>S-BSM10</b> | 623 569 | <b>E-BACD10</b> | 623 569 | <b>H-ZK10L</b> |
| 623 580 | <b>N-SK15</b>   | 623 582 | <b>S-BSM15</b> | 623 581 | <b>BACD15</b>   | 623 581 | <b>H-ZK21</b>  |
| ---     | ---             | ---     | ---            | 624 471 | <b>E-BAF8</b>   | ---     | ---            |
| ---     | ---             | ---     | ---            | 625 356 | <b>F7</b>       | 625 356 | <b>F6</b>      |
| ---     | ---             | 626 357 | <b>S-TIM1</b>  | 626 357 | <b>E-F1</b>     | 626 357 | <b>H-F13</b>   |
| 626 357 | <b>F1</b>       | 626 357 | <b>PBM1</b>    | 626 375 | <b>F1</b>       | 626 357 | <b>F13</b>     |
| 626 390 | <b>BASF1</b>    | 626 392 | <b>BAM21</b>   | 626 391 | <b>BAFD1</b>    | 626 391 | <b>H-BaF8</b>  |
| 636 353 | <b>F6</b>       | 636 354 | <b>PBM6</b>    | 636 353 | <b>F6</b>       | 636 354 | <b>F7</b>      |
| 638 424 | <b>N-KZFS11</b> | ---     | ---            | ---     | ---             | ---     | ---            |
| ---     | ---             | 639 449 | <b>S-BAM12</b> | ---     | ---             | ---     | ---            |
| 639 554 | <b>N-SK18</b>   | 639 554 | <b>S-BSM18</b> | 639 555 | <b>BACD18</b>   | 639 555 | <b>H-ZK11</b>  |

# Glass Reference Chart

| Code    | Schott         | Code    | Ohara          | Code    | Hoya              | Code    | CDGM            |
|---------|----------------|---------|----------------|---------|-------------------|---------|-----------------|
| ---     | ---            | 640 354 | <b>S-TIM27</b> | 640 354 | <b>E-FD7</b>      | 640 354 | <b>H-F51</b>    |
| ---     | ---            | ---     | ---            | ---     | ---               | 640 483 | <b>ZBaF2</b>    |
| 640 601 | <b>N-LAK21</b> | 640 601 | <b>S-BSM81</b> | 640 602 | <b>LACL60</b>     | 640 602 | <b>H-LaK4L</b>  |
| 648 339 | <b>SF2</b>     | 648 338 | <b>PBM22</b>   | 648 338 | <b>FD2</b>        | 648 338 | <b>ZF1</b>      |
| 648 338 | <b>N-SF2</b>   | 648 338 | <b>S-TIM22</b> | 648 338 | <b>E-FD2</b>      | 648 338 | <b>H-ZF1</b>    |
| ---     | ---            | 649 530 | <b>S-BSM71</b> | 649 530 | <b>E-BACEED20</b> | ---     | ---             |
| 651 559 | <b>N-LAK22</b> | 651 562 | <b>S-LAL54</b> | 650 557 | <b>LACL12</b>     | 651 559 | <b>H-LaK10</b>  |
| 652 450 | <b>N-BAF51</b> | ---     | ---            | ---     | ---               | ---     | ---             |
| 652 585 | <b>N-LAK7</b>  | 652 585 | <b>S-LAL7</b>  | 652 584 | <b>LAC7</b>       | 652 584 | <b>H-LaK50A</b> |
| 654 337 | <b>SF9</b>     | 654 336 | <b>PBM29</b>   | 654 337 | <b>FD9</b>        | 654 337 | <b>ZF8</b>      |
| 654 397 | <b>N-KZFS5</b> | 654 397 | <b>S-NBH5</b>  | 654 396 | <b>E-ADF50</b>    | ---     | ---             |
| ---     | ---            | ---     | ---            | ---     | ---               | 657 511 | <b>H-ZBaF3</b>  |
| 658 509 | <b>N-SSK5</b>  | 658 509 | <b>S-BSM25</b> | 658 509 | <b>BACED5</b>     | 658 509 | <b>H-ZBaF50</b> |
| 660 573 | <b>LAK11</b>   | ---     | ---            | 660 573 | <b>LAC11</b>      | 660 574 | <b>H-LaK1</b>   |
| 664 360 | <b>N-BASF2</b> | ---     | ---            | ---     | ---               | ---     | ---             |
| ---     | ---            | ---     | ---            | ---     | ---               | 665 546 | <b>H-LaK11</b>  |
| ---     | ---            | 667 330 | <b>S-TIM39</b> | ---     | ---               | 667 330 | <b>H-ZF39</b>   |
| 667 484 | <b>BAFN11</b>  | 667 483 | <b>S-BAH11</b> | 667 483 | <b>BAF11</b>      | 667 484 | <b>H-ZBaF16</b> |
| 668 419 | <b>BASF6</b>   | ---     | ---            | 668 419 | <b>BAFD6</b>      | 668 419 | <b>ZBaF17</b>   |
| ---     | ---            | ---     | ---            | ---     | ---               | 669 554 | <b>D-LaK70</b>  |
| ---     | ---            | 670 393 | <b>S-BAH32</b> | ---     | ---               | ---     | ---             |
| 670 471 | <b>N-BAF10</b> | 670 473 | <b>S-BAH10</b> | 670 472 | <b>BAF10</b>      | 670 472 | <b>H-ZBaF52</b> |
| ---     | ---            | ---     | ---            | 670 516 | <b>LAL53</b>      | 670 517 | <b>H-LaK67</b>  |
| ---     | ---            | ---     | ---            | ---     | ---               | 671 473 | <b>H-ZBaF5</b>  |
| 673 322 | <b>SF5</b>     | 673 321 | <b>PBM25</b>   | 673 322 | <b>FD5</b>        | 673 322 | <b>ZF2</b>      |
| 673 323 | <b>N-SF5</b>   | 673 321 | <b>S-TIM25</b> | 673 322 | <b>E-FD5</b>      | 673 322 | <b>H-ZF2</b>    |
| ---     | ---            | 673 382 | <b>S-NBH52</b> | ---     | ---               | ---     | ---             |
| ---     | ---            | 678 507 | <b>S-LAL56</b> | ---     | ---               | ---     | ---             |
| 678 552 | <b>N-LAK12</b> | 678 553 | <b>S-LAL12</b> | 678 555 | <b>LAC12</b>      | 678 555 | <b>H-LaK5A</b>  |
| 683 445 | <b>BAF50</b>   | ---     | ---            | 683 447 | <b>BAF22</b>      | 683 445 | <b>ZBaF51</b>   |
| 689 313 | <b>SF8</b>     | 689 311 | <b>PBM28</b>   | 689 312 | <b>FD8</b>        | 689 312 | <b>ZF10</b>     |
| 689 313 | <b>N-SF8</b>   | 689 311 | <b>S-TIM28</b> | 689 312 | <b>E-FD8</b>      | 689 312 | <b>H-ZF10</b>   |
| 689 312 | <b>P-SF8</b>   | 689 311 | <b>L-TIM28</b> | 689 312 | <b>M-FD80</b>     | 689 311 | <b>D-ZF10</b>   |
| 691 547 | <b>N-LAK9</b>  | 691 548 | <b>S-LAL9</b>  | 691 547 | <b>LAC9</b>       | 691 548 | <b>H-LaK59A</b> |
| ---     | ---            | ---     | ---            | ---     | ---               | 692 545 | <b>H-LaK2A</b>  |

# Glass Reference Chart

| Code    | Schott          | Code    | Ohara          | Code    | Hoya            | Code    | CDGM            |
|---------|-----------------|---------|----------------|---------|-----------------|---------|-----------------|
| ---     | ---             | 694 508 | <b>S-LAL58</b> | 694 508 | <b>LACL5</b>    | 694 492 | <b>H-LaF1</b>   |
| 694 533 | <b>N-LAK13</b>  | 694 532 | <b>S-LAL13</b> | 694 533 | <b>LAC13</b>    | 694 534 | <b>H-LaK6A</b>  |
| 694 532 | <b>P-LAK35</b>  | 694 532 | <b>L-LAL13</b> | 694 532 | <b>M-LAC130</b> | 694 531 | <b>D-LaK6</b>   |
| ---     | ---             | 697 485 | <b>S-LAM59</b> | 697 485 | <b>LAFL2</b>    | ---     | ---             |
| 697 554 | <b>N-LAK14</b>  | 697 555 | <b>S-LAL14</b> | 697 555 | <b>LAC14</b>    | 697 555 | <b>H-LaK51A</b> |
| ---     | ---             | ---     | ---            | 697 565 | <b>LAL64</b>    | 697 562 | <b>H-LaK12</b>  |
| 699 302 | <b>SF15</b>     | 699 301 | <b>PBM35</b>   | 699 301 | <b>FD15</b>     | 699 301 | <b>ZF11</b>     |
| 699 302 | <b>N-SF15</b>   | 699 301 | <b>S-TIM35</b> | 699 301 | <b>E-FD15</b>   | 699 301 | <b>H-ZF11</b>   |
| ---     | ---             | 700 481 | <b>S-LAM51</b> | ---     | ---             | 700 481 | <b>H-LaF51</b>  |
| ---     | ---             | ---     | ---            | 702 402 | <b>BAFD15</b>   | ---     | ---             |
| 702 410 | <b>N-BASF52</b> | 702 412 | <b>S-BAH27</b> | 702 412 | <b>BAFD7</b>    | 702 412 | <b>H-ZBaF20</b> |
| 704 394 | <b>N-BASF64</b> | ---     | ---            | ---     | ---             | ---     | ---             |
| 713 538 | <b>N-LAK8</b>   | 713 539 | <b>S-LAL8</b>  | 713 539 | <b>LAC8</b>     | 713 538 | <b>H-LaK7A</b>  |
| 717 295 | <b>SF1</b>      | 717 295 | <b>PBH1</b>    | 717 295 | <b>FD1</b>      | 717 295 | <b>ZF3</b>      |
| 717 296 | <b>N-SF1</b>    | 717 295 | <b>S-TIH1</b>  | 717 295 | <b>E-FD1</b>    | 717 295 | <b>H-ZF3</b>    |
| 717 480 | <b>N-LAF3</b>   | 717 479 | <b>S-LAM3</b>  | 717 480 | <b>LAF3</b>     | 717 479 | <b>H-LaF2</b>   |
| 720 347 | <b>N-KZFS8</b>  | 720 347 | <b>S-NBH8</b>  | ---     | ---             | ---     | ---             |
| ---     | ---             | 720 420 | <b>S-LAM58</b> | ---     | ---             | ---     | ---             |
| ---     | ---             | 720 437 | <b>S-LAM52</b> | ---     | ---             | 720 437 | <b>H-LaF62</b>  |
| ---     | ---             | 720 460 | <b>S-LAM61</b> | ---     | ---             | ---     | ---             |
| 720 506 | <b>N-LAK10</b>  | 720 502 | <b>S-LAL10</b> | 720 503 | <b>LAC10</b>    | 720 503 | <b>H-LaK8A</b>  |
| ---     | ---             | 722 292 | <b>S-TIH18</b> | ---     | ---             | ---     | ---             |
| 724 381 | <b>N-BASF51</b> | 723 380 | <b>S-BAH28</b> | 723 380 | <b>BAFD8</b>    | 723 380 | <b>H-ZBaF21</b> |
| 728 284 | <b>SF10</b>     | 728 285 | <b>PBH10</b>   | 728 283 | <b>FD10</b>     | 728 283 | <b>ZF4</b>      |
| 728 285 | <b>N-SF10</b>   | 728 285 | <b>S-TIH10</b> | 728 283 | <b>E-FD10</b>   | 728 283 | <b>H-ZF4</b>    |
| 729 545 | <b>N-LAK34</b>  | 729 547 | <b>S-LAL18</b> | 729 547 | <b>TAC8</b>     | 729 547 | <b>H-LaK52</b>  |
| ---     | ---             | 731 405 | <b>L-LAM69</b> | 731 405 | <b>M-LAF81</b>  | 731 405 | <b>D-LaF79</b>  |
| ---     | ---             | ---     | ---            | 733 489 | <b>L-LAM72</b>  | 735 488 | <b>D-LaF82L</b> |
| ---     | ---             | 734 515 | <b>S-LAL59</b> | 734 511 | <b>TAC4</b>     | 734 515 | <b>H-LaK54</b>  |
| ---     | ---             | 738 323 | <b>S-NBH53</b> | ---     | ---             | ---     | ---             |
| 740 282 | <b>SF3</b>      | 740 283 | <b>PBH3</b>    | 740 282 | <b>FD3</b>      | 740 282 | <b>ZF5</b>      |
| ---     | ---             | 740 283 | <b>S-TIH3</b>  | ---     | ---             | 740 283 | <b>H-ZF5</b>    |
| 741 276 | <b>SF13</b>     | 741 278 | <b>PBH13</b>   | 741 278 | <b>FD13</b>     | 741 278 | <b>ZF50</b>     |
| ---     | ---             | 741 278 | <b>S-TIH13</b> | 741 278 | <b>E-FD13</b>   | 741 278 | <b>H-ZF50</b>   |
| ---     | ---             | 741 527 | <b>S-LAL61</b> | 741 526 | <b>TAC2</b>     | 741 527 | <b>H-LaK61</b>  |

# Glass Reference Chart

| Code    | Schott          | Code    | Ohara           | Code    | Hoya            | Code    | CDGM             |
|---------|-----------------|---------|-----------------|---------|-----------------|---------|------------------|
| 743 494 | <b>N-LAF35</b>  | 743 493 | <b>S-LAM60</b>  | 743 492 | <b>NBF1</b>     | 743 492 | <b>H-LaF53</b>   |
| ---     | ---             | ---     | ---             | 743 493 | <b>M-NBF1</b>   | 743 493 | <b>D-LaF53</b>   |
| 744 449 | <b>N-LAF2</b>   | 744 448 | <b>S-LAM2</b>   | 744 449 | <b>LAF2</b>     | 744 449 | <b>H-LaF3B</b>   |
| ---     | ---             | ---     | ---             | ---     | ---             | 747 510 | <b>H-LaK3</b>    |
| 750 348 | <b>N-LAF7</b>   | 750 353 | <b>S-LAM7</b>   | 750 350 | <b>E-LAF7</b>   | 750 350 | <b>H-LaF4</b>    |
| 750 350 | <b>LAFN7</b>    | 750 353 | <b>S-NBH51</b>  | ---     | ---             | ---     | ---              |
| ---     | ---             | ---     | ---             | 752 251 | <b>FF8</b>      | ---     | ---              |
| ---     | ---             | ---     | ---             | ---     | ---             | 754 375 | <b>H-LaFL5</b>   |
| 754 523 | <b>N-LAK33A</b> | 755 523 | <b>S-YGH51</b>  | 755 523 | <b>TAC6</b>     | 755 523 | <b>H-LaK53A</b>  |
| 755 274 | <b>N-SF4</b>    | 755 275 | <b>S-TIH4</b>   | 755 275 | <b>E-FD4</b>    | 755 275 | <b>H-ZF6</b>     |
| 755 276 | <b>SF4</b>      | 755 275 | <b>PBH4</b>     | 755 275 | <b>FD4</b>      | 755 275 | <b>ZF6</b>       |
| 755 523 | <b>N-LAK33B</b> | 755 523 | <b>S-YGH51</b>  | ---     | ---             | ---     | ---              |
| 757 478 | <b>LAFN24</b>   | 757 478 | <b>S-LAM54</b>  | 757 477 | <b>NBF2</b>     | 757 477 | <b>H-LaF6LA</b>  |
| 762 265 | <b>SF14</b>     | 762 265 | <b>PBH14</b>    | 762 266 | <b>FD14</b>     | 762 266 | <b>ZF12</b>      |
| 762 265 | <b>N-SF14</b>   | 762 265 | <b>S-TIH14</b>  | 762 266 | <b>FD140</b>    | 762 266 | <b>H-ZF12</b>    |
| ---     | ---             | 762 401 | <b>S-LAM55</b>  | ---     | ---             | 762 401 | <b>H-LaF55</b>   |
| ---     | ---             | ---     | ---             | 768 492 | <b>M-TAF101</b> | 768 493 | <b>D-LaF050</b>  |
| 773 496 | <b>N-LAF34</b>  | 773 496 | <b>S-LAH66</b>  | 773 496 | <b>TAF1</b>     | 773 496 | <b>H-LaF50B</b>  |
| 782 372 | <b>LAF22A</b>   | 783 362 | <b>S-LAM62</b>  | 783 361 | <b>NBFD7</b>    | 782 371 | <b>H-LaF7</b>    |
| ---     | ---             | 785 257 | <b>PBH11</b>    | 785 257 | <b>FD11</b>     | 785 258 | <b>ZF13</b>      |
| 785 257 | <b>N-SF11</b>   | 785 257 | <b>S-TIH11</b>  | 785 257 | <b>FD110</b>    | 785 257 | <b>H-ZF13</b>    |
| 785 258 | <b>SF11</b>     | ---     | ---             | ---     | ---             | ---     | ---              |
| 785 261 | <b>SF56A</b>    | 785 262 | <b>PBH23</b>    | 785 261 | <b>FDS3</b>     | 785 261 | <b>ZF51</b>      |
| ---     | ---             | ---     | ---             | 785 261 | <b>FDS30</b>    | ---     | ---              |
| ---     | ---             | 785 263 | <b>S-TIH23</b>  | ---     | ---             | ---     | ---              |
| 786 441 | <b>N-LAF33</b>  | 786 442 | <b>S-LAH51</b>  | 786 439 | <b>NBFD11</b>   | 786 442 | <b>H-LaF52</b>   |
| 788 475 | <b>N-LAF21</b>  | 788 474 | <b>S-LAH64</b>  | 788 475 | <b>TAF4</b>     | 788 475 | <b>H-LaF10LA</b> |
| ---     | ---             | ---     | ---             | 795 454 | <b>TAF2</b>     | ---     | ---              |
| ---     | ---             | 800 299 | <b>S-NBH55</b>  | ---     | ---             | ---     | ---              |
| 800 424 | <b>N-LAF36</b>  | 800 422 | <b>S-LAH52</b>  | 800 423 | <b>NBFD12</b>   | 800 422 | <b>H-LaF54</b>   |
| 801 350 | <b>N-LASF45</b> | 801 350 | <b>S-LAM66</b>  | ---     | ---             | 801 350 | <b>H-ZLaF66</b>  |
| ---     | ---             | ---     | ---             | 802 443 | <b>NBFD14</b>   | 802 443 | <b>H-ZLaF1</b>   |
| ---     | ---             | ---     | ---             | 803 467 | <b>LAH62</b>    | 803 468 | <b>H-ZLaF2A</b>  |
| ---     | ---             | 804 396 | <b>S-LAH63</b>  | 805 396 | <b>NBFD3</b>    | 805 396 | <b>H-ZLaF51</b>  |
| 804 465 | <b>N-LASF44</b> | 804 466 | <b>S-LAH65V</b> | 804 465 | <b>TAF3</b>     | 804 466 | <b>H-ZLaF50D</b> |

# Glass Reference Chart

| Code    | Schott           | Code     | Ohara           | Code    | Hoya              | Code     | CDGM              |
|---------|------------------|----------|-----------------|---------|-------------------|----------|-------------------|
| 805 254 | <b>SF6</b>       | 805 254  | <b>PBH6</b>     | 805 255 | <b>FD6</b>        | 805 255  | <b>ZF7L</b>       |
| 805 254 | <b>N-SF6</b>     | 805 254  | <b>S-TIH6</b>   | 805 255 | <b>FD60</b>       | 805 255  | <b>H-ZF7LA</b>    |
| ---     | ---              | ---      | ---             | ---     | ---               | 806 254  | <b>ZF7</b>        |
| ---     | ---              | ---      | ---             | 806 333 | <b>NBFD15</b>     | 806 333  | <b>H-ZLaF56B</b>  |
| 806 406 | <b>N-LASF43</b>  | 806 409  | <b>S-LAH53</b>  | 806 407 | <b>NBFD13</b>     | 806 410  | <b>H-ZLaF52</b>   |
| ---     | ---              | ---      | ---             | 806 407 | <b>M-NBFD130</b>  | ---      | ---               |
| ---     | ---              | 808 228  | <b>S-NPH1</b>   | ---     | ---               | ---      | ---               |
| 809 405 | <b>P-LASF50</b>  | ---      | ---             | 808 409 | <b>MC-NBFD135</b> | 809 410  | <b>D-ZLaF81</b>   |
| 810 409 | <b>P-LASF51</b>  | ---      | ---             | ---     | ---               | 810 410  | <b>D-ZLaF52LA</b> |
| ---     | ---              | ---      | ---             | 815 370 | <b>M-NBFD82</b>   | ---      | ---               |
| ---     | ---              | 816 466  | <b>S-LAH59</b>  | 816 466 | <b>TAF5</b>       | 816 466  | <b>H-ZLaF69</b>   |
| 834 373 | <b>N-LASF40</b>  | 834 372  | <b>S-LAH60</b>  | 834 373 | <b>NBFD10</b>     | 834 372  | <b>H-ZLaF53A</b>  |
| 835 431 | <b>N-LASF41</b>  | 835 427  | <b>S-LAH55V</b> | 835 427 | <b>TAFD5F</b>     | 835 427  | <b>H-ZLaF55C</b>  |
| ---     | ---              | ---      | ---             | 835 430 | <b>TAFD5</b>      | ---      | ---               |
| ---     | ---              | 847 238  | <b>S-TIH53</b>  | ---     | ---               | ---      | ---               |
| 847 238 | <b>SF57</b>      | 847 239  | <b>S-NPH53</b>  | 847 238 | <b>FDS9</b>       | 847 238  | <b>ZF52</b>       |
| 847 238 | <b>N-SF57</b>    | 847 238  | <b>S-TIH53</b>  | 847 238 | <b>FDS90</b>      | 847 238  | <b>H-ZF52A</b>    |
| ---     | ---              | ---      | ---             | ---     | ---               | 850 301  | <b>H-ZLaF76</b>   |
| 850 322 | <b>N-LASF9</b>   | 850 323  | <b>S-LAH71</b>  | ---     | ---               | 850 323  | <b>H-ZLaF71</b>   |
| ---     | ---              | ---      | ---             | ---     | ---               | ---      | ---               |
| ---     | ---              | 857 406  | <b>L-LAH85</b>  | 851 401 | <b>TAFD305</b>    | 854 406  | <b>D-ZLaF85L</b>  |
| ---     | ---              | ---      | ---             | 855 366 | <b>TAFD13</b>     | 855 366  | <b>H-ZLaF3</b>    |
| ---     | ---              | ---      | ---             | 882 372 | <b>M-TAFD307</b>  | 884 372  | <b>D-ZLaF67</b>   |
| 881 403 | <b>N-LASF31A</b> | ---      | ---             | ---     | ---               | ---      | ---               |
| 883 410 | <b>N-LASF31</b>  | 883 408  | <b>S-LAH58</b>  | 883 408 | <b>TAFD30</b>     | 883 408  | <b>H-ZLaF68B</b>  |
| ---     | ---              | ---      | ---             | ---     | ---               | 901 371  | <b>H-ZLaF78</b>   |
| 904 313 | <b>N-LASF46A</b> | ---      | ---             | 904 313 | <b>TAFD25</b>     | 904 313  | <b>H-ZLaF75A</b>  |
| 904 313 | <b>N-LASF46B</b> | ---      | ---             | ---     | ---               | ---      | ---               |
| ---     | ---              | ---      | ---             | 911 353 | <b>TAFD35</b>     | 911 353  | <b>H-ZLaF4LA</b>  |
| ---     | ---              | 923 189  | <b>S-NPH2</b>   | ---     | ---               | 923 189  | <b>H-ZF72A</b>    |
| 923 209 | <b>N-SF66</b>    | ---      | ---             | 923 209 | <b>E-FDS1</b>     | 923 209  | <b>H-ZF62</b>     |
| ---     | ---              | ---      | ---             | 946 180 | <b>FDS18</b>      | 946 180  | <b>H-ZF88</b>     |
| ---     | ---              | 959 175  | <b>S-NPH3</b>   | ---     | ---               | 959 175  | <b>H-ZF73</b>     |
| ---     | ---              | ---      | ---             | ---     | ---               | 2001 292 | <b>H-ZLaF92</b>   |
| ---     | ---              | 2003 283 | <b>S-LAH79</b>  | ---     | ---               | 2003 284 | <b>H-ZLaF90</b>   |

## Optical Formulas

To ensure an accurate solution of these and other optical formulas, proper sign convention must be observed. The common illustrative convention (and the one used in this handbook) is to show light traveling from left to right. If this convention is used, then it follows that:

- The object distance,  $s_o$ , is + to a left of the lens and - to the right
- The image distance,  $s_i$ , is + to a right of the lens and - to the left
- A radius is + when its center of curvature is to the right of the surface, and is - when its center of curvature is to the left
- Lens thicknesses and indices of refraction are always positive

# Optical Formulas

The component of a ray of light transmitting from one optical medium into another is refracted according to Snell's Law,

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where  $n_1$  is the index of refraction of the first medium,  $\theta_1$  is the angle of the incident ray to the surface normal,  $n_2$  is the index of refraction of the second medium, and  $\theta_2$  is the angle of the transmitted ray to the surface normal.

The equation above implies that when  $n_1$  is greater than  $n_2$ , no light will pass into the second medium beyond a critical angle,  $\theta_c$ ; it will instead experience total internal reflection

$$\theta_c = \sin^{-1} \left( \frac{n_2}{n_1} \right)$$

The single surface reflectance  $\rho$  of a wave normal to an optical material is determined by the material's index of refraction,  $n$

$$\rho = \left( \frac{n_1 - n_2}{n_1 + n_2} \right)^2$$

When absorption is negligible, the total transmittance  $T$  of a plane parallel plate in incoherent light is

$$T = \frac{2n}{(n^2 + 1)}$$

The portion of light that an optical material with some absorptance transmits internally (neglecting surface reflections) is its internal transmittance  $\tau_i$

$$\tau_i = e^{-\alpha t}$$

where  $\alpha$  is the absorption coefficient of the material and  $t$  is its thickness. Its total transmittance,  $T$ , is then given as

$$T = \frac{(1 - \rho)^2 e^{-\alpha t}}{1 - \rho^2 e^{-2\alpha t}}$$

When attenuation is desired (as in a neutral density filter) we use the term optical density, OD, to describe the ratio of the transmitted energy to the incident energy.

$$OD = \log \left( \frac{1}{T} \right) \quad T = 10^{-OD}$$

where  $T$  is the total transmittance of the sample and 100% is expressed as 1. OD values of stacks of filters add algebraically, and for a given melt batch OD varies directly with thickness (neglecting surface reflections.)

The following lens equations are paraxial, and neglect aberrations inherent in spherical-curve lenses; the best focal spot of a positive lens with low  $f/\#$  will be closer to the lens than its paraxial effective focal length. Distances  $s$  and  $d$  in these equations refer to principal points, which have locations that are not coincident and not in general at the center or the surface of a lens. For simplicity we may approximate their locations as the center of a lens. Equations for the exact location of the principal points are at the end of this section.

# Optical Formulas

The effective focal length,  $f$ , of a lens can be expressed as

$$\frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)t_c}{nR_1R_2} \right)$$

where  $R_1$  and  $R_2$  are the radii of curvature,  $t_c$  is the center thickness, and  $n$  is the lens material's index of refraction.

The following approximation may be used for estimation purposes when  $t_c$  is small compared to the difference between the radii.

$$\frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

The back focal length, BFL, is the distance from the lens' rear surface to its focal point with object at infinite distance. It can be obtained from  $f$  by using

$$BFL = f \left( 1 - \frac{(n-1)t_c}{nR_1} \right)$$

When both object and image are at finite distances  $s_1$  and  $s_2$  from the lens, the conjugate distances are related to  $f$  by the following

$$\frac{1}{f} = \frac{1}{s_1} + \frac{1}{s_2}$$

where  $s_1$  is the distance from the object to the first principal point, and  $s_2$  is the distance from the second principal point to the image. These principal points are not coincident, but for thin lenses we may use the lens center as a useful approximation to their locations.

The resultant focal length of a system made up of multiple separated elements may be obtained by using

$$f_{ab} = \frac{f_a f_b}{f_a + f_b - d}$$

Where  $f_{ab}$  is the resultant focal length of the combination of lenses with focal lengths  $f_a$  and  $f_b$ , and  $d$  is the distance from the first lens' second principal point to the second lens' first principal point. For thin lenses,  $d$  may be approximated as the distance between the lens centers. For systems with more than two elements,  $f_{ab}$  can be used again as though it were the first element when combining with  $f_c$ , etc.

The magnification,  $m$ , of a finite conjugate system is given by

$$m = \frac{s_i}{s_o} = \frac{f}{s_o - f} = \frac{s_i - f}{f}$$

where  $s_i$  is the image distance and  $s_o$  is the object distance, measured from their respective principal points.

The f-number,  $f/\#$ , of a lens is the ratio of its focal length  $f$  to the diameter  $D$  of its entrance pupil.

The numerical aperture, NA, of a lens in air is the sine of the half cone angle of light approaching the focus.

$$f/\# = \frac{f}{D} \cong \frac{1}{2NA} \quad NA = n \sin \theta$$

The sagittal height of a single lens surface,  $h$ , is

$$h = \frac{D^2}{4R \left( 1 + \sqrt{1 - \frac{D^2}{4R^2}} \right)}$$

where  $R$  is the radius of the surface and  $D$  is the diameter of the lens.

# Optical Formulas

The edge thickness of a lens,  $t_e$ , is then

$$t_e = t_c - h_1 + h_2$$

where  $h_1$  and  $h_2$  are the respective surface sagitta of  $R_1$  and  $R_2$ , maintaining our sign conventions, and  $t_c$  is the center thickness.

The total thickness,  $t_t$ , of a cylinder into which the entire lens would fit can be obtained by adding to  $t_c$  the absolute values of sagitta from only concave surfaces.

The volume of a lens with spherical surfaces and cylindrical edge is

$$V = \pi \left[ \frac{D^2}{4} (t_c - h_1 - h_2) + h_1^2 \left( R_1 - \frac{h_1}{3} \right) + h_2^2 \left( R_2 - \frac{h_2}{3} \right) \right]$$

where  $h_1$  and  $h_2$  are the properly signed sagitta of  $R_1$  and  $R_2$ ,  $t_c$  is the lens center thickness, and  $D$  is its diameter. Its mass can be calculated by multiplying its volume by the specific gravity of the lens material.

Principal point locations  $H$  and  $H''$  with respect to the lens vertex points  $V_1$  and  $V_2$  are found by

$$\overline{V_1 H} = \frac{-f(n-1)t_c}{R_2 n} \quad \overline{V_2 H''} = \frac{-f(n-1)t_c}{R_1 n}$$

where the distances are positive when the principal points lie to the right of their respective vertices. Equivalent expressions not requiring the focal length are

$$\overline{V_1 H} = \frac{-R_1 t_c}{n(R_2 - R_1) + t_c(n-1)}$$

$$\overline{V_2 H} = \frac{-R_2 t_c}{n(R_2 - R_1) + t_c(n-1)}$$

Distances  $s_x$  and  $d$  in previous lens equations may be evaluated according to these expressions.

Aspheric surfaces are traditionally described according to their sagitta

$$z(r) = \frac{r^2}{R \left( 1 + \sqrt{1 - (1 + \kappa) \frac{r^2}{R^2}} \right)} + \alpha_4 r^4 + \alpha_6 r^6 + \dots$$

Where  $z_r$  is the sagitta parallel to the optical axis,  $r$  is the radial distance from the optical axis,  $R$  is the vertex radius,  $\kappa$  is the conic constant, and  $\alpha_n$  are coefficients of radial power terms.

The “best-fit sphere” to an (on-axis) asphere is that sphere from which the least volume of material must be removed to reach the asphere. For simplicity it is usually taken as the sphere having the same overall sagitta as the asphere

$$R_{BFS} = \frac{h^2 + \frac{D^2}{4}}{2h}$$

Where  $R_{BFS}$  is the radius of the best-fit sphere,  $D$  is its diameter, and  $h$  is the aspheric sagitta at its full diameter. In some cases this may not represent the very least material removal.

Sight-glass burst pressure,  $P$ , is given as

$$P = \frac{3.48 \sigma t^2}{kA}$$

where  $\sigma$  is the rupture strength of the material,  $t$  is its thickness,  $A$  is the unsupported area and  $k$  is the “safety factor.” Good practice sets  $k \geq 10$  especially where injury or substantial loss is possible.

**NOTE:**  $\sigma$  is rupture strength, not tensile strength. We put “safety factor” in quotes because many unknowns reduce the rupture strength of a given sample. We express no guarantees.

## Optical Materials



Esco Optics stocks most types and grades of UV, visible, and IR materials including, fused quartz and fused silica, optical glass, color filter glass, low expansion materials and display glasses.

### **Fused Quartz or Fused Silica?**

A common optical material question is the difference between fused silica and fused quartz. Fused quartz is made by the melting of highly pure, crushed natural quartz. Fused silica is made by melting highly pure silica through a flame hydrolysis process where it oxidizes and forms an amorphous (crystal-free) structure. Both materials provide a high and broad range of transmission, a low coefficient of thermal expansion, and excellent chemical resistance; however, quartz, due to metallic impurities in the crushed precursor material, does not transmit well in the ultraviolet spectrum.



## UV Grade Fused Silica

Esco's material designation of UV grade fused silica is S1-UV. S1-UV is an excellent choice of material for visible applications as well.

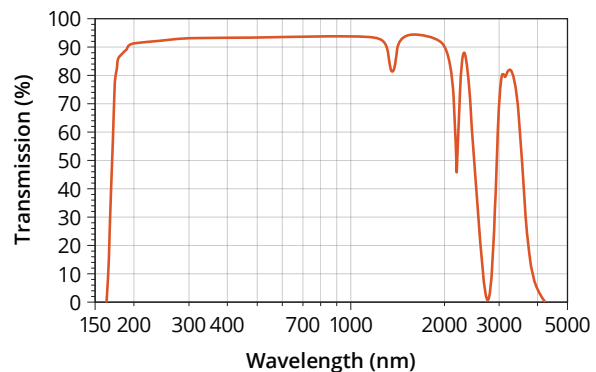
S1-UV materials offer superior transmission and minimal fluorescence and discoloration when employed in UV applications as low as 190 nm. Their outstanding homogeneity makes them ideal for systems where internal wave front performance is critical while also providing the low coefficient of thermal expansion and chemical resistance that is a hallmark of fused silica.

### Optimum Transmission Range:

- 170 nm - 2.2  $\mu\text{m}$
- 2.9  $\mu\text{m}$  - 3.6  $\mu\text{m}$

### Typical Applications:

- Deep UV transmission elements
- Minimum scattering systems
- Microlithography
- Low thermal expansion substrates



## Infrared Grade Fused Silica

Esco's material catalog designation of IR grade fused silica is I2-IR. I2-IR is manufactured from Corning 7979 fused silica. Esco also supplies Heraeus Infrasil 301 and 302 when requested.

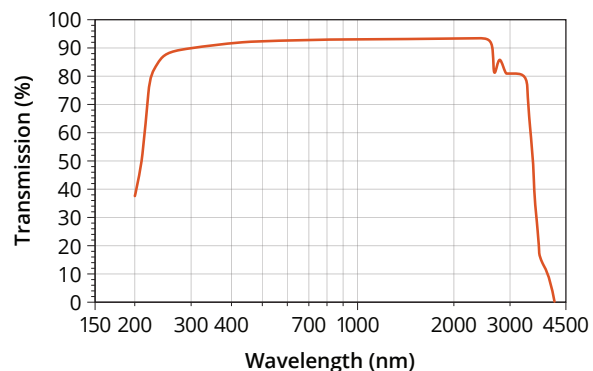
I2-IR grade fused silica is virtually free of OH<sup>-</sup> ions providing superior transmittance at the 2.7  $\mu\text{m}$  wavelength "water band" region where standard UV grade fused silica absorbs light. The low OH content (<1 ppm) expands the overall usable range of fused silica to 3.6 microns. As with other fused silica designations, I2-IR grade also shares the same outstanding homogeneity, bubble characteristics, low coefficient of thermal expansion and chemical resistance.

### Optimum Transmission Range:

- 250 nm - 3.6  $\mu\text{m}$

### Typical Applications:

- SWIR Imaging
- Machine Vision
- Remote Sensing





# Optical Materials

## Commercial Grade Fused Quartz

Esco Optics material designation of commercial fused quartz is G1. G1 grade fused quartz is a commercial grade material not typically used in UV applications due to its fluorescence at UV wavelengths.

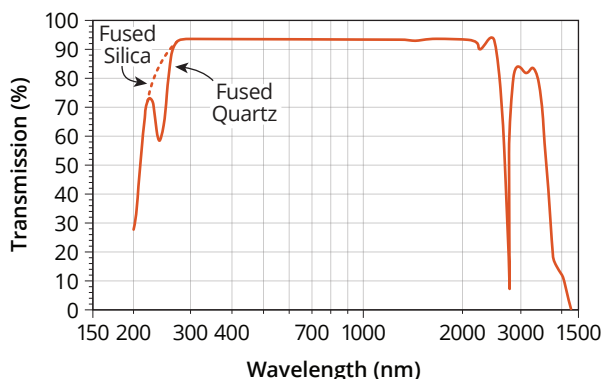
In thin, small pieces, G1 fused quartz is moderately bubble-free. Larger pieces will most likely contain bubbles. Your application should not be sensitive to these inclusions. G1 provides good visible transmission. In cases where simple light gathering and strong mechanical properties are the primary goals, G1 grade provides excellent performance at a low price.

### Optimum Transmission Range:

- 270 nm - 2.5  $\mu\text{m}$

### Typical Applications:

- Optical mirrors
- High temperature and pressure applications
- Low expansion/high purity substrates



## Optical Grade Fused Quartz

A1 grade fused quartz is an optical grade material not typically used in UV applications due to its fluorescence at UV wavelengths.

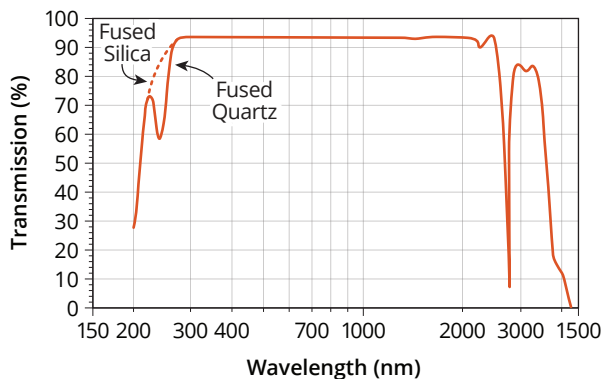
A1 is ideal for all but the most demanding optical applications. All the materials used in this grade are guaranteed to be Grade B or better, providing excellent optical and physical properties at a reasonable price. A1 is an ideal material for larger-sized optical components.

### Optimum Transmission Range:

- 270 nm - 2.5  $\mu\text{m}$

### Typical Applications:

- Condenser optics not concerned with scatter or distortion
- High temperature and pressure applications
- Optical flats, microscope slides and sight glasses





| Indices of Refraction | Wavelength (nm) | Fused Silica/Fused Quartz | N-BK7/S-BSL7 | Sapphire |
|-----------------------|-----------------|---------------------------|--------------|----------|
|                       | 213.86          | 1.53427                   | ---          | ---      |
|                       | 230.21          | 1.52005                   | ---          | ---      |
|                       | 239.94          | 1.51337                   | ---          | ---      |
|                       | 265.20          | 1.50000                   | ---          | 1.83360  |
|                       | 280.35          | 1.49403                   | ---          | 1.82427  |
|                       | 302.15          | 1.48719                   | ---          | 1.81351  |
|                       | 334.15          | 1.47976                   | ---          | 1.80184  |
|                       | 346.62          | 1.47746                   | ---          | 1.79815  |
|                       | 365.02          | 1.47452                   | 1.53626      | 1.79358  |
|                       | 404.66          | 1.46962                   | 1.53024      | 1.78582  |
|                       | 435.84          | 1.46669                   | 1.52669      | 1.78120  |
|                       | 546.07          | 1.46008                   | 1.51872      | 1.77078  |
|                       | 706.52          | 1.45516                   | 1.51289      | 1.76303  |
|                       | 852.11          | 1.45247                   | 1.50981      | 1.75885  |
|                       | 1013.98         | 1.45025                   | 1.50731      | 1.75547  |
|                       | 1529.52         | 1.44427                   | 1.50094      | 1.74660  |
|                       | 1970.09         | 1.43853                   | 1.49500      | 1.73833  |
|                       | 2325.42         | 1.43293                   | 1.48929      | 1.73055  |
|                       | 3243.90         | 1.41315                   | ---          | 1.70437  |
|                       | 3507.00         | 1.40566                   | ---          | 1.69504  |
|                       | 4954.00         | ---                       | ---          | 1.62665  |
|                       | 5577.00         | ---                       | ---          | 1.58638  |

## N-BK7/S-BSL7 Optical Glass

For standard optical glass components, or when optical glass is generically requested for custom elements, Esco Optics uses a grade A fine annealed N-BK7/S-BSL7 or equivalent optical glass. This is a high quality optical material that is used whenever the additional benefits of fused silica are not required.

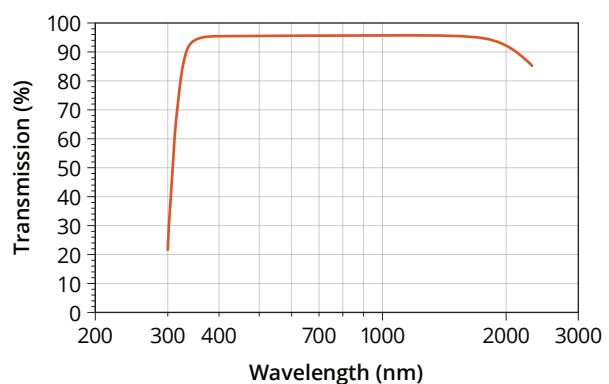
The refractive index of N-BK7/S-BSL7 is 1.51680 @ 587.6 nm and the dispersion is 64.18. Since N-BK7/S-BSL7 performs well in all manufacturing phases, no special handling is required, thus reducing manufacturing costs. It is a relatively hard material with extremely low bubble content, high homogeneity, low cost and easily available. Standard grade N-BK7/S-BSL7 provides excellent transmittance throughout the visible and near infrared spectra and to 350 nm in the ultraviolet. There is a UN-BK7/S-BSL7 material available for applications deeper into the UV region.

### Optimum Transmission Range:

- 350 nm - 2.0  $\mu\text{m}$

### Ideal Applications:

- Optical imaging in the visible spectrum
- Laser optics
- Stable temperature environments
- Low cost - high quality windows and lenses





# Optical Materials

## Optical Glass

Esco Optics stocks most available optical glass types. Ohara, Schott, CDGM, and Hoya are a few of the manufacturers. Please visit our website for information on the vast array of optical glass types offered by Esco Optics. If there is a specific glass that is better suited to your particular application, please contact [sales@EscoOptics.com](mailto:sales@EscoOptics.com) to discuss the design details.

## Colored Filter Glass

Esco Optics offers colored glass filters from Schott, Hoya, and Isuzu. We manufacture and stock filters including long and short bandpass, multiband, or neutral density filters covering the UV, visible, and near-infrared wavelength regions. Color compensation, light balancing, and heat absorbing filters are also available.

Esco Optics provides our polished catalog filters in 12.7 and 25.40 mm diameter as well as square 50.80 mm filters. Neutral density filters are also offered. Esco also fabricates custom sized glass filters in any configuration. Specific manufacturer data sheets can be found on our website at [EscoOptics.com](http://EscoOptics.com)

## Low Expansion Materials

### Borofloat-33:

Borofloat-33 is a heat-resistant, low-expansion industrial borosilicate glass. This low-cost material provides good transmission, excellent thermal stability in noncritical imaging applications, and is often employed as a substrate for reflective metallic and dielectric thin film coatings.

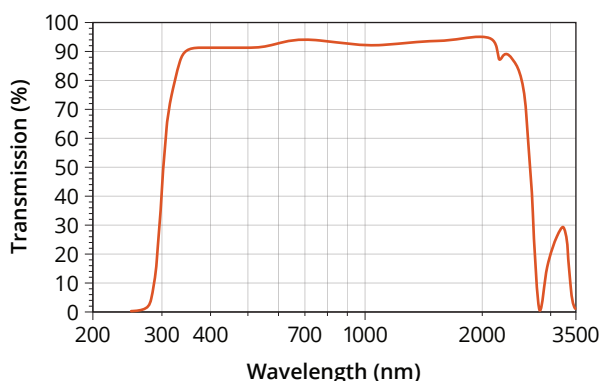
It should be noted that Borofloat-33 and Schott Supremax are essentially the same material and replace Pyrex, which has been discontinued. Borofloat-33 is manufactured by a float process similar to plate glass. This allows it to be used at thickness without further processing. Supremax is manufactured in thicker sheets up to 2¼" thick.

### Optimum Transmission Range:

- 310 nm - 2.5  $\mu$ m

### Typical Applications:

- Non-imaging condensing systems needing a heat resistant material
- First surface mirror substrates





## Ohara CCZ and ZERODUR (Schott)

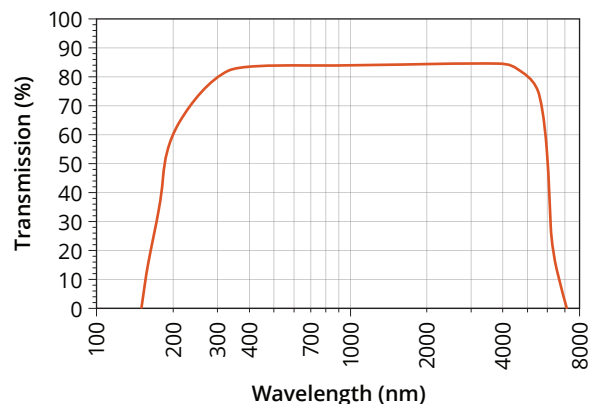
Zerodur and CCZ are a highly homogeneous, glass-ceramic whose thermal and mechanical properties are extremely stable over a wide temperature range. These porous-free materials are a temperature-treated combination of glass, having a positive expansion coefficient, in tandem with a crystalline phase quartz structure with a negative expansion coefficient. The resultant mixture provides a material with a near zero coefficient of thermal expansion. These materials provide outstanding homogeneity, but due to absorption near the blue end of the visible spectrum, is rarely used in transmission applications.

### Ideal Applications:

- High accuracy interferometer mirror substrates
- Large astronomical telescope mirrors
- Ring-laser gyroscope elements
- Any application requiring extremely stable substrates

## Optical Grade Sapphire

Sapphire is an extremely hard material and has a very high modulus of rupture. It is highly resistant to scratching and is chemically inert. These factors make sapphire an excellent choice for high pressure viewport windows and very thin scratch resistant windows. Sapphire lenses are a good choice for harsh environments. The internal transmittance of optical grade sapphire is 150 nm to 6 microns. Esco supplies sapphire windows in many sizes.



This is a short list of the optical materials offered by Esco Optics. Please visit our website for a comprehensive list of materials and manufacturers data sheets.

You can be confident that Esco will select the optimal performing, most cost-effective materials for your components. In addition to the standard materials offered in this catalog, our website has a comprehensive selection of specific materials and manufacturer data sheets offered by Esco. Our technical sales department will be happy to suggest and offer alternate types and grades of materials that best meet the requirements of your unique application.



# Optical Materials

## Optical Characteristics

Below is a brief description of common optical characteristics and properties associated with optical components. We hope this will assist you in your selection of the proper materials and grades.

| Bubbles & Inclusions                                                                                                                                                                                                                                                  | Esco Material | Up to 1.0" Diameter |              | From 1.0" to 2.0" Diameter |              | From 2.0" to 3.0" Diameter |              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|---------------------|--------------|----------------------------|--------------|----------------------------|--------------|
|                                                                                                                                                                                                                                                                       |               | Max Diameter        | Max Quantity | Max Diameter               | Max Quantity | Max Diameter               | Max Quantity |
|                                                                                                                                                                                                                                                                       | S1-UV         | 0.006 Inches        | 0            | 0.008 Inches               | 1            | 0.010 Inches               | 1            |
|                                                                                                                                                                                                                                                                       | A1            | 0.010 Inches        | 1            | 0.015 Inches               | 1            | 0.020 Inches               | 2            |
|                                                                                                                                                                                                                                                                       | G1            | 0.030 Inches        | 3            | 0.040 Inches               | 3            | 0.060 Inches               | 3            |
|                                                                                                                                                                                                                                                                       | I2-IR         | 0.010 Inches        | 3            | 0.015 Inches               | 3            | 0.020 Inches               | 3            |
|                                                                                                                                                                                                                                                                       | N-BK7/S-BSL7  | 0.006 Inches        | 0            | 0.006 Inches               | 0            | 0.010 Inches               | 1            |
| These specifications are worst case conditions.<br>Materials can be selected and guaranteed to customer's requirements.<br>Bubbles less than the maximum diameter count as a fraction of the allowed limit.<br>Bubbles less than 0.004" are regarded as undetectable. |               |                     |              |                            |              |                            |              |

### Bubbles and Inclusions:

Bubbles and inclusions are the most common visible defects associated with optical materials. Bubbles are caused by air trapped inside the material during the melting process. Inclusions are often trapped particles of refractory. Modern manufacturing processes has all but eliminated these defects. Occurrences of either is limited to larger and thicker optics and Esco typically screens out most internal defects unless they are absolutely unavoidable.

### Refractive Index and Dispersion

The refractive index (n) of an optical material is defined as the ratio of the speed of light in a vacuum "c" to the speed of light traveling through an optical material. A simple way to visualize refractive index is to consider how much a ray of light "bends" or refracts through a material. The refractive index of an optical material is usually specified by its index of refraction at 587 nm or the helium "d" line. For example, the refractive index or nd of N-BK7/S-BSL7 is 1.517. It is important to note that the refractive index of a material varies with wavelength.

The dispersion of an optical material can be defined as the rate of change of index within a material. A simple way to visualize this is the iconic prism drawing of white light entering one side of the prism and the rainbow of spectra exiting or dispersing from the prism. The dispersion or Vd of N-BK7/S-BSL7 is 64.2.

Optical glass types are defined by their international code. This is their Nd and Vd combined. The international code for N-BK7/S-BSL7 is 517-642. There are many optical glass types, each with a different international code. These glass types are considered by the optical designer when formulating the end use design of an optical system. Please visit Esco Optics website at [EscoOptics.com](http://EscoOptics.com) for a complete and comprehensive list of optical glass types provided by Esco.

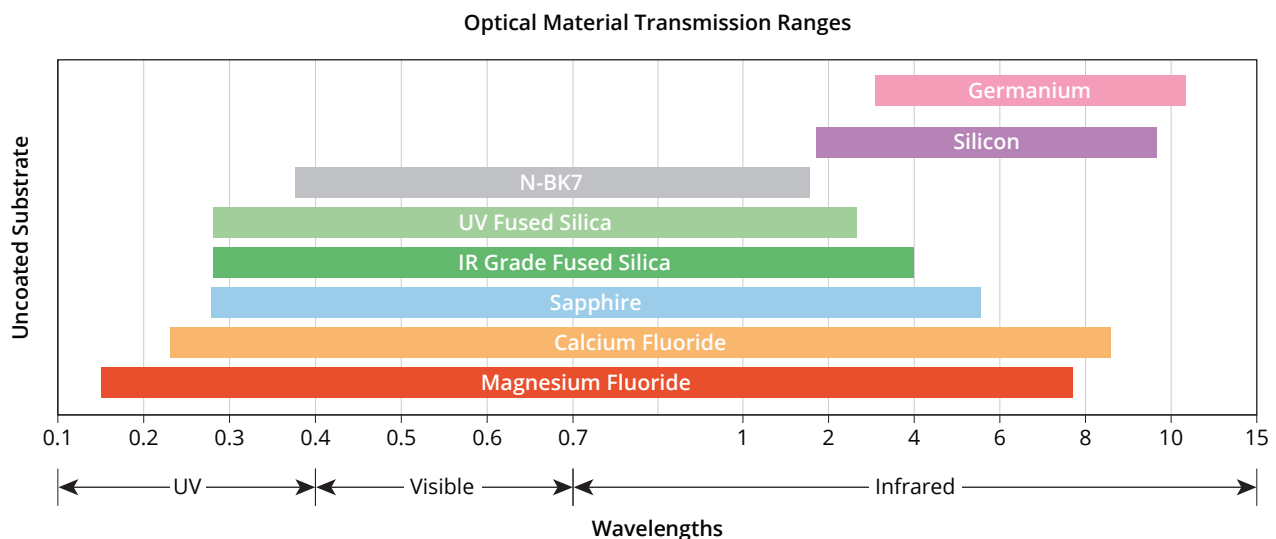
# Optical Materials



## Optical Transmission

Optical transmission can be defined by the percentage of light that is transmitted through an optical material. The optical transmission varies dependent on the wavelength. Light may also be absorbed and/or reflected when contacting the surface of an optical material. Light that passes through an optical material without being reflected or absorbed can be said to have 100% transmission. This is highly unlikely and not practical as all optical materials either absorb and/or reflect light.

The transmission of an optical material is one of the many factors in optical design. If an optical system is being used in the UV region of the spectrum, perhaps a UV grade fused silica will be the chosen material. If a designer needs a system to perform in the IR region, they may choose a material such as Sapphire or Germanium depending upon the application.



## Refractive Index Homogeneity:

Homogeneity refers to the variation in the index of refraction across the entire aperture of the optic. Unless you have a critical imaging or high powered laser application requiring special material grade selection, this is generally not an issue with our standard materials. Esco does test and certify for high homogeneity in smaller block forms when required by the customer. Please visit Esco's website to find specific manufacturers homogeneity grades.

## Stress Birefringence:

Stress Birefringence, or anneal as it is sometimes called, is the result of residual mechanical stress in an optical component. These stresses could result from cooling too quickly when the material is melted or molded. Optical materials are heated and cooled at tightly controlled rates to minimize the effect of stress birefringence. There are different grades of anneal. The units of measure are nm/cm.



# Optical Materials

**Course annealed** ( $>10$  nm/cm) is the result of the material being cooled quickly. In most cases, the material will likely be molded into smaller components.

**Fine annealed** ( $<10$  nm/cm) is what most materials are supplied from the manufacturer.

**Precision annealed** ( $< 6$  nm/cm) materials often go through a secondary annealing process and are cooled at a very slow rate.

There is a direct correlation between the level of anneal present in an optical material and its refractive index homogeneity. Annealing can also raise or lower the refractive index of a material.

## Striae:

Striae refers to localized visible variations in the index of refraction and exhibits a shape like thin threads when viewing the cross section of a material. Grade A means no visible striae. Striae classes are also defined in ISO 10110. Modern manufacturing processes has eliminated striae in all but a few materials such as low expansion borosilicate and commercial grade fused quartz.

## Fluorescence:

Fluorescence in an optical material is the emissive response of a given substrate material when exposed to ultraviolet light. Fused quartz and some optical glasses demonstrate a strong blue fluorescence under these circumstances. Ultraviolet grade fused silica exhibits minimal fluorescence unless subjected to intense UV radiation such as that from an excimer laser. UV laser applications require the use of excimer grade fused silica in order to minimize this problem.

## Thermal Coefficient of Expansion (CTE):

The thermal coefficient of expansion (CTE) of an optical material is determined by its chemical composition. The units are expressed as  $10^{-6} / 0^{\circ} \text{C}$ . The range of temperature an optical component will be exposed to is the leading factor in determining an acceptable CTE.

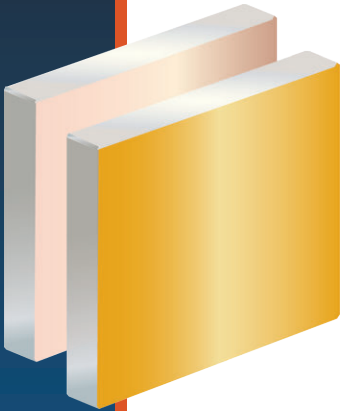
N-BK7/S-BSL7 and most optical glasses have a CTE between  $6 - 8 \times 10^{-6} / 0^{\circ} \text{C}$ . There are some materials that have a very low CTE such as fused silica ( $0.6 \times 10^{-6} / 0^{\circ} \text{C}$ ) and Ohara CCZ ( $0.6 \times 10^{-7} / 0^{\circ} \text{C}$ ). These materials are very stable and will maintain their physical properties across a wide range of temperatures. Some optical materials have an extremely high CTE such as  $\text{CaF}_2$  and Ohara S-FPL51. These materials are greatly affected by temperature variation. Extreme caution is needed when fabricating components from these materials.

| Material Code | Type                         | Striae per MIL-G-174A | Index Variation $\Delta n(\times 10^{-6})$ |
|---------------|------------------------------|-----------------------|--------------------------------------------|
| S1-UVA        | Fused Silica                 | A                     | 6                                          |
| S1-UVB        | Fused Silica                 | A                     | 10                                         |
| A1            | Fused Quartz or Fused Silica | B                     | 10                                         |
| G1            | Fused Quartz or Fused Silica | C-D                   | 20                                         |
| I2-IR         | Fused Quartz                 | A                     | 4                                          |
| N-BK7/S-BSL7  | Optical Glass                | A                     | 10                                         |



100% of Esco Optics components are inspected prior to shipping.

## Coatings



Esco Optics offers the value-added service of thin film coatings to enhance the performance of your optics. Available options include a wide range of anti-reflective designs, interference filters, as well as metal and dielectric high reflectors. Each coating is applied using vacuum deposition technology. Below are descriptions of various standard design options and every effort is made to accommodate custom requests.

### **Anti-Reflective**

- Single layer
- Multilayer, narrowband
- Multilayer, broadband

### **Reflective**

- All-dielectric (MAX R)
- Metallic

### **Partially Reflective (Beamsplitter)**

### **Filter Coatings**

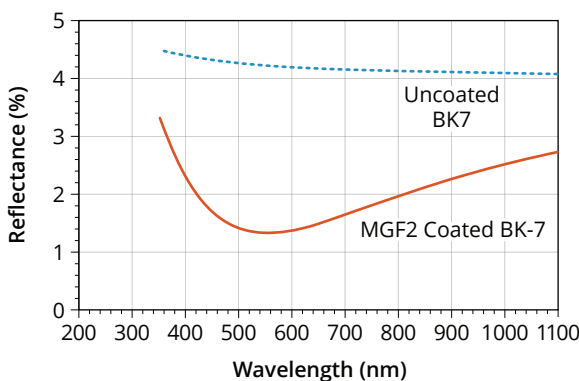


## Anti-Reflection Coatings

Anti-Reflection or “AR” coatings are the most common type of optical coating in the world. Applied to both window and lens elements, these coatings are designed to maximize throughput while minimizing natural back reflections that could otherwise interfere with the preferred operation of an optical system. Esco provides a comprehensive range of AR types to meet the needs of our customers. To discuss the coating that is best suited to your application, please call Esco.

### Single Layer $\text{MgF}_2$ (MGF2):

The index of refraction of magnesium fluoride is ideal for the task of providing minimum reflectance with only a single layer film. When applied at high temperatures,  $\text{MgF}_2$  becomes a hard, durable coating that meets all standard MIL requirements. It exhibits broadband characteristics and can be applied on a variety of substrates for use in spectral regions from the UV to the NIR.  $\text{MgF}_2$  has the best performance-to-cost ratio of any anti-reflection coating.



Typical MGF2 coating shown for visible spectrum

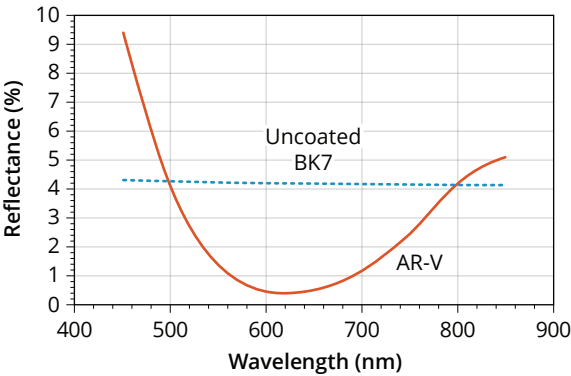
|                             |                                                                                                   |
|-----------------------------|---------------------------------------------------------------------------------------------------|
| Reflectivity (per surface): | ~1.3% for mid-visible on N-BK7/S-BSL7<br>2.00% max on N-BK7/S-BSL7<br>2.25% max on $\text{SiO}_2$ |
| Practical Bandwidth:        | ~300 nm                                                                                           |
| Wavelength Range:           | 200 nm to 1500 nm                                                                                 |
| Substrates:                 | Fused Quartz/Fused Silica (all grades)<br>Any optical glass<br>Other materials on request         |
| Durability:                 | Per MIL-C-48497A                                                                                  |
| Order As:                   | MGF2                                                                                              |
| Please Specify:             | Substrate material/Part no.<br>Surface(s) to be coated<br>Wavelength range<br>Angle of incidence  |



# Coatings

## Narrowband AR ("V") Coating (AR-V):

Commonly called a "V" coating because of its spectral shape, narrowband AR coatings are the simplest of the multilayer coating designs and are used whenever the application involves a single wavelength. A "V" coating usually achieves reflectivity of <0.25% at the design wavelength.

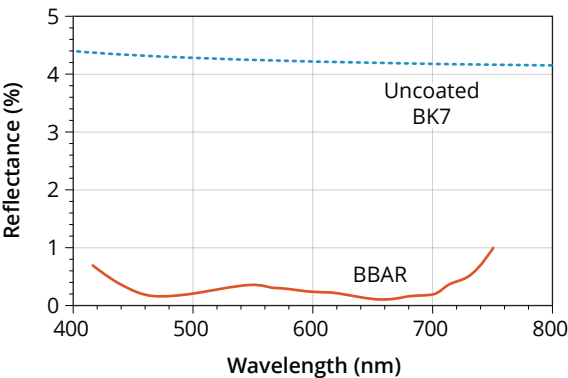


Typical AR-V coating shown at 632.8 nm

|                                    |                                                                                                             |
|------------------------------------|-------------------------------------------------------------------------------------------------------------|
| <b>Reflectivity (per surface):</b> | <0.25% at design wavelength                                                                                 |
| <b>Practical Bandwidth:</b>        | Usually 12% of the design wavelength between 0.5% points                                                    |
| <b>Wavelength Range:</b>           | 400 nm to 1500 nm                                                                                           |
| <b>Substrates:</b>                 | Fused Quartz/Fused Silica (all grades)<br>Any optical glass<br>Other materials on request                   |
| <b>Durability:</b>                 | Per MIL-C-48497A                                                                                            |
| <b>Variation:</b>                  | "V" coatings that minimize reflections at two wavelengths are also possible. For more info please call Esco |
| <b>Order As:</b>                   | AR-V                                                                                                        |
| <b>Please Specify:</b>             | Substrate material/Part no.<br>Surface(s) to be coated<br>Design wavelength<br>Angle of incidence           |

## Broadband Multilayer AR Coating (BBAR):

Broadband anti-reflective coatings provide the low reflectivity of a "V" coating, combined with the broadband characteristics of a single layer coating. These designs are necessary when an optical system operates across a range of wavelengths such as those used in broad spectrum imaging. As broadband depositions are lengthier than a simple single-layer option, the trade-off for their added performance is increased cost.



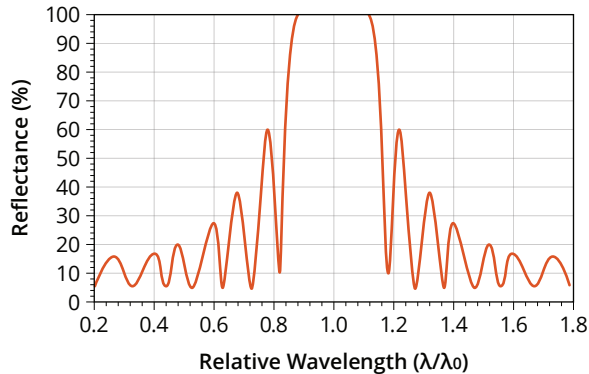
Typical BBAR coating shown for visible spectrum

|                                    |                                                                                                  |
|------------------------------------|--------------------------------------------------------------------------------------------------|
| <b>Reflectivity (per surface):</b> | <1% absolute, within practical bandwidth, <0.5% average                                          |
| <b>Practical Bandwidth:</b>        | ~280 nm, (420 nm - 700 nm)                                                                       |
| <b>Wavelength Range:</b>           | 400 nm to 1500 nm                                                                                |
| <b>Angle of Incidence:</b>         | 0° ± 15°                                                                                         |
| <b>Substrates:</b>                 | Fused Quartz/Fused Silica (all grades)<br>Any optical glass<br>Other materials on request        |
| <b>Durability:</b>                 | Per MIL-C-48497A                                                                                 |
| <b>Order As:</b>                   | BBAR                                                                                             |
| <b>Please Specify:</b>             | Substrate material/Part no.<br>Surface(s) to be coated<br>Wavelength range<br>Angle of incidence |



## Maximum Reflecting Dielectric Coatings

Typically used with lasers, Max R coatings provide nearly complete reflection over a specific spectral range while absorbing negligible incident energy. These high-purity coatings are very durable and designed to meet all standard MIL requirements. On request, custom designs can also be tailored to meet specific laser damage threshold ratings. The trade-off for these high-performance coatings when compared to metal reflectors are cost and increased polarization sensitivity.



|                            |                                                                                                                                                              |
|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Reflectivity:</b>       | >99.5% at design wavelength                                                                                                                                  |
| <b>Typical Bandwidth:</b>  | ~20% of design wavelength at 99% points                                                                                                                      |
| <b>Wavelength Range:</b>   | 300 nm to 3000 nm                                                                                                                                            |
| <b>Angle of Incidence:</b> | 0 - 45°                                                                                                                                                      |
| <b>Substrates:</b>         | Fused Quartz/Fused Silica (all grades)<br>N-BK7/S-BSL7 Optical Glass<br>Borofloat-33/Zerodur<br>Other materials on request                                   |
| <b>Order As:</b>           | MAX R (at specified wavelength)                                                                                                                              |
| <b>Please Specify:</b>     | Wavelength (narrowband)<br>Substrate material/Part no.<br>Surface to be coated<br>Design wavelength<br>Angle of incidence<br>Polarization of incident energy |

## Metallic Reflectors

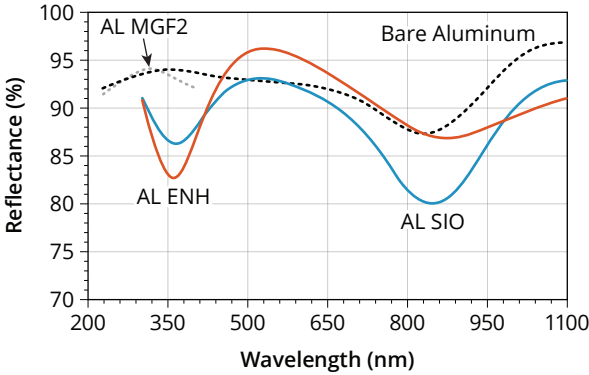
For most mirror applications, metallic coatings offer the best performance:cost ratio of any reflective coating. Many different metals can be evaporated for use as reflectors. The three most common and effective types are listed below. In addition, several dielectric coatings are available as overcoats. These layers are used to enhance reflectivity, durability and/or longevity of the underlying metal.

### Aluminum (Al-SiO, Enhanced Aluminum):

Bare aluminum provides excellent reflectivity from the UV to the IR. Unfortunately, it also oxidizes rapidly and use of a dielectric overcoat is usually required to prevent degradation. Since no overcoat is ideal for all applications, materials best suited to the intended application should be chosen.



# Coatings

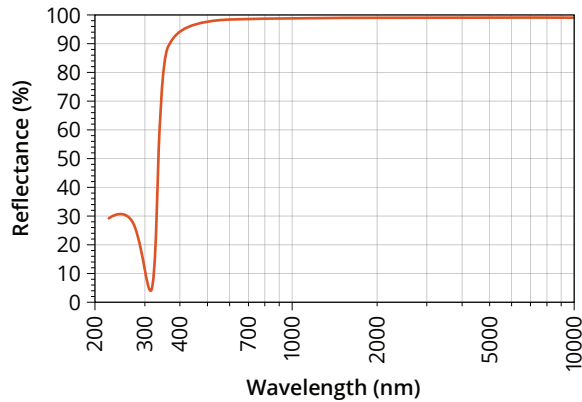


| Aluminum-Silicon Monoxide (AL SIO)                                                                                                                                                                                                         |                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Reflectivity:                                                                                                                                                                                                                              | >85% average, 400 nm - 800 nm                                                                                              |
| Wavelength Range:                                                                                                                                                                                                                          | 350 nm to 3000 nm                                                                                                          |
| Substrates:                                                                                                                                                                                                                                | Fused Quartz/Fused Silica (all grades)<br>N-BK7/S-BSL7 Optical Glass<br>Borofloat-33/Zerodur<br>Other materials on request |
| Durability:                                                                                                                                                                                                                                | Per MIL-C-48497A                                                                                                           |
| Order As:                                                                                                                                                                                                                                  | AL SIO                                                                                                                     |
| Please Specify:                                                                                                                                                                                                                            | Substrate material/Part no.<br>Surface to be coated                                                                        |
| <b>Benefits</b> <ul style="list-style-type: none"><li>General purpose Aluminum coating for use in the visible spectrum</li><li>Inexpensive</li></ul> <b>Trade-offs</b> <ul style="list-style-type: none"><li>Poor UV reflectance</li></ul> |                                                                                                                            |

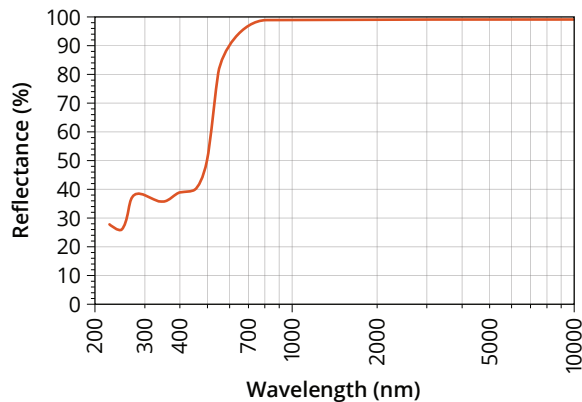
| Enhanced Aluminum (AL ENH)                                                                                                                                                                                                               |                                                                                                                            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Reflectivity:                                                                                                                                                                                                                            | >93% average, 450 nm - 750 nm                                                                                              |
| Wavelength Range:                                                                                                                                                                                                                        | 400 nm to 800 nm                                                                                                           |
| Substrates:                                                                                                                                                                                                                              | Fused Quartz/Fused Silica (all grades)<br>N-BK7/S-BSL7 Optical Glass<br>Borofloat-33/Zerodur<br>Other materials on request |
| Durability:                                                                                                                                                                                                                              | Per MIL-C-48497A                                                                                                           |
| Order As:                                                                                                                                                                                                                                | AL ENH                                                                                                                     |
| Please Specify:                                                                                                                                                                                                                          | Substrate material/Part no.<br>Surface to be coated                                                                        |
| <b>Benefits</b> <ul style="list-style-type: none"><li>Special Aluminum coating for higher reflectivity in the visible spectrum</li></ul> <b>Trade-offs</b> <ul style="list-style-type: none"><li>Poor out-of-band reflectivity</li></ul> |                                                                                                                            |

| Aluminum-Magnesium Fluoride (AL MGF2)                                                                                                                                                                                                                                                                                |                                                                                                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Reflectivity:                                                                                                                                                                                                                                                                                                        | >85% average, 200 nm - 800 nm                                                                                              |
| Wavelength Range:                                                                                                                                                                                                                                                                                                    | 200 nm to 3000 nm                                                                                                          |
| Substrates:                                                                                                                                                                                                                                                                                                          | Fused Quartz/Fused Silica (all grades)<br>N-BK7/S-BSL7 Optical Glass<br>Borofloat-33/Zerodur<br>Other materials on request |
| Order As:                                                                                                                                                                                                                                                                                                            | AL MGF2                                                                                                                    |
| Please Specify:                                                                                                                                                                                                                                                                                                      | Substrate material/Part no.<br>Surface to be coated                                                                        |
| <b>Benefits</b> <ul style="list-style-type: none"><li>General purpose Aluminum coating for use in the UV and visible spectrum</li><li>Relatively inexpensive</li></ul> <b>Trade-offs</b> <ul style="list-style-type: none"><li>Very poor durability, special care must be taken while handling or cleaning</li></ul> |                                                                                                                            |

# Coatings



| Silver (Ag)                                                                                                                                                                                                                                                                                                                      |                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>Reflectivity:</b>                                                                                                                                                                                                                                                                                                             | >96% average, 400 nm - 1000 nm<br>>98% absolute, 2.5 $\mu$ m - 12 $\mu$ m                                           |
| <b>Wavelength Range:</b>                                                                                                                                                                                                                                                                                                         | 400 nm to 12 $\mu$ m                                                                                                |
| <b>Substrates:</b>                                                                                                                                                                                                                                                                                                               | Fused Quartz/Fused Silica (all grades)<br>N-BK7/S-BSL7 Optical Glass<br>Pyrex/Zerodur<br>Other materials on request |
| <b>Durability:</b>                                                                                                                                                                                                                                                                                                               | Per MIL-C-48497A                                                                                                    |
| <b>Order As:</b>                                                                                                                                                                                                                                                                                                                 | Ag                                                                                                                  |
| <b>Please Specify:</b>                                                                                                                                                                                                                                                                                                           | Substrate material/Part no.<br>Surface to be coated<br>Wavelength range                                             |
| <b>Benefits</b> <ul style="list-style-type: none"> <li>• Excellent reflectivity from the visible to the far infrared</li> <li>• Durable overcoat allows front surface use without risk of silver oxidation</li> </ul> <b>Trade-offs</b> <ul style="list-style-type: none"> <li>• Cost</li> <li>• Poor UV reflectivity</li> </ul> |                                                                                                                     |



| Gold (Au)                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>Reflectivity:</b>                                                                                                                                                                                                                                                                                                                                                      | >95% average, 650 nm - 1000 nm<br>>98% absolute, 2.5 $\mu$ m - 12 $\mu$ m                                           |
| <b>Wavelength Range:</b>                                                                                                                                                                                                                                                                                                                                                  | 650 nm to 12 $\mu$ m                                                                                                |
| <b>Substrates:</b>                                                                                                                                                                                                                                                                                                                                                        | Fused Quartz/Fused Silica (all grades)<br>N-BK7/S-BSL7 Optical Glass<br>Pyrex/Zerodur<br>Other materials on request |
| <b>Order As:</b>                                                                                                                                                                                                                                                                                                                                                          | Au                                                                                                                  |
| <b>Please Specify:</b>                                                                                                                                                                                                                                                                                                                                                    | Substrate material/Part no.<br>Surface to be coated (cannot be used as rear surface reflector)                      |
| <b>Benefits</b> <ul style="list-style-type: none"> <li>• Excellent reflectivity from the visible to the far infrared (best 2 - 12 <math>\mu</math>m)</li> <li>• Low scatter surfaces</li> </ul> <b>Trade-offs</b> <ul style="list-style-type: none"> <li>• Cost</li> <li>• Poor UV, visible reflectivity</li> <li>• Poor durability (Contact Esco for details)</li> </ul> |                                                                                                                     |

## Bi-Convex Lenses



Bi-convex lenses are symmetrical elements with positive focal lengths. They are designed for 1:1 finite conjugate imaging where aberrations such as coma and lateral chromatic distortion exactly cancel and spherical aberration is at a minimum. For more information concerning aberrations and other basic characteristics of lenses, please visit our website [EscoOptics.com](http://EscoOptics.com).

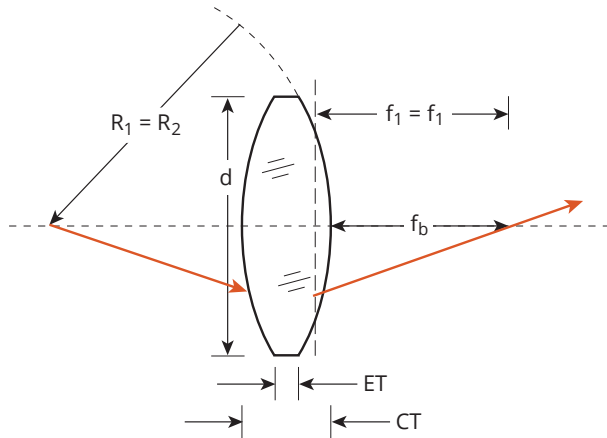
Esco's bi-convex lenses are ideal for finite conjugate imaging over a narrow spectral range. For imaging parallel light (infinite conjugate) or for collimation, plano-convex lenses should be used. For broadband situations where chromatic aberration would be a problem, achromats should be considered. For improved performance involving laser light, bestform lenses could be considered as well.

# Bi-Convex Lenses



## Standard

Esco manufactures bi-convex lenses from most of the optical grade materials listed in this handbook. They are CNC polished to provide superb surface quality and excellent low-cost imaging performance with a variety of light sources.



|                                                                                                                             |                         |
|-----------------------------------------------------------------------------------------------------------------------------|-------------------------|
| <b>Focal Length Tolerance:</b>                                                                                              | ±3%                     |
| <b>Diameter Tolerance:</b>                                                                                                  | ±0.125 mm               |
| <b>Thickness Tolerance:</b>                                                                                                 | ±0.5 mm                 |
| <b>Design Wavelength:</b>                                                                                                   | 546 nm                  |
| <b>Centration:</b>                                                                                                          | <3'                     |
| <b>Surface Quality:</b>                                                                                                     | 60-40, scratch-dig      |
| <b>Edges:</b>                                                                                                               | Fine ground and beveled |
| Optical Materials, pages 25 - 34<br>Optical Coatings, pages 35 - 40<br>All dimensions are in mm unless otherwise specified. |                         |

|                          | P/N       | $f_{nom}$ | Diameter | f/# | CT   | ET  | EFL <sub>546</sub> | EFL <sub>250</sub> | BFL <sub>250</sub> |
|--------------------------|-----------|-----------|----------|-----|------|-----|--------------------|--------------------|--------------------|
| S1-UV Grade Fused Silica | A1BI05005 | 12.7      | 12.7     | 1.0 | 5.3  | 1.5 | 13.7               | 12.6               | 10.7               |
|                          | A1BI05010 | 25.4      | 12.7     | 2.0 | 3.3  | 1.5 | 26.0               | 23.9               | 22.8               |
|                          | A1BI10010 | 25.4      | 25.4     | 1.0 | 9.0  | 1.5 | 27.1               | 25.1               | 21.7               |
|                          | A1BI05015 | 38.1      | 12.7     | 3.0 | 2.7  | 1.5 | 38.6               | 35.5               | 34.6               |
|                          | A1BI10015 | 38.1      | 25.4     | 1.5 | 6.3  | 1.5 | 39.3               | 36.1               | 34.0               |
|                          | A1BI15015 | 38.1      | 38.1     | 1.0 | 13.3 | 2.0 | 40.5               | 37.4               | 32.7               |
|                          | A1BI05020 | 50.8      | 12.7     | 4.0 | 2.4  | 1.5 | 51.2               | 47.1               | 46.3               |
|                          | A1BI10020 | 50.8      | 25.4     | 2.0 | 5.0  | 1.5 | 51.8               | 47.7               | 45.8               |
|                          | A1BI15020 | 50.8      | 38.1     | 1.3 | 10.1 | 2.0 | 52.6               | 48.5               | 45.0               |
|                          | A1BI20020 | 50.8      | 50.8     | 1.0 | 17.0 | 2.0 | 53.9               | 49.8               | 43.7               |
|                          | A1BI10030 | 76.2      | 25.4     | 3.0 | 3.8  | 1.5 | 77.0               | 70.8               | 69.4               |
|                          | A1BI15030 | 76.2      | 38.1     | 2.0 | 7.3  | 2.0 | 77.5               | 71.3               | 68.9               |
|                          | A1BI20030 | 76.2      | 50.8     | 1.5 | 11.5 | 2.0 | 78.2               | 72.1               | 68.1               |
|                          | A1BI10040 | 101.6     | 25.4     | 4.0 | 3.2  | 1.5 | 102.2              | 94.1               | 92.9               |
|                          | A1BI15040 | 101.6     | 38.1     | 2.7 | 5.9  | 2.0 | 102.6              | 94.5               | 92.5               |
|                          | A1BI20040 | 101.6     | 50.8     | 2.0 | 9.0  | 2.0 | 103.2              | 95.0               | 91.9               |
|                          | A1BI20060 | 152.4     | 50.8     | 3.0 | 6.6  | 2.0 | 153.6              | 141.3              | 139.1              |



# Bi-Convex Lenses

| G1 Commercial Grade Fused Quartz | P/N       | $f_{nom}$ | Diameter | f/# | CT   | ET  | EFL <sub>546</sub> | EFL <sub>250</sub> | BFL <sub>250</sub> |
|----------------------------------|-----------|-----------|----------|-----|------|-----|--------------------|--------------------|--------------------|
|                                  | A4BI05005 | 12.7      | 12.7     | 1.0 | 5.3  | 1.5 | 13.7               | 12.9               | 10.7               |
|                                  | A4BI05010 | 25.4      | 12.7     | 2.0 | 3.3  | 1.5 | 26.0               | 24.5               | 22.8               |
|                                  | A4BI10010 | 25.4      | 25.4     | 1.0 | 9.0  | 1.5 | 27.1               | 25.6               | 21.7               |
|                                  | A4BI05015 | 38.1      | 12.7     | 3.0 | 2.7  | 1.5 | 38.6               | 36.4               | 34.6               |
|                                  | A4BI10015 | 38.1      | 25.4     | 1.5 | 6.3  | 1.5 | 39.2               | 37.0               | 34.0               |
|                                  | A4BI15015 | 38.1      | 38.1     | 1.0 | 13.3 | 2.0 | 40.5               | 38.3               | 32.7               |
|                                  | A4BI05020 | 50.8      | 12.7     | 4.0 | 2.4  | 1.5 | 51.2               | 48.3               | 46.3               |
|                                  | A4BI10020 | 50.8      | 25.4     | 2.0 | 5.0  | 1.5 | 51.7               | 48.7               | 45.8               |
|                                  | A4BI15020 | 50.8      | 38.1     | 1.3 | 10.1 | 2.0 | 52.6               | 49.7               | 45.0               |
|                                  | A4BI20020 | 50.8      | 50.8     | 1.0 | 17.0 | 2.0 | 53.9               | 50.9               | 43.7               |
|                                  | A4BI10030 | 76.2      | 25.4     | 3.0 | 3.8  | 1.5 | 76.9               | 72.5               | 69.4               |
|                                  | A4BI15030 | 76.2      | 38.1     | 2.0 | 7.3  | 2.0 | 77.5               | 73.1               | 68.9               |
|                                  | A4BI20030 | 76.2      | 50.8     | 1.5 | 11.5 | 2.0 | 78.2               | 73.8               | 68.1               |
|                                  | A4BI10040 | 101.6     | 25.4     | 4.0 | 3.2  | 1.5 | 102.2              | 96.3               | 92.9               |
|                                  | A4BI15040 | 101.6     | 38.1     | 2.7 | 5.9  | 2.0 | 102.6              | 96.8               | 92.5               |
|                                  | A4BI20040 | 101.6     | 50.8     | 2.0 | 9.0  | 2.0 | 103.2              | 97.3               | 91.9               |
|                                  | A4BI20060 | 152.4     | 50.8     | 3.0 | 6.6  | 2.0 | 153.6              | 144.8              | 139.1              |

| N-BK7/S-BSL7 Optical Glass | P/N       | $f_{nom}$ | Diameter | f/# | CT   | ET  | EFL <sub>546</sub> | EFL <sub>300</sub> | BFL <sub>300</sub> |
|----------------------------|-----------|-----------|----------|-----|------|-----|--------------------|--------------------|--------------------|
|                            | A6BI05005 | 12.7      | 12.7     | 1.0 | 4.8  | 1.5 | 13.7               | 13.5               | 11.9               |
|                            | A6BI05010 | 25.4      | 12.7     | 2.0 | 3.1  | 1.5 | 26.2               | 25.9               | 24.9               |
|                            | A6BI10010 | 25.4      | 25.4     | 1.0 | 8.5  | 2.0 | 27.2               | 26.9               | 23.9               |
|                            | A6BI05015 | 38.1      | 12.7     | 3.0 | 2.5  | 1.5 | 39.0               | 38.5               | 37.7               |
|                            | A6BI10015 | 38.1      | 25.4     | 1.5 | 6.2  | 2.0 | 39.6               | 39.2               | 37.1               |
|                            | A6BI15015 | 38.1      | 38.1     | 1.0 | 11.8 | 2.0 | 40.6               | 40.2               | 36.1               |
|                            | A6BI05020 | 50.8      | 12.7     | 4.0 | 2.3  | 1.5 | 51.8               | 51.2               | 50.4               |
|                            | A6BI10020 | 50.8      | 25.4     | 2.0 | 5.1  | 2.0 | 52.3               | 51.7               | 49.9               |
|                            | A6BI15020 | 50.8      | 38.1     | 1.3 | 9.2  | 2.0 | 53.0               | 52.4               | 49.3               |
|                            | A6BI20020 | 50.8      | 50.8     | 1.0 | 15.1 | 2.0 | 54.0               | 53.4               | 48.2               |
|                            | A6BI10030 | 76.2      | 25.4     | 3.0 | 4.1  | 2.0 | 77.8               | 76.9               | 75.5               |
|                            | A6BI15030 | 76.2      | 38.1     | 2.0 | 6.7  | 2.0 | 78.2               | 77.3               | 75.1               |
|                            | A6BI20030 | 76.2      | 50.8     | 1.5 | 10.4 | 2.0 | 78.9               | 78.0               | 74.4               |
|                            | A6BI10040 | 101.6     | 25.4     | 4.0 | 3.5  | 2.0 | 103.4              | 102.2              | 101.0              |
|                            | A6BI15040 | 101.6     | 38.1     | 2.7 | 5.5  | 2.0 | 103.7              | 102.5              | 100.7              |
|                            | A6BI20040 | 101.6     | 50.8     | 2.0 | 8.2  | 2.0 | 104.2              | 103.0              | 100.2              |
|                            | A6BI20060 | 152.4     | 50.8     | 3.0 | 6.1  | 2.0 | 155.2              | 153.4              | 151.4              |

# Bi-Convex Lenses



## Custom

In addition to our standard lines of bi-convex lenses, we also manufacture a variety of custom elements including bi-convex and biconcave lenses (negative focal length components with symmetrical concave radii of curvature). For more information on these and other custom products or applications, please contact Esco or visit our website at [EscoOptics.com](http://EscoOptics.com).

### Sizes:

From 5.0 mm to 380.0 mm diameter

### Materials:

Fused Quartz/Fused Silica (all grades)

Borofloat/Supremax

N-BK7/S-BSL7 Optical Glass

Other materials upon request

### Focal Lengths:

Any design greater than  $f/1.0$  is possible. Research quantities of some custom focal lengths may be available off-the-shelf. Please contact Esco for more information.

### Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply bi-convex elements with surface quality better than 10-5 laser grade and surface accuracies better than  $\lambda/10$ . An Esco sales engineer can assist with your custom requirements.

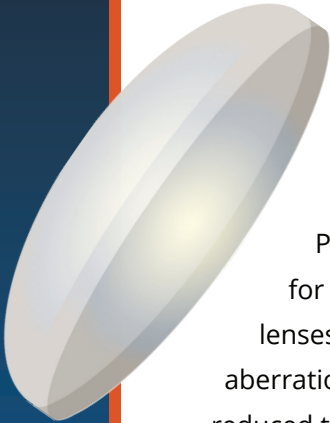
### Tolerances:

The dimensional tolerances for bi-convex lenses shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

### Coatings:

Anti-Reflection coatings that allow efficient energy throughput are available. For more information, see pages 36 - 37 or call Esco.

## Plano-Convex Lenses



Plano-Convex lenses are positive focal length elements with one spherical surface and one flat surface. They are designed for infinite conjugate (parallel light) use or simple imaging in non-critical applications.

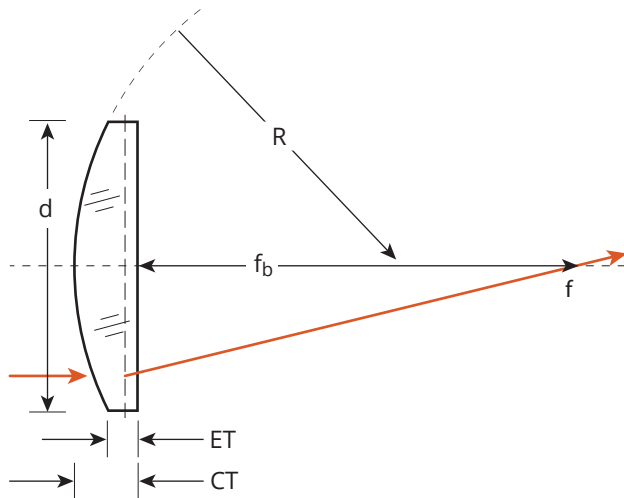
Plano-Convex lenses are ideal all-purpose focusing elements. However, for finite conjugate imaging with limited off-axis aberrations, bi-convex lenses are often better suited. For broadband situations where chromatic aberrations would be a problem, or when spherical aberrations must be reduced to a minimum, achromats should be considered. For improved performance involving laser light, bestform lenses should be considered as well.

# Plano-Convex Lenses



## Standard

Esco manufactures plano-convex lenses from most of the optical grade materials listed in this catalog. They are pitch polished to provide good surface quality and excellent low-cost imaging performance with a variety of light sources.



|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Focal Length Tolerance:</b>                       | ±3%                     |
| <b>Diameter Tolerance:</b>                           | ±0.125 mm               |
| <b>Thickness Tolerance:</b>                          | ±0.5 mm                 |
| <b>Design Wavelength:</b>                            | 546 nm                  |
| <b>Centration:</b>                                   | <3'                     |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig      |
| <b>Edges:</b>                                        | Fine ground and beveled |
| Optical Materials, pages 25 - 34                     |                         |
| Optical Coatings, pages 35 - 40                      |                         |
| All dimensions are in mm unless otherwise specified. |                         |

| S1-UV Grade Fused Silica | P/N     | $f_{nom}$ | Diameter | f/#  | CT   | ET  | EFL <sub>250</sub> | BFL <sub>250</sub> |
|--------------------------|---------|-----------|----------|------|------|-----|--------------------|--------------------|
|                          | A105010 | 25.4      | 12.7     | 2.0  | 3.3  | 1.5 | 23.9               | 21.7               |
|                          | A105015 | 38.1      | 12.7     | 3.0  | 2.7  | 1.5 | 35.1               | 33.3               |
|                          | A110015 | 38.1      | 25.4     | 1.5  | 6.9  | 1.5 | 35.1               | 30.4               |
|                          | A105020 | 50.8      | 12.7     | 4.0  | 2.4  | 1.5 | 46.7               | 45.1               |
|                          | A110020 | 50.8      | 25.4     | 2.0  | 5.3  | 1.5 | 46.7               | 43.2               |
|                          | A115020 | 50.8      | 38.1     | 1.3  | 11.8 | 2.0 | 46.7               | 38.8               |
|                          | A105030 | 76.2      | 12.7     | 6.0  | 2.1  | 1.5 | 70.1               | 68.7               |
|                          | A110030 | 76.2      | 25.4     | 3.0  | 3.9  | 1.5 | 70.1               | 67.5               |
|                          | A115030 | 76.2      | 38.1     | 2.0  | 7.6  | 2.0 | 70.1               | 65.0               |
|                          | A120030 | 76.2      | 50.8     | 1.5  | 12.9 | 2.0 | 70.1               | 61.5               |
|                          | A105040 | 101.6     | 12.7     | 8.0  | 1.9  | 1.5 | 93.5               | 92.2               |
|                          | A110040 | 101.6     | 25.4     | 4.0  | 3.3  | 1.5 | 93.5               | 91.3               |
|                          | A115040 | 101.6     | 38.1     | 2.7  | 6.1  | 2.0 | 93.5               | 89.4               |
|                          | A120040 | 101.6     | 50.8     | 2.0  | 9.5  | 2.0 | 93.5               | 87.1               |
|                          | A110050 | 127.0     | 25.4     | 5.0  | 2.9  | 1.5 | 116.8              | 114.9              |
|                          | A115050 | 127.0     | 38.1     | 3.3  | 5.2  | 2.0 | 116.8              | 113.4              |
|                          | A120050 | 127.0     | 50.8     | 2.5  | 7.8  | 2.0 | 116.8              | 111.6              |
|                          | A110060 | 152.4     | 25.4     | 6.0  | 2.7  | 1.5 | 140.2              | 138.4              |
|                          | A115060 | 152.4     | 38.1     | 4.0  | 4.6  | 2.0 | 140.2              | 137.1              |
|                          | A120060 | 152.4     | 50.8     | 3.0  | 6.8  | 2.0 | 140.2              | 135.7              |
|                          | A110070 | 177.8     | 25.4     | 7.0  | 2.5  | 1.5 | 163.6              | 161.9              |
|                          | A115070 | 177.8     | 38.1     | 4.7  | 4.2  | 2.0 | 163.6              | 160.7              |
|                          | A120070 | 177.8     | 50.8     | 3.5  | 6.0  | 2.0 | 163.6              | 159.5              |
|                          | A110080 | 203.2     | 25.4     | 8.0  | 2.4  | 1.5 | 186.9              | 185.4              |
|                          | A115080 | 203.2     | 38.1     | 5.3  | 4.0  | 2.0 | 186.9              | 184.3              |
|                          | A120080 | 203.2     | 50.8     | 4.0  | 5.5  | 2.0 | 186.9              | 183.3              |
|                          | A110100 | 254.0     | 25.4     | 10.0 | 2.2  | 1.5 | 233.7              | 232.2              |
|                          | A115100 | 254.0     | 38.1     | 6.7  | 3.6  | 2.0 | 233.7              | 231.3              |
|                          | A120100 | 254.0     | 50.8     | 5.0  | 4.8  | 2.0 | 233.7              | 230.5              |
|                          | A110120 | 304.8     | 25.4     | 12.0 | 2.1  | 1.5 | 280.4              | 279.0              |
|                          | A115120 | 304.8     | 38.1     | 8.0  | 3.3  | 2.0 | 280.4              | 278.2              |
|                          | A120120 | 304.8     | 50.8     | 6.0  | 4.3  | 2.0 | 280.4              | 277.5              |



# Plano-Convex Lenses

| G1 Commercial Grade Fused Quartz | P/N     | $f_{nom}$ | Diameter | f/#  | CT   | ET  | EFL <sub>300</sub> | BFL <sub>300</sub> |
|----------------------------------|---------|-----------|----------|------|------|-----|--------------------|--------------------|
|                                  | A405010 | 25.4      | 12.7     | 2.0  | 3.3  | 1.5 | 24.5               | 22.3               |
|                                  | A405015 | 38.1      | 12.7     | 3.0  | 2.7  | 1.5 | 35.9               | 34.1               |
|                                  | A410015 | 38.1      | 25.4     | 1.5  | 6.9  | 1.5 | 35.9               | 31.2               |
|                                  | A405020 | 50.8      | 12.7     | 4.0  | 2.4  | 1.5 | 47.9               | 46.2               |
|                                  | A410020 | 50.8      | 25.4     | 2.0  | 5.3  | 1.5 | 47.9               | 44.4               |
|                                  | A415020 | 50.8      | 38.1     | 1.3  | 11.8 | 2.0 | 47.9               | 39.9               |
|                                  | A405030 | 76.2      | 12.7     | 6.0  | 2.1  | 1.5 | 71.8               | 70.4               |
|                                  | A410030 | 76.2      | 25.4     | 3.0  | 3.9  | 1.5 | 71.8               | 69.2               |
|                                  | A415030 | 76.2      | 38.1     | 2.0  | 7.6  | 2.0 | 71.8               | 66.7               |
|                                  | A420030 | 76.2      | 50.8     | 1.5  | 12.9 | 2.0 | 71.8               | 63.2               |
|                                  | A405040 | 101.6     | 12.7     | 8.0  | 1.9  | 1.5 | 95.8               | 94.5               |
|                                  | A410040 | 101.6     | 25.4     | 4.0  | 3.3  | 1.5 | 95.8               | 93.6               |
|                                  | A415040 | 101.6     | 38.1     | 2.7  | 6.1  | 2.0 | 95.8               | 91.7               |
|                                  | A420040 | 101.6     | 50.8     | 2.0  | 9.5  | 2.0 | 95.8               | 89.4               |
|                                  | A410050 | 127.0     | 25.4     | 5.0  | 2.9  | 1.5 | 119.7              | 117.8              |
|                                  | A415050 | 127.0     | 38.1     | 3.3  | 5.2  | 2.0 | 119.7              | 116.2              |
|                                  | A420050 | 127.0     | 50.8     | 2.5  | 7.8  | 2.0 | 119.7              | 114.5              |
|                                  | A410060 | 152.4     | 25.4     | 6.0  | 2.7  | 1.5 | 143.7              | 141.9              |
|                                  | A415060 | 152.4     | 38.1     | 4.0  | 4.6  | 2.0 | 143.7              | 140.5              |
|                                  | A420060 | 152.4     | 50.8     | 3.0  | 6.8  | 2.0 | 143.7              | 139.1              |
|                                  | A410070 | 177.8     | 25.4     | 7.0  | 2.5  | 1.5 | 167.6              | 165.9              |
|                                  | A415070 | 177.8     | 38.1     | 4.7  | 4.2  | 2.0 | 167.6              | 164.7              |
|                                  | A420070 | 177.8     | 50.8     | 3.5  | 6.0  | 2.0 | 167.6              | 163.5              |
|                                  | A410080 | 203.2     | 25.4     | 8.0  | 2.4  | 1.5 | 191.5              | 190.0              |
|                                  | A415080 | 203.2     | 38.1     | 5.3  | 4.0  | 2.0 | 191.5              | 188.9              |
|                                  | A420080 | 203.2     | 50.8     | 4.0  | 5.5  | 2.0 | 191.5              | 187.8              |
|                                  | A410100 | 254.0     | 25.4     | 10.0 | 2.2  | 1.5 | 239.4              | 238.0              |
|                                  | A415100 | 254.0     | 38.1     | 6.7  | 3.6  | 2.0 | 239.4              | 237.0              |
|                                  | A420100 | 254.0     | 50.8     | 5.0  | 4.8  | 2.0 | 239.4              | 236.2              |
|                                  | A410120 | 304.8     | 25.4     | 12.0 | 2.1  | 1.5 | 287.3              | 285.9              |
|                                  | A415120 | 304.8     | 38.1     | 8.0  | 3.3  | 2.0 | 287.3              | 285.1              |
|                                  | A420120 | 304.8     | 50.8     | 6.0  | 4.3  | 2.0 | 287.3              | 284.4              |

# Plano-Convex Lenses



| N-BK7/S-BSL7 Optical Glass | P/N     | $f_{nom}$ | Diameter | f/#  | CT   | ET  | EFL <sub>546</sub> | BFL <sub>546</sub> |
|----------------------------|---------|-----------|----------|------|------|-----|--------------------|--------------------|
|                            | A605010 | 25.4      | 12.7     | 2.0  | 3.1  | 1.5 | 26.0               | 24.0               |
|                            | A605015 | 38.1      | 12.7     | 3.0  | 2.6  | 1.5 | 38.1               | 36.4               |
|                            | A610015 | 38.1      | 25.4     | 1.5  | 6.1  | 1.5 | 38.1               | 34.1               |
|                            | A605020 | 50.8      | 12.7     | 4.0  | 2.3  | 1.5 | 50.8               | 49.3               |
|                            | A610020 | 50.8      | 25.4     | 2.0  | 4.8  | 1.5 | 50.8               | 47.7               |
|                            | A615020 | 50.8      | 38.1     | 1.3  | 10.2 | 2.0 | 50.8               | 44.1               |
|                            | A605030 | 76.2      | 12.7     | 6.0  | 2.0  | 1.5 | 76.2               | 74.9               |
|                            | A610030 | 76.2      | 25.4     | 3.0  | 3.6  | 1.5 | 76.2               | 73.8               |
|                            | A615030 | 76.2      | 38.1     | 2.0  | 6.9  | 2.0 | 76.2               | 71.6               |
|                            | A620030 | 76.2      | 50.8     | 1.5  | 11.3 | 2.0 | 76.2               | 68.8               |
|                            | A605040 | 101.6     | 12.7     | 8.0  | 1.9  | 1.5 | 101.6              | 100.4              |
|                            | A610040 | 101.6     | 25.4     | 4.0  | 3.1  | 1.5 | 101.6              | 99.6               |
|                            | A615040 | 101.6     | 38.1     | 2.7  | 5.6  | 2.0 | 101.6              | 97.9               |
|                            | A620040 | 101.6     | 50.8     | 2.0  | 8.5  | 2.0 | 101.6              | 96.0               |
|                            | A610050 | 127.0     | 25.4     | 5.0  | 2.7  | 1.5 | 127.0              | 125.2              |
|                            | A615050 | 127.0     | 38.1     | 3.3  | 4.8  | 2.0 | 127.0              | 123.8              |
|                            | A620050 | 127.0     | 50.8     | 2.5  | 7.1  | 2.0 | 127.0              | 122.3              |
|                            | A610060 | 152.4     | 25.4     | 6.0  | 2.5  | 1.5 | 152.4              | 150.7              |
|                            | A615060 | 152.4     | 38.1     | 4.0  | 4.3  | 2.0 | 152.4              | 149.5              |
|                            | A620060 | 152.4     | 50.8     | 3.0  | 6.2  | 2.0 | 152.4              | 148.3              |
|                            | A610070 | 177.8     | 25.4     | 7.0  | 2.4  | 1.5 | 177.8              | 176.2              |
|                            | A615070 | 177.8     | 38.1     | 4.7  | 4.0  | 2.0 | 177.8              | 175.2              |
|                            | A620070 | 177.8     | 50.8     | 3.5  | 5.6  | 2.0 | 177.8              | 174.1              |
|                            | A610080 | 203.2     | 25.4     | 8.0  | 2.3  | 1.5 | 203.2              | 201.7              |
|                            | A615080 | 203.2     | 38.1     | 5.3  | 3.7  | 2.0 | 203.2              | 200.7              |
|                            | A620080 | 203.2     | 50.8     | 4.0  | 5.1  | 2.0 | 203.2              | 199.8              |
|                            | A610100 | 254.0     | 25.4     | 10.0 | 2.5  | 1.5 | 254.0              | 252.6              |
|                            | A615100 | 254.0     | 38.1     | 6.7  | 3.4  | 2.0 | 254.0              | 251.8              |
|                            | A620100 | 254.0     | 50.8     | 5.0  | 4.5  | 2.0 | 254.0              | 251.0              |
|                            | A610120 | 304.8     | 25.4     | 12.0 | 2.0  | 1.5 | 304.8              | 303.5              |
|                            | A615120 | 304.8     | 38.1     | 8.0  | 3.2  | 2.0 | 304.8              | 302.7              |
|                            | A620120 | 304.8     | 50.8     | 6.0  | 4.1  | 2.0 | 304.8              | 302.1              |



# Plano-Convex Lenses

## Custom

In addition to our standard lines of plano-convex lenses, we also manufacture a variety of custom elements including plano-concave lenses (negative focal length components with one concave surface). For more information on these and other custom products or applications, please contact Esco at 1-800-922-ESCO (3726).

## Sizes:

From 5.0 mm to 380.0 mm diameter

## Materials:

Fused Quartz/Fused Silica (all grades)

Borofloat/Supremax

N-BK7/S-BSL7 Optical Glass

Other materials upon request

## Focal Lengths:

Nearly any focal length is possible. Research quantities of some focal lengths may be available off-the-shelf. Please contact Esco for more information.

## Surface Quality:

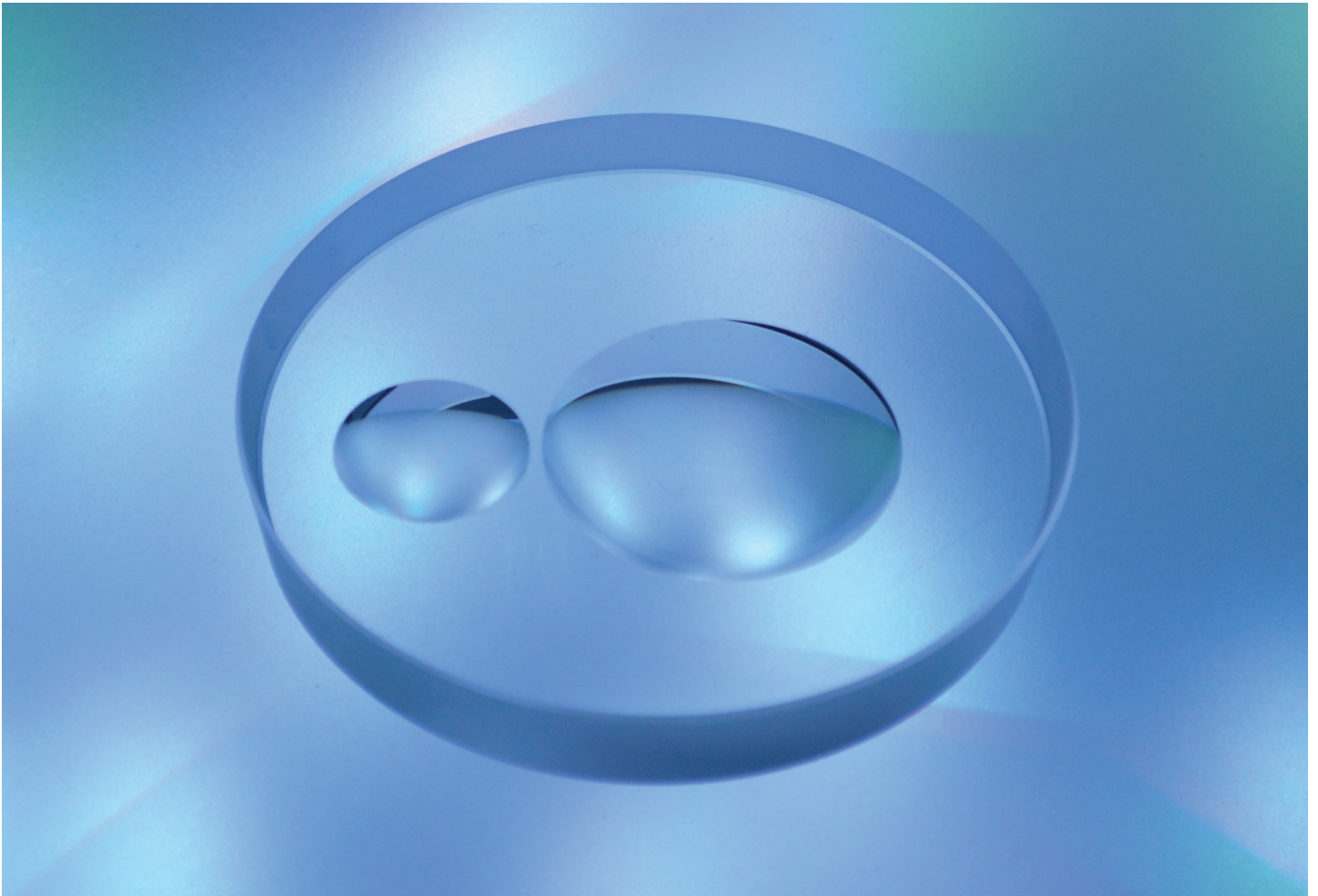
Some applications may require surface qualities better than that of commercially available products. Esco can supply plano-convex elements with surface quality better than 10-5 laser grade and surface accuracies better than  $\lambda/10$ . An Esco sales engineer can assist with your custom requirements.

## Tolerances:

The dimensional tolerances for bi-convex lenses shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

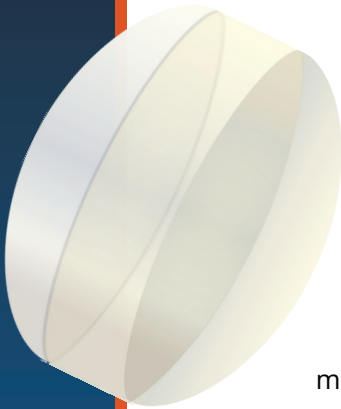
## Coatings:

Anti-Reflection coatings that allow efficient energy throughput are available. For more information, see pages 36 - 37 or call Esco.



Esco Optics has over 50 years of prototype and catalog lens experience.

## Achromatic Lenses



Achromatic lenses are doublet systems consisting of one crown and one flint element cemented together along a matching curvature.

They are designed to minimize spherical and chromatic aberrations for infinite conjugate, visible spectrum, imaging applications.

These Achromats provide diffraction-limited performance over nearly their entire clear aperture. To achieve this performance, the individual lens elements are precision ground and polished to provide minimum wavefront distortion. Each surface is optically centered to ensure optimum alignment.

The lens designs are optimized to ensure that chromatic and spherical aberrations are simultaneously minimized. This optimization, combined with careful machining, also limits many off-axis aberrations such as coma.

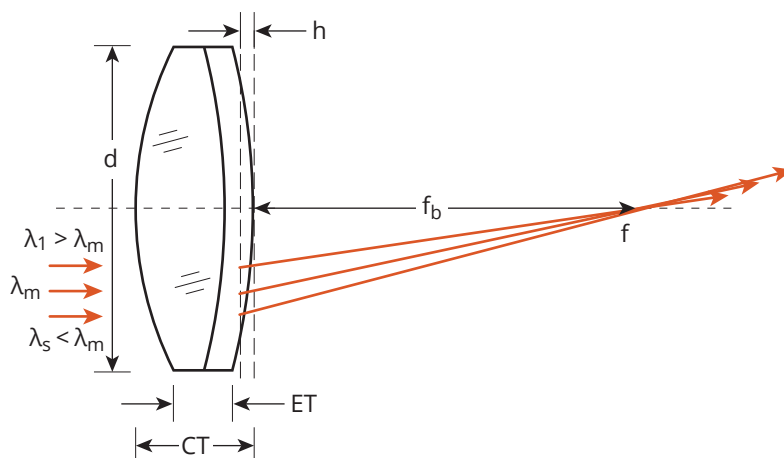
# Achromatic Lenses



## Standard

Esco Achromatic Lenses are suitable for use in most high resolution imaging systems or any application where spherical and chromatic aberrations must be minimized. Their performance is superior to that of all single element lenses, even in monochromatic applications.

Because achromats are asymmetric elements, they must be used in the proper orientation to ensure optimum performance. A general rule of thumb is that the flattest side should face toward the image.



|                                                      |                                            |
|------------------------------------------------------|--------------------------------------------|
| <b>Focal Length Tolerance:</b>                       | $\pm 2\%$ at 546 nm                        |
| <b>Clear Aperture:</b>                               | 80%                                        |
| <b>Diameter Tolerance:</b>                           | $+0/-0.15$ mm                              |
| <b>Thickness Tolerance:</b>                          | $\pm 0.25$ mm                              |
| <b>Centration:</b>                                   | $< 3'$                                     |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig                         |
| <b>Surface Accuracy:</b>                             | Better than $1\lambda$ over clear aperture |
| <b>Edges:</b>                                        | Fine ground and beveled                    |
| <b>Coating:</b>                                      | MGF2, single layer $MgF_2$                 |
| All dimensions are in mm unless otherwise specified. |                                            |

The crown and flint glasses that compose our achromats are Grade A optical quality materials. Since more than just a few glass types are necessary to provide a complete line of optimized designs, it is not possible to list here the specifications of all those that are used. If you require details about the specific glass types used in the achromats listed below, please contact Esco.

All standard achromatic lenses are supplied with single layer  $MgF_2$  anti-reflection coatings on both outside surfaces. The total energy throughput exceeds 98% average across the visible spectrum.



# Achromatic Lenses

| P/N     | $f_{\text{nom}}$ | Diameter | f/#  | CT   | ET   | EFL <sub>588</sub> | BFL <sub>588</sub> | $h_{588}$ |
|---------|------------------|----------|------|------|------|--------------------|--------------------|-----------|
| A912025 | 25               | 12.7     | 2.0  | 5.5  | 4.2  | 25.3               | 22.4               | 2.9       |
| A912030 | 30               | 12.7     | 2.4  | 5.0  | 3.9  | 30.2               | 27.6               | 2.6       |
| A912050 | 50               | 12.7     | 4.0  | 4.5  | 3.8  | 50.9               | 48.8               | 2.1       |
| A925050 | 50               | 25.4     | 2.0  | 9.8  | 5.9  | 51.5               | 46.4               | 5.1       |
| A912075 | 75               | 12.7     | 6.0  | 5.0  | 4.6  | 76.0               | 73.5               | 2.5       |
| A925075 | 75               | 25.4     | 3.0  | 7.5  | 5.8  | 76.2               | 72.4               | 3.8       |
| A938075 | 75               | 38.1     | 2.0  | 14.1 | 8.8  | 76.8               | 69.6               | 7.2       |
| A912100 | 100              | 12.7     | 8.0  | 3.8  | 3.3  | 99.7               | 98.1               | 1.6       |
| A925100 | 100              | 25.4     | 4.0  | 7.2  | 5.8  | 100.0              | 96.5               | 3.5       |
| A938100 | 100              | 38.1     | 2.7  | 12.7 | 8.3  | 100.6              | 94.3               | 6.3       |
| A950100 | 100              | 50.8     | 2.0  | 20.5 | 12.5 | 101.4              | 91.1               | 10.3      |
| A912150 | 150              | 12.7     | 12.0 | 5.2  | 5.0  | 150.0              | 147.8              | 2.2       |
| A925150 | 150              | 25.4     | 6.0  | 6.2  | 5.3  | 150.0              | 147.1              | 2.9       |
| A938150 | 150              | 38.1     | 4.0  | 10.8 | 7.9  | 150.5              | 145.5              | 5.0       |
| A950150 | 150              | 50.8     | 3.0  | 14.3 | 9.1  | 150.8              | 143.7              | 7.1       |
| A925175 | 175              | 25.4     | 7.0  | 6.3  | 5.5  | 175.0              | 172.1              | 2.9       |
| A938175 | 175              | 38.1     | 4.7  | 10.4 | 7.9  | 175.5              | 170.8              | 4.7       |
| A950175 | 175              | 50.8     | 3.5  | 12.8 | 8.3  | 175.7              | 169.4              | 6.3       |
| A925200 | 200              | 25.4     | 8.0  | 8.1  | 7.2  | 200.1              | 194.7              | 5.4       |
| A938200 | 200              | 38.1     | 5.3  | 9.5  | 7.3  | 200.4              | 196.1              | 4.3       |
| A950200 | 200              | 50.8     | 4.0  | 11.9 | 8.0  | 200.6              | 194.8              | 5.8       |
| A925250 | 250              | 25.4     | 10.0 | 5.3  | 4.5  | 249.5              | 247.2              | 2.3       |
| A938250 | 250              | 38.1     | 6.7  | 8.8  | 7.1  | 249.9              | 246.1              | 3.8       |
| A950250 | 250              | 50.8     | 5.0  | 10.5 | 7.4  | 250.0              | 245.1              | 4.9       |
| A925500 | 500              | 25.4     | 20.0 | 6.5  | 6.1  | 499.6              | 496.6              | 3.0       |
| A938500 | 500              | 38.1     | 13.3 | 10.0 | 9.1  | 500.0              | 495.5              | 4.5       |
| A950500 | 500              | 50.8     | 10.0 | 13.0 | 11.9 | 500.4              | 494.7              | 5.7       |

# Achromatic Lenses



## Custom

In addition to our standard lines of achromatic lenses, we are often called upon to design and manufacture a variety of custom elements including:

- Negative achromats
- Lenses designed for finite conjugate systems
- Lenses whose designs have been optimized for other wavelength regions such as the ultraviolet or near infrared.

For more information on these and other custom products or applications, please contact Esco at 1-800-922-ESCO (3726).

## Sizes:

Up to 152.4 mm diameter

## Focal Lengths:

Any focal length greater than about  $f/2.0$  is possible. Research quantities of some focal lengths may be available off-the-shelf. Please contact Esco for more information.

## Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply elements with surface quality better than 10-5 laser grade and surface accuracies better than  $\lambda/20$ . To provide such precision, however, these systems often must be air-spaced rather than cemented. Please contact Esco for more information.

For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Tolerances:

The dimensional tolerances for achromatic lenses shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Coatings:

Anti-Reflection coatings that allow efficient energy throughput are available. Yet because of the high index of the flint element, coatings more sophisticated than single-layer  $\text{MgF}_2$  often provide only an incremental improvement. To discuss your particular needs, please contact Esco.

## Cylindrical Lenses



Ordinary lenses have one or more spherical surfaces, yet a curved surface on a cylindrical lens is shaped (as the name suggests) like a cylinder. Instead of a focal point, their performance is characterized by a focal line that lies parallel to the cylindrical axis. The same lens formulas that describe the behavior of common spherical elements also apply to cylindrical lenses, but in one dimension only.

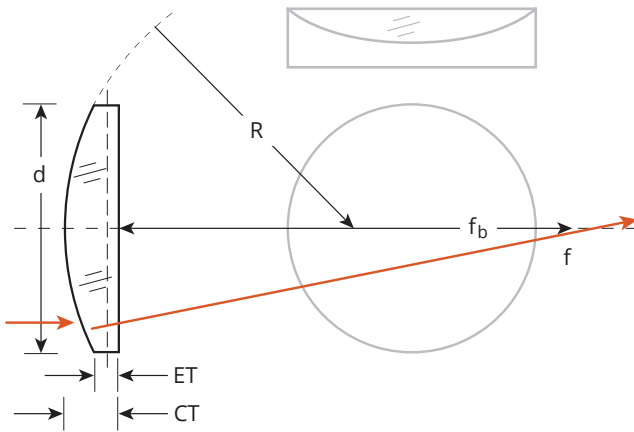
Cylindrical lenses are useful in applications such as optical data storage and retrieval systems for imaging linear arrays, spectroscopic instrumentation for imaging slits, and other processes involving scanning techniques. In addition, they are frequently used with lasers to generate a narrow line of light that is used for measurement or alignment.

# Cylindrical Lenses



## Standard

Esco manufactures a variety of standard plano-convex cylindrical lenses. All are CNC polished to provide excellent surface quality and accuracy.



|                                                                     |                         |
|---------------------------------------------------------------------|-------------------------|
| <b>Focal Length Tolerance:</b>                                      | ±3%                     |
| <b>Thickness Tolerance:</b>                                         | ±0.5 mm                 |
| <b>Design Wavelength:</b>                                           | 546 nm                  |
| <b>Axis Linearity:</b>                                              | <6'                     |
| <b>Surface Quality:</b>                                             | 60-40, scratch-dig      |
| <b>Edges:</b>                                                       | Fine ground and beveled |
| Optical Materials, pages 25 - 34<br>Optical Coatings, pages 35 - 40 |                         |

| S1-UV Grade Fused Silica | P/N     | $f_{nom}$ | Diameter | f/#  | CT   | ET  | EFL <sub>250</sub> | BFL <sub>250</sub> |
|--------------------------|---------|-----------|----------|------|------|-----|--------------------|--------------------|
|                          | B110015 | 38.1      | 25.4     | 1.5  | 6.9  | 1.5 | 35.1               | 30.4               |
|                          | B110020 | 50.8      | 25.4     | 2.0  | 5.3  | 1.5 | 46.7               | 43.2               |
|                          | B115020 | 50.8      | 38.1     | 1.3  | 11.8 | 2.0 | 46.7               | 38.8               |
|                          | B110030 | 76.2      | 25.4     | 3.0  | 3.9  | 1.5 | 70.1               | 67.5               |
|                          | B115030 | 76.2      | 38.1     | 2.0  | 7.6  | 2.0 | 70.1               | 65.0               |
|                          | B120030 | 76.2      | 50.8     | 1.5  | 12.9 | 2.0 | 70.1               | 61.5               |
|                          | B110040 | 101.6     | 25.4     | 4.0  | 3.3  | 1.5 | 93.5               | 91.3               |
|                          | B115040 | 101.6     | 38.1     | 2.7  | 6.1  | 2.0 | 93.5               | 89.4               |
|                          | B120040 | 101.6     | 50.8     | 2.0  | 9.5  | 2.0 | 93.5               | 87.1               |
|                          | B110060 | 152.4     | 25.4     | 6.0  | 2.7  | 1.5 | 140.2              | 138.4              |
|                          | B115060 | 152.4     | 38.1     | 4.0  | 4.6  | 2.0 | 140.2              | 137.1              |
|                          | B120060 | 152.4     | 50.8     | 3.0  | 6.8  | 2.0 | 140.2              | 135.7              |
|                          | B110100 | 254.0     | 25.4     | 10.0 | 2.2  | 1.5 | 233.7              | 232.2              |
|                          | B115100 | 254.0     | 38.1     | 6.7  | 3.6  | 2.0 | 233.7              | 231.3              |
|                          | B120100 | 254.0     | 50.8     | 5.0  | 4.8  | 2.0 | 233.7              | 230.5              |



# Cylindrical Lenses

| G1 Optical Grade Fused Quartz | P/N     | $f_{\text{nom}}$ | Diameter | f/#  | CT   | ET  | EFL <sub>300</sub> | BFL <sub>300</sub> |
|-------------------------------|---------|------------------|----------|------|------|-----|--------------------|--------------------|
|                               | B410015 | 38.1             | 25.4     | 1.5  | 6.9  | 1.5 | 35.9               | 31.2               |
|                               | B410020 | 50.8             | 25.4     | 2.0  | 5.3  | 1.5 | 47.9               | 44.4               |
|                               | B415020 | 50.8             | 38.1     | 1.3  | 11.8 | 2.0 | 47.9               | 39.9               |
|                               | B410030 | 76.2             | 25.4     | 3.0  | 3.9  | 1.5 | 71.8               | 69.2               |
|                               | B415030 | 76.2             | 38.1     | 2.0  | 7.6  | 2.0 | 71.8               | 66.7               |
|                               | B420030 | 76.2             | 50.8     | 1.5  | 12.9 | 2.0 | 71.8               | 63.2               |
|                               | B410040 | 101.6            | 25.4     | 4.0  | 3.3  | 1.5 | 95.8               | 93.6               |
|                               | B415040 | 101.6            | 38.1     | 2.7  | 6.1  | 2.0 | 95.8               | 91.7               |
|                               | B420040 | 101.6            | 50.8     | 2.0  | 9.5  | 2.0 | 95.8               | 89.4               |
|                               | B410060 | 152.4            | 25.4     | 6.0  | 2.7  | 1.5 | 143.7              | 141.9              |
|                               | B415060 | 152.4            | 38.1     | 4.0  | 4.6  | 2.0 | 143.7              | 140.5              |
|                               | B420060 | 152.4            | 50.8     | 3.0  | 6.8  | 2.0 | 143.7              | 139.1              |
|                               | B410100 | 254.0            | 25.4     | 10.0 | 2.2  | 1.5 | 239.4              | 238.0              |
|                               | B415100 | 254.0            | 38.1     | 6.7  | 3.6  | 2.0 | 239.4              | 237.0              |
|                               | B420100 | 254.0            | 50.8     | 5.0  | 4.8  | 2.0 | 239.4              | 236.2              |

| N-BK7/S-BL7 Optical Glass | P/N     | $f_{\text{nom}}$ | Diameter | f/#  | CT   | ET  | EFL <sub>546</sub> | BFL <sub>546</sub> |
|---------------------------|---------|------------------|----------|------|------|-----|--------------------|--------------------|
|                           | B610015 | 38.1             | 25.4     | 1.5  | 6.1  | 1.5 | 38.1               | 34.1               |
|                           | B610020 | 50.8             | 25.4     | 2.0  | 4.8  | 1.5 | 50.8               | 47.7               |
|                           | B615020 | 50.8             | 38.1     | 1.3  | 10.2 | 2.0 | 50.8               | 44.1               |
|                           | B610030 | 76.2             | 25.4     | 3.0  | 3.6  | 1.5 | 76.2               | 73.8               |
|                           | B615030 | 76.2             | 38.1     | 2.0  | 6.9  | 2.0 | 76.2               | 71.6               |
|                           | B620030 | 76.2             | 50.8     | 1.5  | 11.3 | 2.0 | 76.2               | 68.8               |
|                           | B610040 | 101.6            | 25.4     | 4.0  | 3.1  | 1.5 | 101.6              | 99.6               |
|                           | B615040 | 101.6            | 38.1     | 2.7  | 5.6  | 2.0 | 101.6              | 97.9               |
|                           | B620040 | 101.6            | 50.8     | 2.0  | 8.5  | 2.0 | 101.6              | 96.0               |
|                           | B610060 | 152.4            | 25.4     | 6.0  | 2.5  | 1.5 | 152.4              | 150.7              |
|                           | B615060 | 152.4            | 38.1     | 4.0  | 4.3  | 2.0 | 152.4              | 149.5              |
|                           | B620060 | 152.4            | 50.8     | 3.0  | 6.2  | 2.0 | 152.4              | 148.3              |
|                           | B610100 | 254.0            | 25.4     | 10.0 | 2.1  | 1.5 | 254.0              | 252.6              |
|                           | B615100 | 254.0            | 38.1     | 6.7  | 3.4  | 2.0 | 254.0              | 251.8              |
|                           | B620100 | 254.0            | 50.8     | 5.0  | 4.5  | 2.0 | 254.0              | 251.0              |

# Cylindrical Lenses



## Custom

In addition to our standard lines of cylindrical lenses, we also manufacture a variety of custom elements including negative cylindrical lenses and lenses made of other optical materials. We're also pleased to announce the manufacturing capability of Aspheric Cylindrical Lenses (see page 61). For more information on these and other custom products or applications, please contact Esco at 1-800-922-ESCO (3726).

## Sizes:

Rectangular or round, maximum and minimum sizes vary depending on other dimensions. Please inquire.

## Materials:

Fused Quartz/Fused Silica (all grades)  
Borofloat/Supremax  
N-BK7/S-BSL7 Optical Glass  
Other materials upon request

## Focal Lengths:

Nearly any focal length is possible. Research quantities of some focal lengths may be available off-the-shelf. For certain OEM applications, looser tolerances may lead to cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply cylindrical elements with improved surface accuracy and quality. Please inquire.

## Tolerances:

The dimensional tolerances for cylindrical lenses shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Coatings:

Anti-Reflection coatings that allow efficient energy throughput are available. For more information, see pages 36 - 37 or call Esco.

## Aspheric Lenses



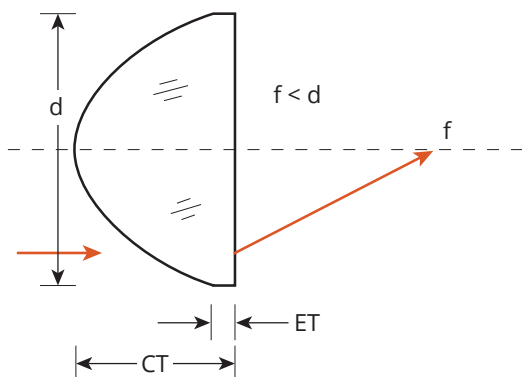
An aspheric lens is a single optical element with one aspheric convex surface and one plano or spherical convex surface. Characterized by f-numbers less than 1.0, aspheres provide maximum energy throughput over a limited path length. An aspheric lens' complex surface profile can reduce or eliminate spherical aberration as well as other aberrations, such as astigmatism.

# Aspheric Lenses



## Standard

Esco manufactures aspheric lenses from high quality optical crown glass. They are precision CNC generated and polished to provide excellent performance in critical condenser applications.



|                                                      |                                                                     |
|------------------------------------------------------|---------------------------------------------------------------------|
| <b>Material:</b>                                     | Schott K5 Crown glass or equivalent<br>$n_d = 1.522$ , $v_d = 59.5$ |
| <b>Focal Length Tolerance:</b>                       | $\pm 7\%$                                                           |
| <b>Diameter Tolerance:</b>                           | $\pm 0.5$ mm                                                        |
| <b>Center Thickness Tolerance:</b>                   | $\pm 0.5$ mm                                                        |
| <b>Surface Quality:</b>                              | 80-50, scratch-dig                                                  |
| <b>Max Operating Temperature:</b>                    | 175°C                                                               |
| All dimensions are in mm unless otherwise specified. |                                                                     |

| P/N     | $f_{nom}$ | Diameter | f/#  | CT   |
|---------|-----------|----------|------|------|
| C118150 | 15.0      | 18.0     | 0.83 | 7.4  |
| C124180 | 18.0      | 24.0     | 0.75 | 10.6 |
| C134240 | 24.0      | 34.0     | 0.63 | 14.0 |
| C150355 | 35.5      | 50.0     | 0.71 | 21.1 |
| C160390 | 39.0      | 60.0     | 0.65 | 27.0 |

## Coatings:

Anti-Reflection coatings that allow efficient energy throughput are available. Because of the steepness of the aspheric surface, however, multilayer coatings may not perform properly. Single layer  $MgF_2$  is recommended for most applications. For more information, see pages 36 - 37 or contact an Esco Sales Engineer.



# Aspheric Lenses

## Esco Optics Is Now Fabricating Aspheric Cylindrical Lenses

Esco Optics is pleased to announce the manufacturing capability of Aspheric Cylindrical Lenses. With the use of OptiPro CNC UFF Polishing machines, Esco is producing and repeating precision A-Cylinders of various materials and sizes. This product is currently being offered as a new line of custom optics, and Esco is quoting both prototype and production quantities.

### How do Acylindrical Lenses differ from Aspherical Lenses?

A plano-convex aspherical lens focuses an incident ray in two dimensions to a precise focal point, while A-Cylindrical Lenses focus the incident ray in one dimension along a linear axis parallel to the cylindrical or acylindrical surface. The resultant focused beam is a line instead of a single point.

The typical configuration of an aspherical cylinder (or acylinder) is plano-convex. The non-plano surface is polished using aspheric coefficients in relation to a best fit cylinder radius, thus reducing spherical aberration in one dimension. Plano-concave Acylinders are also possible but not as common. Acylindrical lenses can be manufactured using high index materials to aid in the reduction of chromatic aberration.

### Benefits and applications of an acylindrical lens include:

- Collimation of laser diode fast axis
- Optimum in line focus by reducing spherical aberration on one dimension
- Increase the performance of a system requiring magnification in one dimension
- A plano-convex acylindrical lens can be optimized for infinite conjugate configurations
- Create a thin line profile when using a monochromatic light source
- Short focal length, thus reducing the optical path length of a particular system

Esco Optics fabricates A-Cylindrical components from virtually any material, with cylinder lengths upwards of 200mm. To ensure the high accuracy that is generally required with Aspheric Cylinders, Esco uses an OptiPro OptiTrace 3D Profilometer. Esco is able to polish A-Cylinders to an RMS wavefront error of less than 0.5 microns, and surface quality of 10-5 depending on the material. Please contact [sales@EscoOptics.com](mailto:sales@EscoOptics.com) for more information regarding your A-Cylindrical needs.



Esco Optics works closely with our customers in developing custom optical element configurations and solutions.

## Bestform (Laser) Lenses



To ensure that only minimum spherical aberration is introduced by an optical element, it is necessary to consider its shape. For each condition there is a preferred lens shape that minimizes spherical aberration. For example, in 1:1 imaging applications, the best shape is a symmetric bi-convex lens.

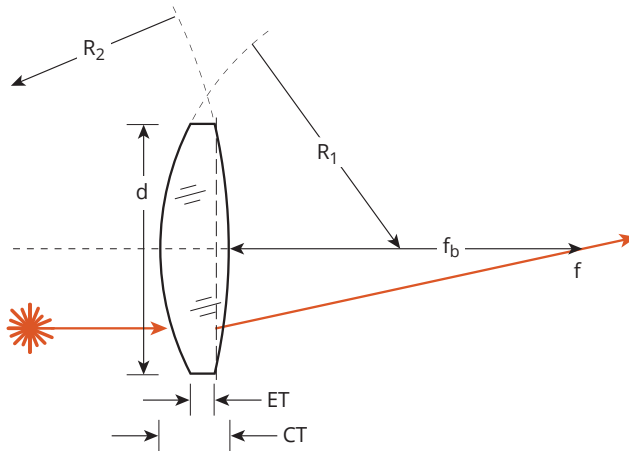
In the infinite conjugate case of focusing a laser beam to a minimum spot, the shape of a single element lens that most effectively reduces spherical aberration is called Bestform. The front and back radii of these lenses are chosen to be of a specific ratio. This ratio is determined by the proper shape factor, which is governed by the lens material.

# Bestform (Laser) Lenses



## Standard

Esco manufactures Bestform lenses from the highest quality optical grade materials. Only materials with superior homogeneity should be used in laser applications. CNC polishing provides excellent surface quality which is a necessary characteristic for limiting scatter.



|                                |                                                                            |
|--------------------------------|----------------------------------------------------------------------------|
| <b>Focal Length Tolerance:</b> | ±3%                                                                        |
| <b>Diameter Tolerance:</b>     | ±0.15 mm                                                                   |
| <b>Thickness Tolerance:</b>    | ±0.2 mm                                                                    |
| <b>Centration:</b>             | <3'                                                                        |
| <b>Surface Quality:</b>        | 20-10, scratch-dig                                                         |
| <b>Surface Accuracy:</b>       | $\lambda/10$ or better over 80% of clear aperture                          |
| <b>Edges:</b>                  | Fine ground and beveled                                                    |
| <b>Coating:</b>                | AR-V Multilayer AR coating at the design wavelength available upon request |

Optical Materials, pages 25 - 34

Optical Coatings, pages 35 - 40

All dimensions are in mm unless otherwise specified.

| S1-UVA Fused Silica | P/N     | $f_{nom}$ | Diameter | $\lambda_{des}$ | CT  | ET  | $EFL_{des}$ | $BFL_{des}$ | Beam Diameter | Spot Diameter |
|---------------------|---------|-----------|----------|-----------------|-----|-----|-------------|-------------|---------------|---------------|
|                     | A610510 | 10        | 5.0      | 325 nm          | 2.6 | 1.5 | 11.1        | 9.6         | 1.0           | 4.6 $\mu m$   |
|                     | A611220 | 20        | 12.7     | 325 nm          | 5.6 | 1.5 | 19.4        | 16.1        | 2.0           | 4.0 $\mu m$   |
|                     | A612510 | 100       | 25.4     | 325 nm          | 4.4 | 1.5 | 100.4       | 97.9        | 8.0           | 5.2 $\mu m$   |
|                     | A612525 | 250       | 25.4     | 325 nm          | 2.6 | 1.5 | 248.5       | 247.0       | 15.0          | 6.8 $\mu m$   |
|                     | A615011 | 1100      | 50.8     | 325 nm          | 3.1 | 2.0 | 1087.8      | 1086.0      | 45.0          | 9.9 $\mu m$   |
|                     | A650510 | 10        | 5.0      | 1064 nm         | 2.6 | 1.5 | 11.6        | 10.1        | 1.0           | 15.7 $\mu m$  |
|                     | A651220 | 20        | 12.7     | 1064 nm         | 5.6 | 1.5 | 20.1        | 16.8        | 2.0           | 13.5 $\mu m$  |
|                     | A652510 | 100       | 25.4     | 1064 nm         | 4.5 | 1.5 | 102.4       | 99.8        | 8.0           | 18.6 $\mu m$  |
|                     | A652525 | 250       | 25.4     | 1064 nm         | 2.7 | 1.5 | 248.9       | 247.4       | 15.0          | 23.4 $\mu m$  |
|                     | A655011 | 1100      | 50.8     | 1064 nm         | 3.0 | 2.0 | 1109.5      | 1107.8      | 45.0          | 33.4 $\mu m$  |

| N-BK7/S-BSL7 Optical Glass | P/N     | $f_{nom}$ | Diameter | $\lambda_{des}$ | CT  | ET  | $EFL_{des}$ | $BFL_{des}$ | Beam Diameter | Spot Diameter |
|----------------------------|---------|-----------|----------|-----------------|-----|-----|-------------|-------------|---------------|---------------|
|                            | A630510 | 10        | 5.0      | 633 nm          | 2.6 | 1.5 | 10.5        | 9.0         | 1.0           | 8.6 $\mu m$   |
|                            | A631220 | 20        | 12.7     | 633 nm          | 5.6 | 1.5 | 20.4        | 17.4        | 2.0           | 8.2 $\mu m$   |
|                            | A632510 | 100       | 25.4     | 633 nm          | 4.2 | 1.5 | 101.2       | 98.8        | 8.0           | 10.2 $\mu m$  |
|                            | A632525 | 250       | 25.4     | 633 nm          | 2.6 | 1.5 | 244.0       | 242.5       | 15.0          | 13.1 $\mu m$  |
|                            | A635011 | 1100      | 50.8     | 633 nm          | 2.9 | 2.0 | 1133.5      | 1131.9      | 45.0          | 20.3 $\mu m$  |



# Bestform (Laser) Lenses

## Custom

In addition to our standard lines of Bestform lenses, we also manufacture a variety of custom designs. For more information on these and other custom products or applications, please contact Esco at 1-800-922-ESCO (3726).

## Sizes:

Up to 50 mm diameter

## Materials:

S1-UV Fused Silica (both grades)

I2-IR Fused Quartz

A1 Optical Grade Fused Quartz

N-BK7/S-BSL7 Optical Glass

Other materials upon request

## Focal Lengths:

Although  $f/\#$ s greater than approximately  $f/1.33$  are physically possible, very little is gained by using 'fast' Bestform lenses. Since the intention of this design is to minimize aberrations, focal lengths as long as possible should be considered to maximize the lens' performance. Research quantities of some focal lengths may be available off-the-shelf. For more information, please contact Esco.

## Surface Quality:

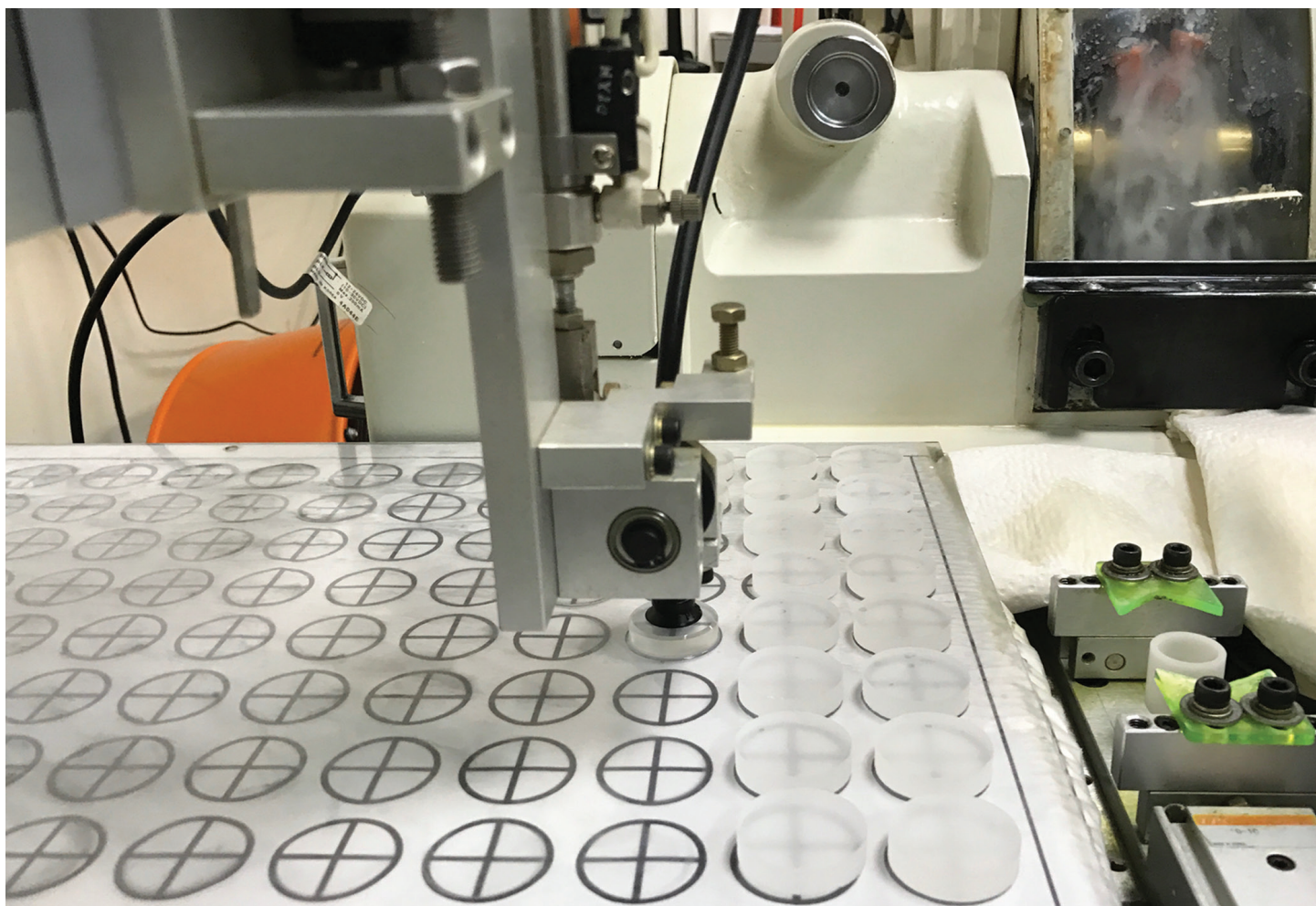
Some applications may require surface qualities better than that of commercially available products. Esco can supply Bestform lenses with surface quality better than 10-5 laser grade and surface accuracies better than  $\lambda/20$ . An Esco sales engineer can assist with your custom requirements.

## Tolerances:

The dimensional tolerances shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Coatings:

Anti-Reflection coatings that allow efficient energy throughput are available. For more information, see pages 36 - 37 or call Esco.



Optical mirror blanks being beveled on 1 of 4 robotic chamfering stations.

## Industrial Laser Lenses



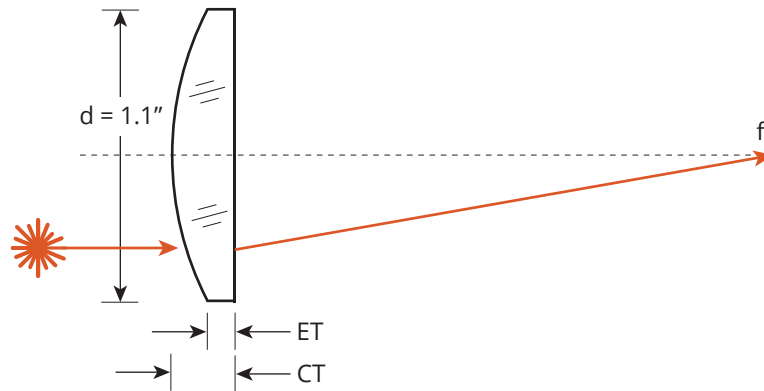
Nd:YAG lasers are used in manufacturing for engraving, etching, or marking a variety of metals and plastics. They are extensively used in manufacturing for cutting and welding steel, semiconductors, and various alloys. Esco manufactures catalog and custom plano-convex lenses as replacement elements for industrial Nd:YAG laser systems that operate at 1.06  $\mu\text{m}$ .

# Industrial Laser Lenses



## Standard

Esco industrial laser lenses are guaranteed to meet or exceed the performance requirements of the original laser equipment. They are manufactured from high purity fused silica and are multilayer AR coated.



|                                |                                                                              |
|--------------------------------|------------------------------------------------------------------------------|
| <b>Material:</b>               | S1-UV Grade Fused Silica                                                     |
| <b>Design Wavelength:</b>      | 1.06 $\mu\text{m}$                                                           |
| <b>Focal Length Tolerance:</b> | $\pm 2\%$                                                                    |
| <b>Diameter:</b>               | 1.1" (27.94 mm) $\pm 0.125$ mm                                               |
| <b>Clear Aperture:</b>         | 1" (25.4 mm)                                                                 |
| <b>Edge Thickness:</b>         | 1.5 mm $\pm 0.5$ mm                                                          |
| <b>Surface Quality:</b>        | 20-10, scratch dig                                                           |
| <b>Coating:</b>                | AR-V Multilayer AR coating for $<0.25\%$ R per surface at 1.06 $\mu\text{m}$ |

Optical Materials, pages 25 - 34

Optical Coatings, pages 35 - 40

All dimensions are in mm unless otherwise specified.

| P/N     | $f_{\text{nom}}$ | $f/\#$ | CT  |
|---------|------------------|--------|-----|
| A711020 | 50.8 (2")        | 1.8    | 6.3 |
| A711040 | 101.6 (4")       | 3.6    | 3.7 |
| A711060 | 152.4 (6")       | 5.5    | 2.9 |
| A711080 | 203.2 (8")       | 7.3    | 2.6 |
| A711100 | 254.0 (10")      | 9.1    | 2.4 |
| A711120 | 304.8 (12")      | 10.9   | 2.2 |



# Industrial Laser Lenses

## Custom

Besides our standard line of industrial laser lenses, we also manufacture custom elements designed specifically for individual applications. To discuss your custom specifications or applications, please contact Esco at 1-800-922-ESCO (3726).

## Materials:

Fused Quartz/Fused Silica (all grades)  
N-BK7/S-BSL7 Optical Glass  
Other precision quality materials upon request

## Focal Lengths:

Nearly any focal length is possible. Research quantities of some non-standard focal lengths may be available off-the-shelf. Please contact Esco for more information.

## Surface Quality:

Because of the high power nature of most industrial lasers, Esco strongly recommends using lenses whose surface characteristics are conducive to scatter-free operation.

## Tolerances:

The dimensional tolerances for industrial laser lenses shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Coatings:

Because of the high power nature of most industrial lasers, Esco strongly recommends using lenses with AR-V coatings to minimize the potential for system damage due to back reflections.



Esco supplies aspherical, acylindrical, and free form components to satisfy the most demanding requirements.

## Optical Flats



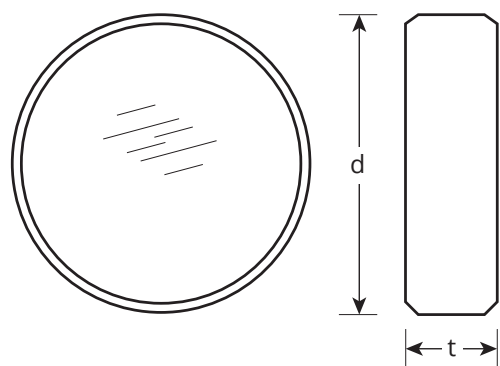
Optical flats are most commonly used as test plates to evaluate the accuracy of flat optical surfaces. Holding the precision face of an optical flat against a test surface under monochromatic light creates a fringe pattern that is visible through the back surface of the flat. This fringe pattern describes the contour of the test surface.

# Optical Flats



Esco manufactures optical flats out of fused quartz. The low thermal expansion, abrasion resistance and general stability of this material allow continuous use with minimum degradation over time.

Optical flats are available with either one or two precision surfaces. The fringe pattern that is visible through an optical flat is not affected by the accuracy of the rear surface. Some users, however, require the versatility and extended lifetime that two precision surfaces offer.



|                                                      |                               |
|------------------------------------------------------|-------------------------------|
| <b>Material:</b>                                     | G1 Optical Grade Fused Quartz |
| <b>Diameter Tolerance:</b>                           | ±1.0 mm                       |
| <b>Thickness Tolerance:</b>                          | ±1.0 mm                       |
| <b>Parallelism:</b>                                  | <15'                          |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig            |
| <b>Clear Aperture:</b>                               | 90%                           |
| All dimensions are in mm unless otherwise specified. |                               |

|                                                       |              | Flatness, One Precision Surface |                                |                               | Flatness, Two Precision Surfaces |                                |                               |
|-------------------------------------------------------|--------------|---------------------------------|--------------------------------|-------------------------------|----------------------------------|--------------------------------|-------------------------------|
| Diameter                                              | Thickness    | $\lambda/_{20}$<br>(0.000001")  | $\lambda/_{10}$<br>(0.000002") | $\lambda/_{4}$<br>(0.000005") | $\lambda/_{20}$<br>(0.000001")   | $\lambda/_{10}$<br>(0.000002") | $\lambda/_{4}$<br>(0.000005") |
| 25.4 (1")                                             | 12.7 (.5")   | F101001                         | F101002                        | F101005                       | F201001                          | F201002                        | F201005                       |
| 50.8 (2")                                             | 12.7 (.5")   | F102001                         | F102002                        | F102005                       | F202001                          | F202002                        | F202005                       |
| 76.2 (3")                                             | 15.9 (.625") | F103001                         | F103002                        | F103005                       | F203001                          | F203002                        | F203005                       |
| Larger optical flats are also available upon request. |              |                                 |                                |                               |                                  |                                |                               |

## Windows

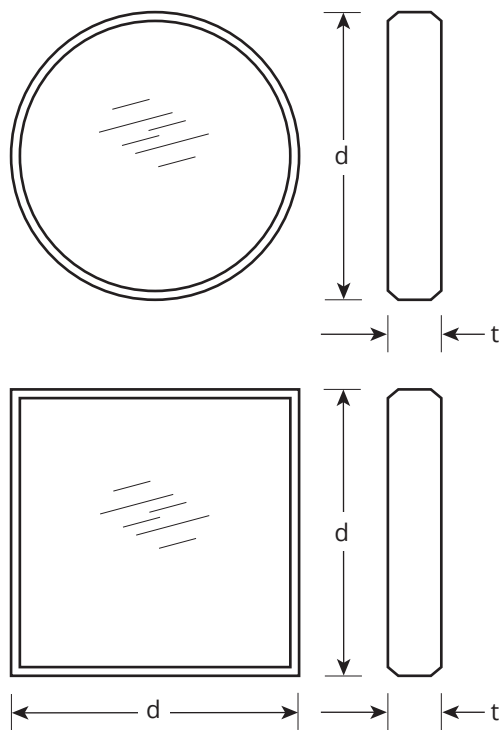
Esco offers flat windows made from a wide variety of optical materials. A wide range of optical quality and configurations are available to suit any application.





## Commercial Quality Flat Windows

Esco Optics is one of the largest American suppliers of commercial quality flat windows. Our standard product line is perhaps the most complete listing available. These windows are commonly used for a variety of applications including sight glasses, instrument windows, beamsplitter substrates, and vacuum windows to name a few. All products listed are available in single or large OEM quantities. For more information, please visit our website at [EscoOptics.com](http://EscoOptics.com)



|                                |                              |
|--------------------------------|------------------------------|
| <b>Diameter Tolerance:</b>     | ±0.125 mm                    |
| <b>Length/Width Tolerance:</b> | ±0.125 mm                    |
| <b>Thickness Tolerance:</b>    | ±0.125 mm                    |
| <b>Surface Accuracy:</b>       | -5λ per inch                 |
| <b>Surface Quality:</b>        | 40-20, scratch-dig or better |
| <b>Parallelism:</b>            | 1.5 mm ±0.5 mm               |
| <b>Edges:</b>                  | Fine ground and beveled      |

### Material:

Esco manufactures commercial quality windows out of every material listed in this handbook. For your reference, apply the prefixes shown below to the part numbers in the table.

## PREFIXES

### Circular Windows:

|                        |                        |
|------------------------|------------------------|
| S1-UV.....P1           | N-BK7/S-BSL7.....P9    |
| I2-IR.....P2           | G1 Fused Quartz.....P6 |
| A1 Fused Quartz.....P3 | Borofloat.....P7       |

### Square Windows:

|                     |                  |
|---------------------|------------------|
| S1-UV.....Q1        | G1.....Q6        |
| N-BK7/S-BSL7.....Q9 | A1.....Q3        |
| I2-IR.....Q2        | Borofloat.....Q7 |

## EXAMPLE

|                                         |                           |
|-----------------------------------------|---------------------------|
| S1-UV window, 2" diameter, 1/4" thk:    | P1 + 20250 = P/N: P120250 |
| N-BK7/S-BSL7 window, 4" x 4", 1/8" thk: | Q9 + 40125 = P/N: Q940125 |

All dimensions are in mm unless otherwise specified.



# Windows

| Circular Windows | Thickness, mm (Inches) |            |               |              |               |             |              |            |
|------------------|------------------------|------------|---------------|--------------|---------------|-------------|--------------|------------|
|                  | Diameter               | 1.0 (.04") | 1.59 (.0625") | 3.18 (.125") | 4.76 (.1875") | 6.35 (.25") | 9.53 (.375") | 12.7 (.5") |
|                  | 12.7 (.5")             | +05040     | +05063        | +05125       | +05188        | +05250      | +05375       | +05500     |
|                  | 19.05 (.75")           | +07040     | +07063        | +07125       | +07188        | +07250      | +07375       | +07500     |
|                  | 25.4 (1")              | +10040     | +10063        | +10125       | +10188        | +10250      | +10375       | +10500     |
|                  | 31.75 (1.25")          | +12040     | +12063        | +12125       | +12188        | +12250      | +12375       | +12500     |
|                  | 38.1 (1.5")            | +15040     | +15063        | +15125       | +15188        | +15250      | +15375       | +15500     |
|                  | 44.45 (1.75")          | +17040     | +17063        | +17125       | +17188        | +17250      | +17375       | +17500     |
|                  | 50.8 (2")              | +20040     | +20063        | +20125       | +20188        | +20250      | +20375       | +20500     |
|                  | 63.5 (2.5")            | +25040     | +25063        | +25125       | +25188        | +25250      | +25375       | +25500     |
|                  | 76.2 (3")              | +30040     | +30063        | +30125       | +30188        | +30250      | +30375       | +30500     |
|                  | 88.9 (3.5")            | +35040     | +35063        | +35125       | +35188        | +35250      | +35375       | +35500     |
|                  | 101.6 (4")             | +40040     | +40063        | +40125       | +40188        | +40250      | +40375       | +40500     |
|                  | 127.0 (5")             | +50040     | +50063        | +50125       | +50188        | +50250      | +50375       | +50500     |
|                  | 152.4 (6")             | +60040     | +60063        | +60125       | +60188        | +60250      | +60375       | +60500     |

| Square Windows | Thickness, mm (Inches) |            |               |              |               |             |              |            |
|----------------|------------------------|------------|---------------|--------------|---------------|-------------|--------------|------------|
|                | Square                 | 1.0 (.04") | 1.59 (.0625") | 3.18 (.125") | 4.76 (.1875") | 6.35 (.25") | 9.53 (.375") | 12.7 (.5") |
|                | 25.4 (1")              | +10040     | +10063        | +10125       | +10188        | +10250      | +10375       | +10500     |
|                | 31.75 (1.25")          | +12040     | +12063        | +12125       | +12188        | +12250      | +12375       | +12500     |
|                | 38.1 (1.5")            | +15040     | +15063        | +15125       | +15188        | +15250      | +15375       | +15500     |
|                | 44.45 (1.75")          | +17040     | +17063        | +17125       | +17188        | +17250      | +17375       | +17500     |
|                | 50.8 (2")              | +20040     | +20063        | +20125       | +20188        | +20250      | +20375       | +20500     |
|                | 63.5 (2.5")            | +25040     | +25063        | +25125       | +25188        | +25250      | +25375       | +25500     |
|                | 76.2 (3")              | +30040     | +30063        | +30125       | +30188        | +30250      | +30375       | +30500     |
|                | 88.9 (3.5")            | +35040     | +35063        | +35125       | +35188        | +35250      | +35375       | +35500     |
|                | 101.6 (4")             | +40040     | +40063        | +40125       | +40188        | +40250      | +40375       | +40500     |
|                | 127.0 (5")             | +50040     | +50063        | +50125       | +50188        | +50250      | +50375       | +50500     |
|                | 152.4 (6")             | +60040     | +60063        | +60125       | +60188        | +60250      | +60375       | +60500     |

**NOTE:** To specify a Window's material when ordering, add the appropriate Material Prefix in front of these Part Numbers.

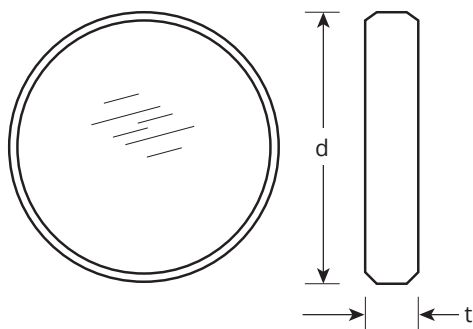
# Windows



## Precision Flat Windows

These elements are ideal for applications such as:

- Interferometer flats
- Laser windows
- Beamsplitter substrates
- Parallel plates, etc.

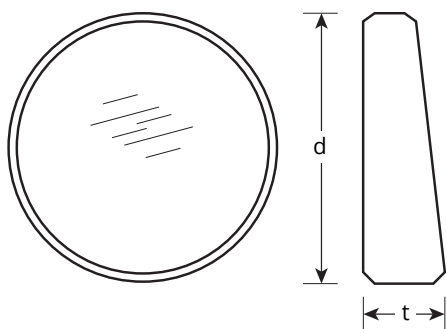


|                                                      |                                                  |
|------------------------------------------------------|--------------------------------------------------|
| <b>Material:</b>                                     | N-BK7/S-BSL7 Optical Glass or S1-UV Fused Silica |
| <b>Diameter Tolerance:</b>                           | ±0.125 mm                                        |
| <b>Thickness Tolerance:</b>                          | ±0.125 mm                                        |
| <b>Surface Quality:</b>                              | 20-10, scratch-dig                               |
| <b>Clear Aperture:</b>                               | 90%                                              |
| <b>Edges:</b>                                        | Fine ground and beveled                          |
| All dimensions are in mm unless otherwise specified. |                                                  |

| Diameter | Thickness | Parallelism | Flatness     | N-BK7/<br>S-BSL7 P/N | S1-UV P/N |
|----------|-----------|-------------|--------------|----------------------|-----------|
| 25.4     | 6.35      | 10'         | $\lambda/4$  | E610250              | E210250   |
| 25.4     | 6.35      | 5"          | $\lambda/10$ | E810250              | E410250   |
| 38.1     | 6.35      | 10'         | $\lambda/4$  | E615250              | E215250   |
| 38.1     | 6.35      | 5"          | $\lambda/10$ | E815250              | E415250   |
| 50.8     | 9.53      | 10'         | $\lambda/4$  | E620375              | E220375   |
| 50.8     | 9.53      | 5"          | $\lambda/10$ | E820375              | E420375   |

## Wedge Windows

These elements are similar to the precision flat windows described above, but have a deliberate wedge of  $30' \pm 5'$ . They are ideal for applications where direct back reflections would usually be a problem.



|                                                      |                                                  |
|------------------------------------------------------|--------------------------------------------------|
| <b>Material:</b>                                     | N-BK7/S-BSL7 Optical Glass or S1-UV Fused Silica |
| <b>Diameter Tolerance:</b>                           | ±0.125 mm                                        |
| <b>Thickness Tolerance:</b>                          | ±0.125 mm                                        |
| <b>Surface Quality:</b>                              | 20-10, scratch-dig                               |
| <b>Clear Aperture:</b>                               | 90%                                              |
| <b>Edges:</b>                                        | Fine ground and beveled                          |
| All dimensions are in mm unless otherwise specified. |                                                  |

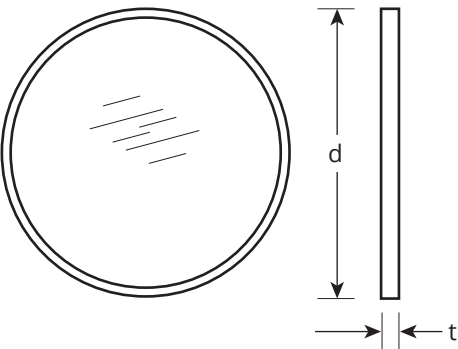
| Diameter | Thickness | Parallelism | Flatness     | N-BK7/<br>S-BSL7 P/N | S1-UV P/N |
|----------|-----------|-------------|--------------|----------------------|-----------|
| 25.4     | 6.35      | 30'         | $\lambda/4$  | V210250              | V510250   |
| 25.4     | 6.35      | 30'         | $\lambda/10$ | V310250              | V610250   |
| 38.1     | 9.53      | 30'         | $\lambda/4$  | V215375              | V515375   |
| 38.1     | 9.53      | 30'         | $\lambda/10$ | V315375              | V615375   |
| 50.8     | 9.53      | 30'         | $\lambda/4$  | V220375              | V520375   |
| 50.8     | 9.53      | 30'         | $\lambda/10$ | V320375              | V620375   |



# Windows

## Sapphire Windows

Because of its wide spectral transmission, extreme hardness and excellent durability, sapphire makes an ideal window material for many applications. Due to reduced scatter losses and high polarization uniformity, it has easily twice the life span of other crystals used in high power laser applications.



|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Material:</b>                                     | Optical Grade Sapphire  |
| <b>Diameter Tolerance:</b>                           | ±0.05 mm                |
| <b>Thickness Tolerance:</b>                          | ±0.05 mm                |
| <b>Surface Quality:</b>                              | 1 micron-inch, RMS      |
| <b>Surface Accuracy:</b>                             | ~15λ per inch           |
| <b>Clear Aperture:</b>                               | 90%                     |
| <b>Edges:</b>                                        | Fine ground and beveled |
| All dimensions are in mm unless otherwise specified. |                         |

| Thickness, mm (Inches) |              |              |              |              |
|------------------------|--------------|--------------|--------------|--------------|
| Diameter               | 0.5 (0.020") | 1.0 (0.040") | 2.0 (0.080") | 3.0 (0.125") |
| 6.35 (.25")            | G102020      | G102040      | G102080      | G102125      |
| 9.53 (.375")           | G103020      | G103040      | G103080      | G103125      |
| 12.7 (.5")             | G105020      | G105040      | G105080      | G105125      |
| 15.88 (.625")          | G106020      | G106040      | G106080      | G106125      |
| 19.05 (.75")           | G107020      | G107040      | G107080      | G107125      |
| 22.23 (.875")          | G108020      | G108040      | G108080      | G108125      |
| 25.4 (1")              | G110020      | G110040      | G110080      | G110125      |
| 28.58 (1.125")         | G111020      | G111040      | G111080      | G111125      |

## Custom Windows - All Types

In addition to our catalog offerings of windows, we also manufacture a variety of custom windows and machined plano components.

### Sizes:

Over 24" diagonal measure on more common materials and sapphire up to 6" diameter.

### Materials:

Esco manufactures standard and custom windows out of every material listed in this catalog. Additional materials are readily available upon request. Please contact Esco for more information.

### Aspect Ratio:

Flatness and parallelism are greatly impacted by the aspect ratio of the component. It is often necessary to use a window whose aspect ratio (overall diagonal : thickness) is as low as possible. All materials act differently, however a good rule of thumb for  $\lambda/10$  surface accuracy is about a 6:1 aspect ratio.

# Windows



## **Parallelism:**

Esco can manufacture windows to  $<1$  arc second parallelism. The tighter the requirement, the more costly the window is to manufacture. If you are unsure about your needs or requirements, please contact Esco for assistance.

## **Surface Quality:**

Some applications may require surface qualities better than that of commercially available products. Esco can supply windows with surface quality better than laser grade, 10-5 or surface accuracies better than  $\lambda/20$ .

## **Surface Roughness:**

In keeping with today's high power laser and growing multi layered coating requirements, Esco polishes fused silica and other optical materials to very low surface roughness. Esco employs our state of the art manufacturing equipment coupled with a Zygo New View 8300 to inspect and certify our components to  $<1$  Angstrom RMS.

## **Tolerances:**

The dimensional and optical tolerances shown on the preceding pages are the standard tolerances used for our catalog components. These tolerances are usually in line with the typical uses for these components. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## **Coatings:**

Esco will apply AR or beamsplitter coatings to any window. For more information concerning coatings, please see pages 35 - 40 or contact Esco.

## Laboratory Supplies



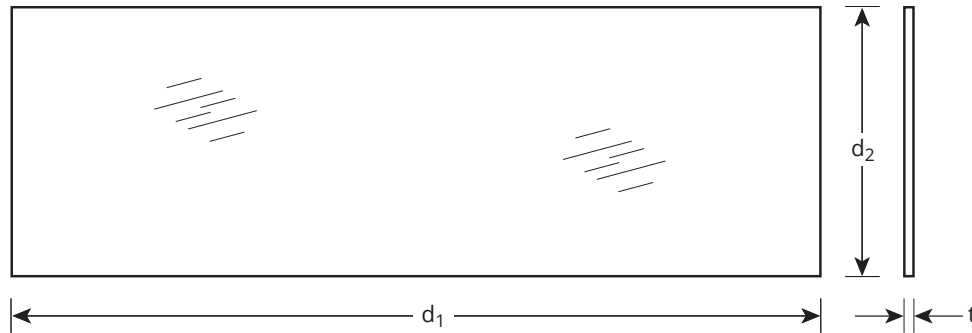
Esco offers a special line of flat optical elements for use with various laboratory applications such as preparing samples for viewing under a microscope. These parts provide optical characteristics not found in ordinary glass slides and cover slips. Their above average material and surface quality can dramatically enhance image quality.

# Laboratory Supplies



## Microscope Slides

Esco provides microscope slides made from a variety of optical materials and in several different convenient sizes. This assortment, like that of our standard optical windows, is the most comprehensive on the market. Although they possess excellent surface quality, the aspect ratio of these elements is very high and good surface accuracy is not achievable.

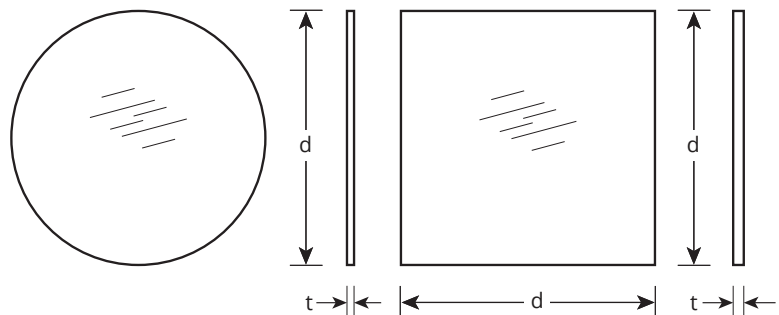


|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Diameter Tolerance:</b>                           | ±0.125 mm               |
| <b>Thickness Tolerance:</b>                          | ±0.125 mm               |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig      |
| <b>Clear Aperture:</b>                               | 90%                     |
| <b>Edges:</b>                                        | Fine ground and beveled |
| All dimensions are in mm unless otherwise specified. |                         |

| Size         | Thickness | S1-UV   | A1      | Pyrex   |
|--------------|-----------|---------|---------|---------|
| 25.4 x 25.4  | 1.0       | Q110040 | Q310040 | Q710040 |
| 50.8 x 25.4  | 1.0       | R320110 | R120110 | R220110 |
| 76.2 x 25.4  | 1.0       | R330110 | R130110 | R230110 |
| 101.6 x 25.4 | 1.5       | R340115 | R140115 | R240115 |
| 152.4 x 25.4 | 2.0       | R360120 | R160120 | R260120 |

## Cover Slips

These ultra-thin elements are made from high quality materials and provide above average optical characteristics to enhance image quality.

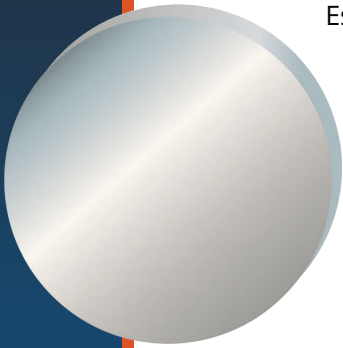


|                                                      |                    |
|------------------------------------------------------|--------------------|
| <b>Thickness:</b>                                    | 0.16 ±0.01 mm      |
| <b>Dimensional Tolerance:</b>                        | ±0.125 mm          |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig |
| <b>Clear Aperture:</b>                               | 90%                |
| All dimensions are in mm unless otherwise specified. |                    |

| Diameter | S1-UV   | A1      | Pyrex   |
|----------|---------|---------|---------|
| 12.0     | R412000 | R512000 | R612000 |
| 25.0     | R425000 | R525000 | R625000 |

| Size        | S1-UV   | A1      | Pyrex   |
|-------------|---------|---------|---------|
| 12.0 x 12.0 | R412012 | R512012 | R612012 |
| 25.0 x 25.0 | R425025 | R525025 | R625025 |

## Mirrors



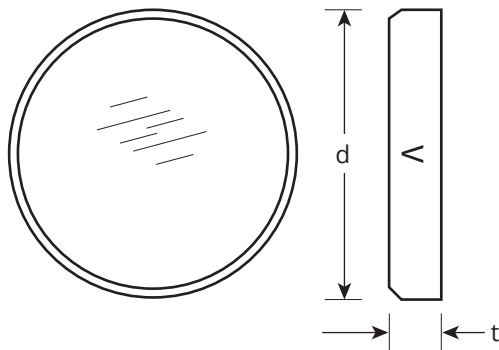
Esco offers a variety of flat mirror substrates using sodalime, Borofloat and Zerodur to suit a wide range of applications. Available stock coatings include UV-Enhanced Aluminum, Standard Enhanced Aluminum and Protected Silver. All mirrors are over-coated with silicon monoxide to improve durability. For detailed information concerning the characteristics of optical coatings, see pages 35 - 40.

For higher reflectivity or in cases where high laser energy requires the use of nonmetallic thin films, Esco provides dielectric laser-quality mirror coatings customized to meet the demanding requirements of your system. Order as UNCOATED and add the desired coating specifications from pages 38 - 40 or contact an Esco sales representative to discuss your custom application.

# Mirrors



## Precision (Laser) Quality Flat Mirrors



|                                                      |                               |
|------------------------------------------------------|-------------------------------|
| <b>Materials:</b>                                    | G1 Optical Grade Fused Quartz |
| <b>Surface Quality:</b>                              | 40-20, scratch-dig            |
| <b>Dimensions:</b>                                   | ±0.15 mm                      |
| <b>Rear Surface:</b>                                 | Fine ground                   |
| <b>Edges:</b>                                        | Fine ground and beveled       |
| All dimensions are in mm unless otherwise specified. |                               |

## Laser Quality Mirrors:

| G1 Optical Grade Fused Quartz | Diameter | Thickness | Surface Accuracy | Uncoated | Al-SiO  | Al-MgF <sub>2</sub> | MAX R 488/514.5 nm | MAX R 532 nm | MAX R 633 nm |
|-------------------------------|----------|-----------|------------------|----------|---------|---------------------|--------------------|--------------|--------------|
|                               | 12.7     | 3.2       | $\lambda/10$     | D405000  | D405100 | D405200             | D405488-0          | D405532-0    | D405633-0    |
|                               | 12.7     | 3.2       | $\lambda/10$     | ---      | ---     | ---                 | D405488-45         | D405532-45   | D405633-45   |
|                               | 25.4     | 6.4       | $\lambda/4$      | D310000  | D310100 | D310200             | ---                | ---          | ---          |
|                               | 25.4     | 6.4       | $\lambda/10$     | D410000  | D410100 | D410200             | D410488-0          | D410532-0    | D410633-0    |
|                               | 25.4     | 6.4       | $\lambda/10$     | ---      | ---     | ---                 | D410488-45         | D410532-45   | D410633-45   |
|                               | 50.8     | 12.7      | $\lambda/4$      | D320000  | D320100 | D320200             | ---                | ---          | ---          |
|                               | 50.8     | 12.7      | $\lambda/10$     | D420000  | D420100 | D420200             | ---                | ---          | ---          |
|                               | 76.2     | 19.1      | $\lambda/10$     | D430000  | D430100 | D430200             | ---                | ---          | ---          |
|                               | 101.6    | 25.4      | $\lambda/10$     | D440000  | D440100 | D440200             | ---                | ---          | ---          |
|                               | 152.4    | 38.1      | $\lambda/10$     | D460000  | D460100 | D460200             | ---                | ---          | ---          |

**NOTE:** The spectral performance of an all dielectric coated mirror depends on the angle at which it is used. For your convenience, Esco provides off-the-shelf MAX R coated mirrors at three common wavelength areas, designed for use at either 0° (normal) or 45° incidence, as indicated above by the section of the part number following the dash.

## Ultra-Stable Laser Quality Mirrors:

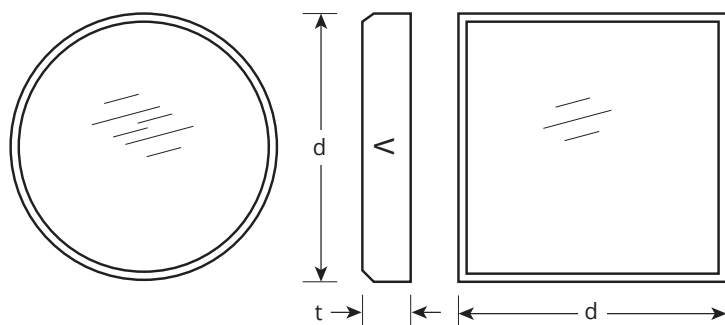
|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Materials:</b>                                    | Zerodur                 |
| <b>Surface Quality:</b>                              | 20-10, scratch-dig      |
| <b>Dimensions:</b>                                   | ±0.15 mm                |
| <b>Rear Surface:</b>                                 | Fine ground             |
| <b>Edges:</b>                                        | Fine ground and beveled |
| All dimensions are in mm unless otherwise specified. |                         |

| Zerodur | Diameter | Thickness | Surface Accuracy | Uncoated | Al-SiO  | Al-MgF <sub>2</sub> |
|---------|----------|-----------|------------------|----------|---------|---------------------|
|         | 12.7     | 3.2       | $\lambda/20$     | D205000  | D205100 | D205200             |
|         | 25.4     | 6.4       | $\lambda/20$     | D210000  | D210100 | D210200             |
|         | 50.8     | 12.7      | $\lambda/20$     | D220000  | D220100 | D220200             |
|         | 76.2     | 19.1      | $\lambda/20$     | D230000  | D230100 | D230200             |
|         | 101.6    | 25.4      | $\lambda/20$     | D240000  | D240100 | D240200             |
|         | 152.4    | 38.1      | $\lambda/20$     | D260000  | D260100 | D260200             |



# Mirrors

## Commercial Quality Flat Mirrors



|                                                      |                          |
|------------------------------------------------------|--------------------------|
| <b>Material:</b>                                     | Soda-lime Float Glass    |
| <b>Coating:</b>                                      | Al-SiO                   |
| <b>Surface Quality:</b>                              | 80-50, scratch-dig       |
| <b>Dimensions:</b>                                   | ±0.5 mm                  |
| <b>Rear Surface:</b>                                 | Commercial Polish        |
| <b>Edges:</b>                                        | Fine ground and polished |
| All dimensions are in mm unless otherwise specified. |                          |

|                    | P/N     | Length (L) | Width (W) | Thickness |
|--------------------|---------|------------|-----------|-----------|
| Square/Rectangular | D610010 | 25.4       | 25.4      | 6.0       |
|                    | D610020 | 25.4       | 50.8      | 6.0       |
|                    | D620030 | 50.8       | 76.2      | 6.0       |
|                    | D620060 | 50.8       | 152.4     | 9.5       |
|                    | D630050 | 76.2       | 127       | 9.5       |

|       | P/N     | Diameter | Thickness |
|-------|---------|----------|-----------|
| Round | D502500 | 25.0     | 6.0       |
|       | D505000 | 50.0     | 6.0       |
|       | D507500 | 75.0     | 6.0       |
|       | D510000 | 100.0    | 6.0       |

## Custom Mirrors - All Types

In addition to our standard lines of mirrors, we also manufacture a variety of custom elements. For more information on these and other custom products or applications, please contact Esco at 1-800-922-ESCO (3726).

### Shapes:

Concave and convex spherical, ellipsoidal, flat, square, round or custom.

### Sizes:

Concave, <12" diameter. Flat, nearly any size is possible. Please contact Esco to discuss your particular application.

### Aspect Ratio:

If good surface accuracy is required, it is often necessary to use a mirror whose aspect ratio (diameter : thickness) is as low as possible. Although all materials act differently, a good rule of thumb for  $\lambda/10$  surface accuracy is about a 6:1 aspect ratio.

# Mirrors



## Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply elements with surface quality better than 10-5 laser grade and surface accuracies better than  $\lambda/10$ .

## Tolerances:

The dimensional tolerances shown on the preceding pages are the standard tolerances used for off-the-shelf elements. If your application requires modified tolerances, Esco can typically accommodate for such changes. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

## Materials:

Fused Quartz/Fused Silica (all grades)  
Borofloat  
Any optical glass  
Other materials upon request

## Thermal Expansion:

For thermal environments that may affect the surface accuracy of a mirror, we suggest using a substrate material with good thermal expansion properties. Contact Esco to discuss which material is best for your application.

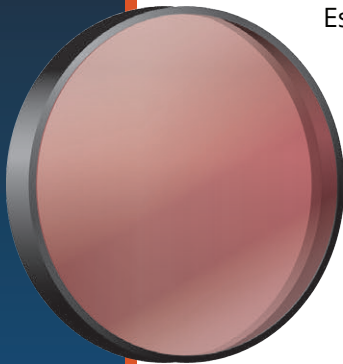
## Rear Surface:

For metallized front surface mirrors, such as our standard lines, an unpolished rear surface presents a cost savings and does not interfere with the performance of the mirror. For dielectrically coated mirrors, however, a fine ground rear surface can be a source of scatter of any transmitted radiation and may degrade the mirror or the system's performance. Back reflections from this surface cannot only interfere with the desired wavefront, but can (in the case of high power lasers) heat the substrate, causing deformation of the reflecting surface. In these cases, Esco recommends a polished rear surface with an anti-reflection coating.

## Coatings:

Al-SiO  
Silver  
Gold  
Dielectric High Reflectors  
Other coatings upon request

## Filters



Esco Optics offers a complete selection of colored glass, neutral density, and bandpass filters. Our filter materials are manufactured from Schott, Hoya and Isuzu materials. If you cannot find the particular filter to satisfy your specific application, our sales engineers will be happy to assist you in selecting a custom filter to meet your needs. A complete list of data sheets and specifications are available on our website.

# Filters



## Color Filter Glass

Esco is pleased to offer Schott color filter glasses in standard 2" squares. Although we stock the most common thickness for each type, other thicknesses and sizes are available upon request. For more information concerning the specific transmission characteristics, properties, or applications, please contact Esco.

|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Size:</b>                                         | 50.8 mm x 50.8 mm       |
| <b>Dimensional Tolerance:</b>                        | ±0.25 mm                |
| <b>Surface Accuracy:</b>                             | <5λ per 25 mm           |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig      |
| <b>Parallelism:</b>                                  | <10'                    |
| <b>Edges:</b>                                        | Fine ground and beveled |
| All dimensions are in mm unless otherwise specified. |                         |

| Schott Designation | Schott Designation | Thickness | P/N     |
|--------------------|--------------------|-----------|---------|
|                    | UG 1               | 1.0       | S284001 |
|                    | UG 3               | 1.0       | S284003 |
|                    | UG 5               | 1.0       | S284005 |
|                    | UG 11              | 1.0       | S284011 |
|                    | BG 3               | 1.0       | S224003 |
|                    | BG 7               | 1.0       | S224007 |
|                    | BG 18              | 1.0       | S224018 |
|                    | BG 25              | 1.0       | S224025 |
|                    | BG 38              | 1.0       | S224038 |
|                    | BG 39              | 1.0       | S224039 |
|                    | BG 40              | 1.0       | S224040 |
|                    | BG 42              | 1.0       | S224042 |
|                    | WG 280             | 1.0       | S294280 |
|                    | WG 295             | 1.0       | S294295 |
|                    | WG 305             | 1.0       | S294305 |
|                    | WG 320             | 1.0       | S294320 |
|                    | KG 1               | 2.0       | S254001 |
|                    | KG 2               | 2.0       | S254002 |
|                    | KG 3               | 2.0       | S254003 |
|                    | KG 4               | 2.0       | S254004 |
|                    | KG 5               | 2.0       | S254005 |
|                    | FG 3               | 1.0       | S234003 |
|                    | FG 6               | 1.0       | S234006 |
|                    | FG 13              | 2.0       | S234013 |
|                    | GG 395             | 1.0       | S244395 |
|                    | GG 400             | 2.0       | S244400 |

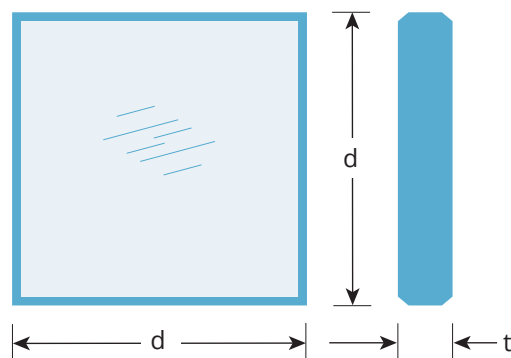
| Schott Designation | Schott Designation | Thickness | P/N     |
|--------------------|--------------------|-----------|---------|
|                    | GG 420             | 2.0       | S244420 |
|                    | GG 435             | 2.0       | S244435 |
|                    | GG 455             | 2.0       | S244455 |
|                    | GG 475             | 2.0       | S244475 |
|                    | GG 495             | 2.0       | S244495 |
|                    | OG 515             | 3.0       | S264515 |
|                    | OG 530             | 3.0       | S264530 |
|                    | OG 550             | 3.0       | S264550 |
|                    | OG 570             | 3.0       | S264570 |
|                    | OG 590             | 3.0       | S264590 |
|                    | RG 610             | 3.0       | S274610 |
|                    | RG 630             | 3.0       | S274630 |
|                    | RG 645             | 3.0       | S274645 |
|                    | RG 665             | 3.0       | S274665 |
|                    | RG 695             | 3.0       | S274695 |
|                    | RG 715             | 3.0       | S274715 |
|                    | RG 780             | 3.0       | S274780 |
|                    | RG 830             | 3.0       | S274830 |
|                    | RG 850             | 3.0       | S274850 |
|                    | RG 1000            | 3.0       | S274100 |
|                    | NG 1               | 1.0       | S261001 |
|                    | NG 3               | 1.0       | S261003 |
|                    | NG 4               | 1.0       | S261004 |
|                    | NG 5               | 1.0       | S261005 |
|                    | NG 9               | 1.0       | S261009 |
|                    | NG 11              | 1.0       | S261011 |
|                    | VG 9               | 1.0       | S281009 |
|                    | VG 20              | 1.0       | S281020 |



# Filters

## Custom Colored Glass Filters

In addition to our standard line of Schott color filter glass, we also supply a range of colored glasses from other manufacturers. Esco can provide you with custom machined and polished shapes and configurations.



### Sizes:

Color glass is only available in sheets up to 165 mm. Maximum thickness varies with glass-type. Please contact Esco for more information.

### Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply color filter glass with surface quality 10-5 or surface accuracies better than  $\lambda/20$ . In these cases, glass types with excellent homogeneity and no visible striae should be used.

### Tolerances:

The dimensional tolerances shown on the preceding pages are the standard tolerances used for catalog components. To discuss your particular needs, please contact Esco at 1-800-922-ESCO (3726).

# Filters



## Neutral Density Filters

Neutral density (ND) filters are used to attenuate incident radiation without altering its spectral distribution. The neutral density value (D) of an ND filter is related to the transmittance (T) by:

$$T = 10^{-OD} \text{ or } OD = \log\left(\frac{1}{T}\right)$$

If two or more filters are placed in sequence, the resultant density value is calculated from either the sum of the individual density values or the product of the transmittances. This holds true if no multiple reflections occur between elements. ND filters are available in two types. The first uses neutral density color filter glass such as the NG types made by Schott.

- These filters can be AR coated to prevent back reflections.
- They can handle higher input energy, especially if actively cooled.
- Very accurate ND values are possible by controlling the thickness of the color glass.

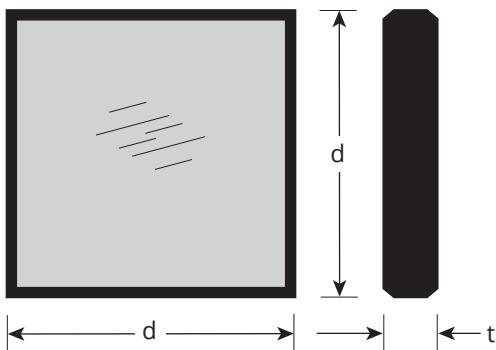
The second type of ND filter is a glass or quartz substrate with a precision metallic coating (Inconel) that provides uniform attenuation across a wide spectral range. Some advantages of metallic coated ND filters include:

- Coating on quartz allows controlled attenuation in the UV.
- Coating provides attenuation with greater linearity over a wide spectral range.
- The filter can handle higher intensity light sources because part of the beam is reflected rather than absorbed.

The Inconel film is comprised of a very hard alloy material that is resistant to degradation under normal conditions. Use at high temperatures can cause oxidation however, and is not recommended.

**NOTE:** Use of any of these neutral density filters with high power lasers or other extreme light sources can cause catastrophic failure and is not recommended.

### Neutral Density Color Glass Filters:

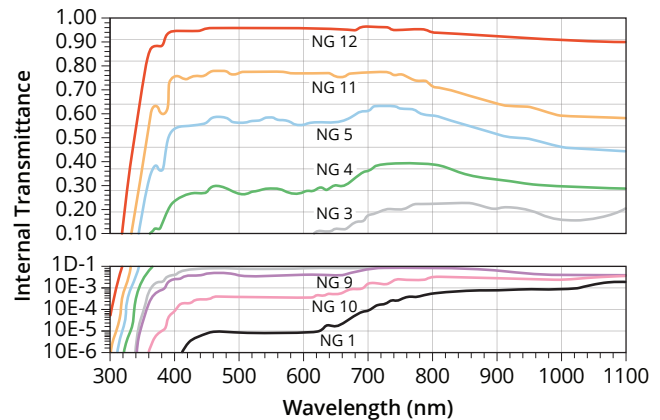


|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Size:</b>                                         | 50.8 mm x 50.8 mm       |
| <b>Dimensional Tolerance:</b>                        | ±0.25 mm                |
| <b>Density Tolerance:</b>                            | ±4% at 550 nm           |
| <b>Surface Accuracy:</b>                             | <5λ per 25 mm           |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig      |
| <b>Parallelism:</b>                                  | <10'                    |
| <b>Edges:</b>                                        | Fine ground and beveled |
| All dimensions are in mm unless otherwise specified. |                         |



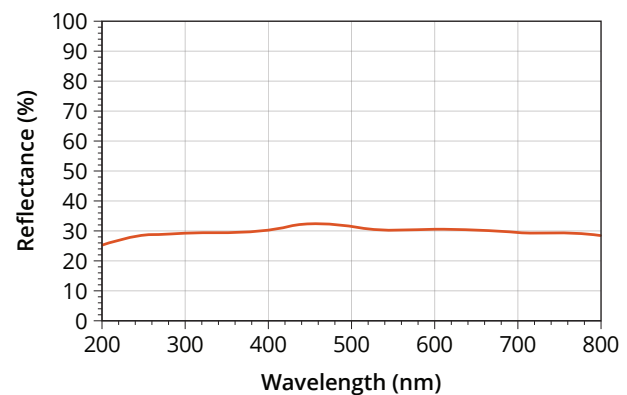
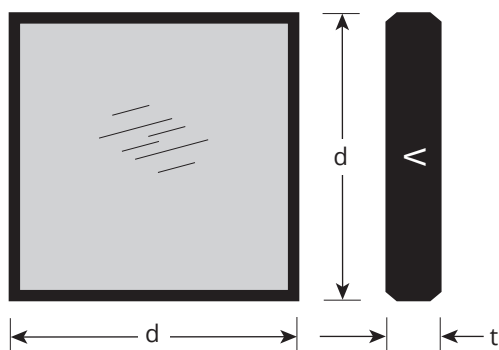
# Filters

| Nominal Density | Transmission | Glass Type | P/N     |
|-----------------|--------------|------------|---------|
| 0.1             | 79.4%        | NG12       | S301000 |
| 0.2             | 63.1%        | NG11       | S302000 |
| 0.3             | 50.1%        | NG11       | S303000 |
| 0.4             | 39.8%        | NG11       | S304000 |
| 0.5             | 31.6%        | NG11       | S305000 |
| 0.6             | 25.1%        | NG5        | S306000 |
| 1.0             | 10.0%        | NG5        | S310000 |
| 2.0             | 1.0%         | NG4        | S320000 |
| 3.0             | 0.1%         | NG3        | S330000 |
| 4.0             | 0.01%        | NG3        | S340000 |
| Set of all 10   | ---          | ---        | S300000 |



Transmission (internal) measured at 550 nm. For a small charge, Esco will provide curves showing the actual transmission characteristics of any standard or custom neutral density filter.

## Metallic Coated Neutral Density Filters:



|                                                      |                                                         |
|------------------------------------------------------|---------------------------------------------------------|
| <b>Substrate Materials:</b>                          | K5 Crown Glass and S1-UV Ultraviolet Grade Fused Silica |
| <b>Size:</b>                                         | 50.8 mm x 50.8 mm                                       |
| <b>Thickness:</b>                                    | 1.0 mm                                                  |
| <b>Density Tolerance:</b>                            | ±10% of density for values <0.5 and ±5% for values >0.5 |
| <b>Dimensional Tolerance:</b>                        | ±0.25 mm                                                |
| <b>Surface Accuracy:</b>                             | <5λ per 25 mm                                           |
| <b>Surface Quality:</b>                              | 60-40, scratch-dig                                      |
| <b>Parallelism:</b>                                  | <10'                                                    |
| <b>Edges:</b>                                        | Fine ground and beveled                                 |
| All dimensions are in mm unless otherwise specified. |                                                         |

| Nominal Density | Transmission | N-BK7/S-BSL7 | Fused Quartz |
|-----------------|--------------|--------------|--------------|
| 0.1             | 79.4%        | S701000      | S501000      |
| 0.2             | 63.1%        | S702000      | S502000      |
| 0.3             | 50.1%        | S703000      | S503000      |
| 0.4             | 39.8%        | S704000      | S504000      |
| 0.5             | 31.6%        | S705000      | S505000      |
| 0.6             | 25.1%        | S706000      | S506000      |
| 1.0             | 10.0%        | S710000      | S510000      |
| 2.0             | 1.0%         | S720000      | S520000      |
| 3.0             | 0.1%         | S730000      | S530000      |
| 4.0             | 0.01%        | S740000      | S540000      |
| Set of all 10   | ---          | S700000      | S500000      |

Transmission measured at 550 nm. For a small charge, Esco will provide curves showing the actual transmission characteristics of any standard or custom neutral density filter.

# Filters



## Custom Neutral Density Filters

In addition to our standard lines of neutral density filters, we also manufacture a variety of custom elements. For more information on these and other custom products or applications, please contact Esco.

### Sizes:

Up to 165 mm for color filter glass, larger for metallic coated.

**NOTE:** Coating thickness variations can occur on larger substrates. This can lead to non-linear attenuation across the face of the filter. Please contact Esco if you are considering neutral density filters larger than 50 mm.

### Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply neutral density filters with surface quality better than laser grade, 10-5 or surface accuracies better than  $\lambda/20$ . In these cases, materials with excellent homogeneity should be used. For more information, please contact Esco.

### Materials:

Fused Quartz/Fused Silica (all grades)  
Borofloat  
N-BK7/S-BSL7 Optical Glass  
Other materials upon request

### Tolerances:

The dimensional tolerances shown on the preceding pages are the standard tolerances used for off-the shelf elements. Esco can manufacture custom products with different tolerances upon request. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

### Coatings:

Although AR coatings cannot be used on metallic coated ND filters, they are available for color filter glass models. Please see pages 36 - 37 for more information or contact Esco.



# Filters

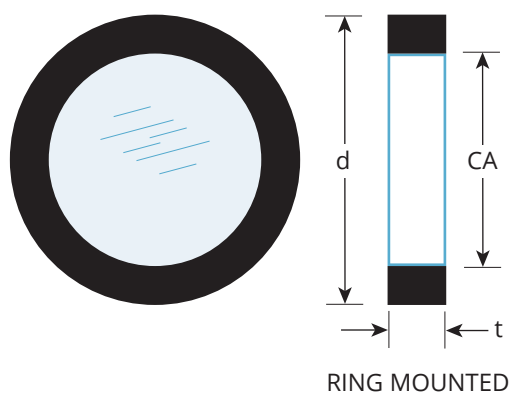
## Bandpass Filters

Thin film bandpass filters are optical elements that are designed to transmit a specific spectral band with high efficiency, while rejecting, by both absorption and reflection, all unwanted energy outside that region. The characteristics of the passband are controlled by multilayer dielectric coatings. Blocking is usually achieved with a combination of color filter glass and specially designed metallic films. The bandpass and blocking elements are laminated (epoxied) together to form a single unit and then edge sealed to prevent degradation due to moisture.

Bandpass filters are used in any application requiring the isolation of a narrow spectral bandwidth and a high signal-to-noise ratio. Esco supplies bandpass filters that provide transmission bands from the ultraviolet to the near infrared.

Esco provides standard bandpass filters that are designed for use at several common wavelengths. All models provide out of band blocking of better than  $10^{-4}$ . Two sizes are available: 0.5" and 1.0" diameter. Each filter is provided sealed in metal (aluminum) rings. These rings provide additional protection against degradation due to water absorption, as well as, a more accurate edge that can often help in mounting situations. Upon request, Esco will provide individual curves showing the actual transmission characteristics of any filter.

For a small charge, Esco will provide individual curves showing the actual transmission characteristics of any filter.



**NOTE:** Bandpass Filters will be shipped as RING-MOUNTED unless unmounted filters are requested at the time of the order.

|                                     |                                                         |
|-------------------------------------|---------------------------------------------------------|
| <b>Sizes (Clear Aperture):</b>      | 12.7 mm (8.1 mm) diameter<br>25.4 mm (20.3 mm) diameter |
| <b>Dimensional Tolerance:</b>       | +0/-0.13 mm                                             |
| <b>Thickness:</b>                   | <6.4 mm                                                 |
| <b>Center Wavelength Tolerance:</b> | 254-313 nm: $\pm 3$ nm<br>340-1064 nm: $\pm 2$ nm       |
| <b>Bandwidth Tolerance:</b>         | 254-313 nm: $\pm 2.5$ nm<br>340-1064 nm: $\pm 2$ nm     |
| <b>Surface Accuracy:</b>            | Not applicable                                          |
| <b>Surface Quality:</b>             | 80-50, scratch-dig                                      |
| <b>Blocking:</b>                    | Better than $10^{-4}$ from X-ray to far infrared        |
| <b>Temperature Limits:</b>          | -50°C to +80°C                                          |

# Filters

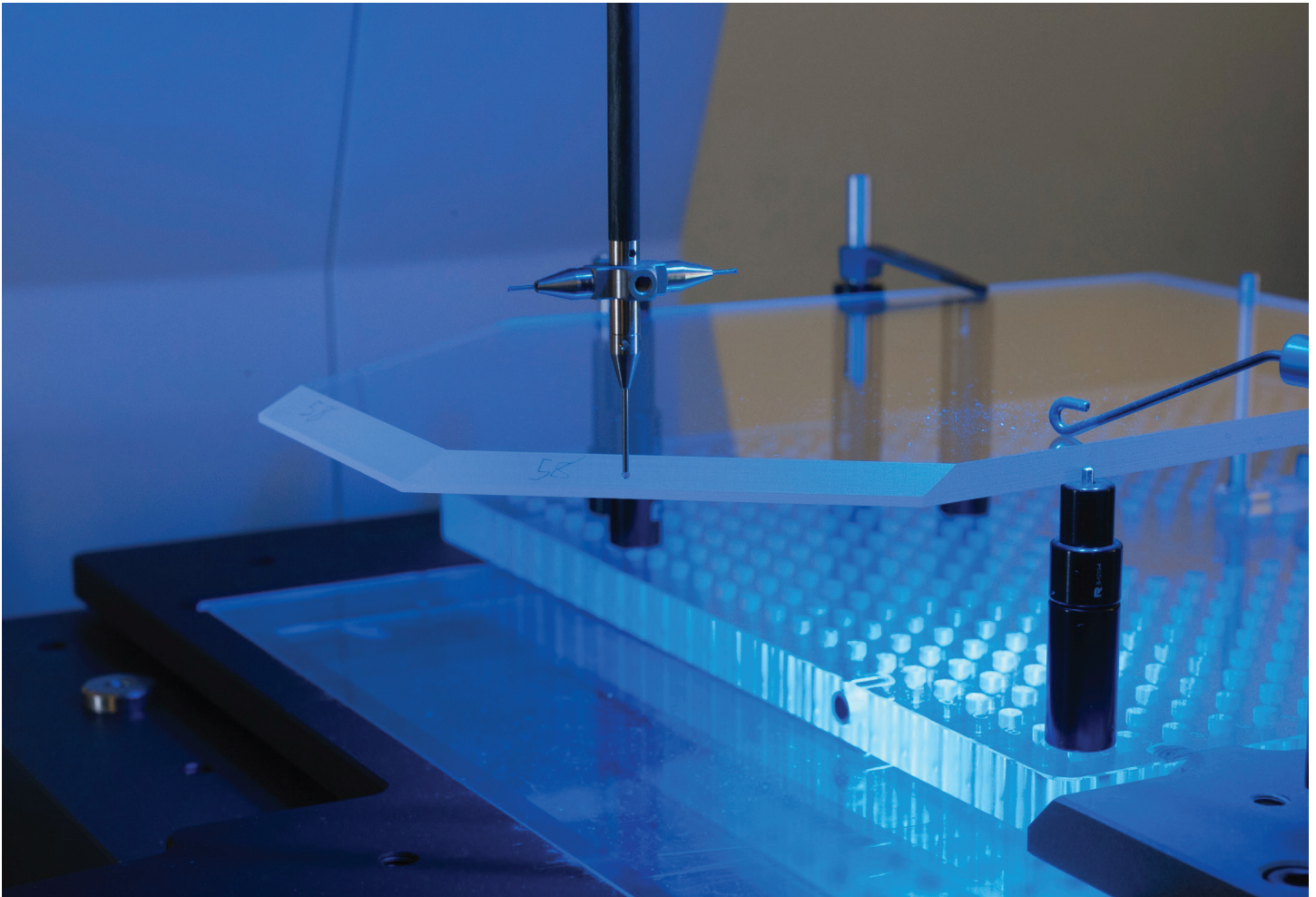


| Wavelength (nm) | Bandwidth | Minimum Transmission | 12.7 mm Diameter | 25.4 mm Diameter |
|-----------------|-----------|----------------------|------------------|------------------|
| 254.0           | 10        | 17                   | S912540          | S902540          |
| 265.0           | 10        | 17                   | S912650          | S902650          |
| 280.0           | 10        | 17                   | S912800          | S902800          |
| 289.0           | 10        | 17                   | S912890          | S902890          |
| 297.0           | 10        | 17                   | S912970          | S902970          |
| 308.0           | 10        | 17                   | S913080          | S903080          |
| 313.0           | 10        | 17                   | S913130          | S903130          |
| 334.0           | 10        | 20                   | S913340          | S903340          |
| 337.1           | 10        | 20                   | S913371          | S903371          |
| 340.0           | 10        | 35                   | S913400          | S903400          |
| 350.0           | 10        | 35                   | S913500          | S903500          |
| 360.0           | 10        | 35                   | S913600          | S903600          |
| 370.0           | 10        | 35                   | S913700          | S903700          |
| 378.0           | 10        | 35                   | S913780          | S903780          |
| 380.0           | 10        | 35                   | S913800          | S903800          |
| 390.0           | 10        | 35                   | S913900          | S903900          |
| 394.0           | 10        | 35                   | S913940          | S903940          |
| 400.0           | 10        | 40                   | S914000          | S904000          |
| 405.0           | 10        | 40                   | S914050          | S904050          |
| 410.0           | 10        | 40                   | S914100          | S904100          |
| 420.0           | 10        | 40                   | S914200          | S904200          |
| 430.0           | 10        | 40                   | S914300          | S904300          |
| 435.8           | 10        | 45                   | S914358          | S904358          |
| 440.0           | 10        | 45                   | S914400          | S904400          |
| 441.6           | 10        | 45                   | S914416          | S904416          |
| 450.0           | 10        | 50                   | S914500          | S904500          |
| 457.9           | 10        | 50                   | S914579          | S904579          |
| 460.0           | 10        | 50                   | S914600          | S904600          |
| 470.0           | 10        | 50                   | S914700          | S904700          |
| 480.0           | 10        | 50                   | S914800          | S904800          |
| 488.0           | 10        | 50                   | S914880          | S904880          |
| 490.0           | 10        | 50                   | S914900          | S904900          |
| 500.0           | 10        | 50                   | S915000          | S905000          |
| 510.0           | 10        | 50                   | S915100          | S905100          |
| 514.5           | 10        | 50                   | S915145          | S905145          |
| 520.0           | 10        | 50                   | S915200          | S905200          |
| 530.0           | 10        | 50                   | S915300          | S905300          |
| 532.0           | 10        | 50                   | S915320          | S905320          |
| 540.0           | 10        | 50                   | S915400          | S905400          |
| 546.1           | 10        | 50                   | S915461          | S905461          |
| 550.0           | 10        | 50                   | S915500          | S905500          |
| 560.0           | 10        | 50                   | S915600          | S905600          |
| 570.0           | 10        | 50                   | S915700          | S905700          |
| 577.7           | 10        | 50                   | S915777          | S905777          |
| 580.0           | 10        | 50                   | S915800          | S905800          |
| 589.6           | 10        | 50                   | S915896          | S905896          |
| 590.0           | 10        | 50                   | S915900          | S905900          |
| 600.0           | 10        | 50                   | S916000          | S906000          |
| 610.0           | 10        | 50                   | S916100          | S906100          |
| 620.0           | 10        | 50                   | S916200          | S906200          |
| 630.0           | 10        | 50                   | S916300          | S906300          |



# Filters

| Wavelength (nm) | Bandwidth | Minimum Transmission | 12.7 mm Diameter | 25.4 mm Diameter |
|-----------------|-----------|----------------------|------------------|------------------|
| 632.8           | 10        | 50                   | S916328          | S906328          |
| 640.0           | 10        | 50                   | S916400          | S906400          |
| 650.0           | 10        | 50                   | S916500          | S906500          |
| 656.3           | 10        | 50                   | S916560          | S906560          |
| 660.0           | 10        | 50                   | S916600          | S906600          |
| 670.0           | 10        | 50                   | S916700          | S906700          |
| 671.0           | 10        | 50                   | S916710          | S906710          |
| 680.0           | 10        | 50                   | S916800          | S906800          |
| 690.0           | 10        | 50                   | S916900          | S906900          |
| 694.3           | 10        | 50                   | S916943          | S906943          |
| 700.0           | 10        | 50                   | S917000          | S907000          |
| 710.0           | 10        | 45                   | S917100          | S907100          |
| 720.0           | 10        | 45                   | S917200          | S907200          |
| 730.0           | 10        | 45                   | S917300          | S907300          |
| 740.0           | 10        | 45                   | S917400          | S907400          |
| 750.0           | 10        | 45                   | S917500          | S907500          |
| 760.0           | 10        | 45                   | S917600          | S907600          |
| 765.0           | 10        | 45                   | S917650          | S907650          |
| 770.0           | 10        | 45                   | S917700          | S907700          |
| 780.0           | 10        | 45                   | S917800          | S907800          |
| 790.0           | 10        | 45                   | S917900          | S907900          |
| 800.0           | 10        | 45                   | S918000          | S908000          |
| 810.0           | 10        | 45                   | S918100          | S908100          |
| 820.0           | 10        | 45                   | S918200          | S908200          |
| 830.0           | 10        | 45                   | S918300          | S908300          |
| 840.0           | 10        | 45                   | S918400          | S908400          |
| 850.0           | 10        | 45                   | S918500          | S908500          |
| 852.0           | 10        | 45                   | S918520          | S908520          |
| 860.0           | 10        | 45                   | S918600          | S908600          |
| 870.0           | 10        | 45                   | S918700          | S908700          |
| 880.0           | 10        | 45                   | S918800          | S908800          |
| 890.0           | 10        | 45                   | S918900          | S908900          |
| 900.0           | 10        | 45                   | S919000          | S909000          |
| 905.0           | 10        | 45                   | S919050          | S909050          |
| 910.0           | 10        | 45                   | S919100          | S909100          |
| 920.0           | 10        | 45                   | S919200          | S909200          |
| 930.0           | 10        | 45                   | S919300          | S909300          |
| 940.0           | 10        | 45                   | S919400          | S909400          |
| 950.0           | 10        | 45                   | S919500          | S909500          |
| 960.0           | 10        | 45                   | S919600          | S909600          |
| 970.0           | 10        | 45                   | S919700          | S909700          |
| 980.0           | 10        | 45                   | S919800          | S909800          |
| 990.0           | 10        | 45                   | S919900          | S909900          |
| 1000.0          | 10        | 45                   | S911000          | S901000          |
| 1010.0          | 10        | 45                   | S911010          | S901010          |
| 1020.0          | 10        | 45                   | S911020          | S901020          |
| 1030.0          | 10        | 45                   | S911030          | S901030          |
| 1040.0          | 10        | 45                   | S911040          | S901040          |
| 1050.0          | 10        | 45                   | S911050          | S901050          |
| 1060.0          | 10        | 45                   | S911060          | S901060          |
| 1064.0          | 10        | 45                   | S911064          | S901064          |



Esco manufactures custom windows, mirrors and head up display substrates. Shown here is our Zeiss O-Inspect measuring a machined window.

## Beamsplitters



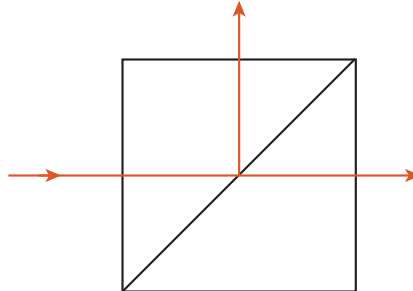
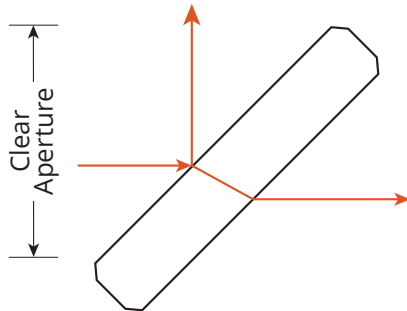
A beamsplitter is any optical component that is used to split light into, or recombine from, two separate beam paths. Esco provides two different types of beamsplitters: plates and cubes. Each has certain advantages and disadvantages depending on the intended application. Please call Esco to discuss the form that is best suited to your application.

# Beamsplitters



## Beamsplitter Plates

Esco manufactures general purpose beamsplitter plates for use in the visible and UV spectra. If you require elements with different spectral or physical characteristics, please contact Esco.



### Features:

- Compact, lighter than cubes with similar apertures
- No epoxy is used, so use with higher power lasers is possible
- Transmitted and reflected wavefronts are easier to manipulate
- Beams travel different optical paths
- R/T ratio is dependent on the state of polarization
- Internal reflection from second surface produces ghost image in reflected path
- Can be built with custom wedge to divert back reflections from beam path
- Beam can be shifted angularly by controlling the wedge or, laterally by controlling the thickness

|         |                             |                         |
|---------|-----------------------------|-------------------------|
| General | <b>Dimension Tolerance:</b> | ±0.125 mm               |
|         | <b>Thickness Tolerance:</b> | ±0.125 mm               |
|         | <b>Parallelism:</b>         | 10'                     |
|         | <b>Surface Quality:</b>     | 60-40, scratch-dig      |
|         | <b>Edges:</b>               | Fine ground and beveled |

|                                                      |                                 |                               |
|------------------------------------------------------|---------------------------------|-------------------------------|
| For Visible                                          | <b>Material:</b>                | N-BK7/S-BSL7 Optical Glass    |
|                                                      | <b>Coatings</b>                 |                               |
|                                                      | <b>First Surface:</b>           | BEAMSPLITTER (All-dielectric) |
|                                                      | Angle of Incidence:             | 45°                           |
|                                                      | Polarization:                   | Unpolarized                   |
|                                                      | Wavelength Range:               | 400-700 nm                    |
|                                                      | R/T Ratio:                      | 50/50 ±5%                     |
|                                                      | <b>Back Surface:</b>            | ANTI-REFLECTION               |
|                                                      | Single layer MgF <sub>2</sub> : | <1.5% R average 400-700 nm    |
| All dimensions are in mm unless otherwise specified. |                                 |                               |

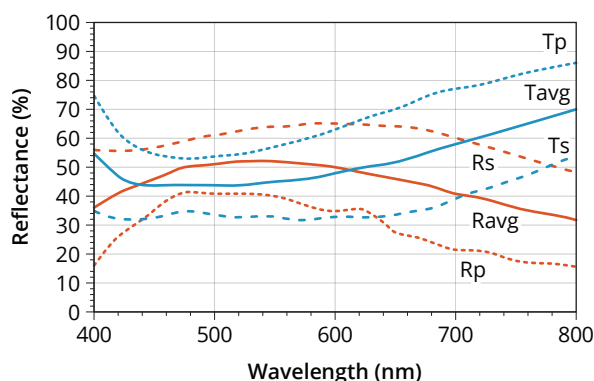
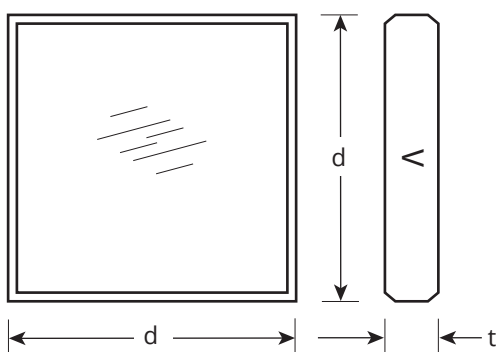
|                                                      |                                 |                            |
|------------------------------------------------------|---------------------------------|----------------------------|
| For UV                                               | <b>Material:</b>                | S1-UV Grade Fused Silica   |
|                                                      | <b>Coatings</b>                 |                            |
|                                                      | <b>First Surface:</b>           | BEAMSPLITTER (Metallic)    |
|                                                      | Angle of Incidence:             | 45°                        |
|                                                      | Polarization:                   | Unpolarized                |
|                                                      | Wavelength Range:               | 200-700 nm                 |
|                                                      | R/T Ratio:                      | 30/30 ±5% (200-400 nm)     |
|                                                      | <b>Back Surface:</b>            | ANTI-REFLECTION            |
|                                                      | Single layer MgF <sub>2</sub> : | <1.5% R average 200-400 nm |
| All dimensions are in mm unless otherwise specified. |                                 |                            |



# Beamsplitters

| Square | Size        | Thickness | Surface Accuracy | For Visible | For UV  |
|--------|-------------|-----------|------------------|-------------|---------|
|        | 25.4 × 25.4 | 1.0       | $3\lambda/25$ mm | 0101010     | 0201010 |
|        | 50.8 × 50.8 | 1.0       | $3\lambda/25$ mm | 0102020     | 0202020 |
|        | 25.4 × 25.4 | 5.0       | $\lambda/10$     | 0111010     | 0211010 |
|        | 50.8 × 50.8 | 10.0      | $\lambda/10$     | 0112020     | 0212020 |

| Round | Size | Thickness | Surface Accuracy | For Visible | For UV  |
|-------|------|-----------|------------------|-------------|---------|
|       | 25.4 | 1.0       | $3\lambda/25$ mm | 0101000     | 0201000 |
|       | 50.8 | 1.0       | $3\lambda/25$ mm | 0102000     | 0202000 |
|       | 25.4 | 5.0       | $\lambda/10$     | 0111000     | 0211000 |
|       | 50.8 | 10.0      | $\lambda/10$     | 0112000     | 0212000 |



## Beamsplitter Cubes

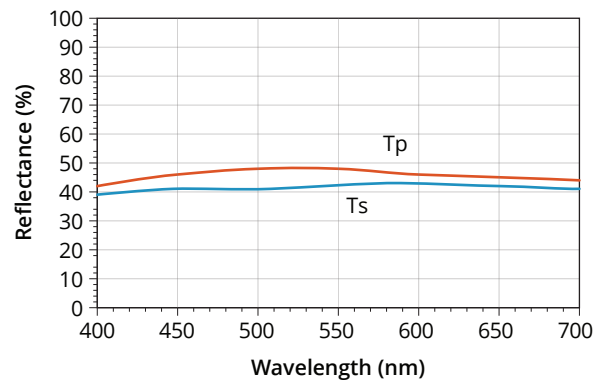
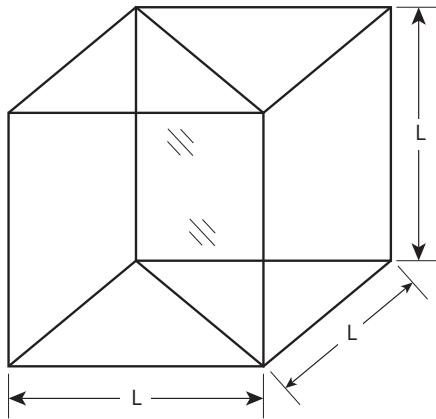
### Standard:

Beamsplitter cubes are constructed by cementing two right angle prisms together along their hypotenuses. They are supplied with one of the beamsplitter coatings described below applied to the hypotenuse of one of the prisms. The leg faces are uncoated, but can be AR coated upon request. Esco manufactures general purpose beamsplitter cubes for use in the visible and UV spectra. If you require elements with different spectral or physical characteristics, please contact Esco.

### Features:

- Transmitted beam is neither displaced nor deflected
- Reflected and transmitted beams travel identical optical path lengths
- No ghost images
- Less susceptible to mechanical stress
- R/T ratio dependent on the state of polarization
- Designed for use with collimated beams
- Contains cemented interface that may not be suited for high power laser applications
- Cemented interface may introduce undesired wave front distortion in larger cubes

# Beamsplitters



|         |                             |                         |
|---------|-----------------------------|-------------------------|
| General | <b>Dimension Tolerance:</b> | ±0.5 mm                 |
|         | <b>Surface Quality:</b>     | 60-40, scratch-dig      |
|         | <b>Edges:</b>               | Fine ground and beveled |

|             |                          |                                        |
|-------------|--------------------------|----------------------------------------|
| For Visible | <b>Material:</b>         | N-BK7/S-BSL7 Optical Glass             |
|             | <b>Coating:</b>          | Beamsplitter (Hybrid metal-dielectric) |
|             | <b>Polarization:</b>     | Unpolarized                            |
|             | <b>Wavelength range:</b> | 400-700 nm                             |
|             | <b>R/T ratio:</b>        | 45/45 ±5%                              |
|             | <b>Absorption:</b>       | ~10%                                   |

|        |                          |                          |
|--------|--------------------------|--------------------------|
| For UV | <b>Material:</b>         | S1-UV Grade Fused Silica |
|        | <b>Coating:</b>          | Beamsplitter (metallic)  |
|        | <b>Polarization:</b>     | Unpolarized              |
|        | <b>Wavelength range:</b> | 200-700 nm               |
|        | <b>R/T ratio:</b>        | 30/30 ±5% (200-400 nm)   |

|           |                            |                               |
|-----------|----------------------------|-------------------------------|
| For Laser | <b>Material:</b>           | S1-UV Grade Fused Silica      |
|           | <b>Coating:</b>            | Beamsplitter (All-dielectric) |
|           | <b>Angle of Incidence:</b> | 45°                           |
|           | <b>Polarization:</b>       | Unpolarized                   |
|           | <b>Wavelength range:</b>   | SPECIFY                       |
|           | <b>R/T ratio:</b>          | 45/45 ±5%                     |

|                                                                                     | Size (mm) | Flatness        | For Visible | For UV  | For Laser* |
|-------------------------------------------------------------------------------------|-----------|-----------------|-------------|---------|------------|
| Beamsplitter Cubes                                                                  | 15        | 1λ              | 0315015     | 0415015 | 0515015    |
|                                                                                     | 20        | 1λ              | 0320020     | 0420020 | 0520020    |
|                                                                                     | 15        | λ <sub>10</sub> | 0315115     | 0415115 | 0515115    |
|                                                                                     | 20        | λ <sub>10</sub> | 0320120     | 0420120 | 0520120    |
|                                                                                     | 25        | 1λ              | 0325025     | 0425025 | 0525025    |
|                                                                                     | 38        | 1λ              | 0338038     | 0438038 | 0538038    |
|                                                                                     | 50        | 1λ              | 0350050     | 0450050 | 0550050    |
| *IMPORTANT: Specify laser wavelength when ordering. Call Esco for more information. |           |                 |             |         |            |



# Beamsplitters

## Custom

In addition to our standard beamsplitters, we also manufacture a variety of custom elements including custom plates and cubes. For more information concerning beamsplitter variations or applications, please contact Esco at 1-800-922-ESCO (3726).

### Sizes:

Plates: nearly any size is possible.

Cubes: up to 100.0 mm

Size may limit the choice of coating. Please contact Esco to discuss your particular application.

### Materials:

Fused Quartz/Fused Silica (all grades)

Any optical glass

Other materials upon request

### Surface Quality:

Some applications may require surface qualities better than that of commercially available products. Esco can supply beamsplitters with surface quality better than 10-5 laser grade or surface accuracies better than  $\lambda/20$ . Please inquire.

### Wavefront Distortion:

If higher quality wavefront distortion is required, it is necessary to use a beamsplitter plate whose aspect ratio (diameter:thickness) is as low as possible. Although all materials act differently, a good rule of thumb for  $\lambda/10$  surface accuracy is about a 6:1 aspect ratio.

It is often difficult to achieve good wavefront distortion with large beamsplitter cubes, despite the surface accuracy of the constituent prisms. Many optical epoxies cause stress that can adversely affect wavefront performance in cubes larger than about 30 mm. Please contact Esco for more information.

### Tolerances:

The dimensional tolerances shown above are the standard tolerances used for off-the-shelf elements. Although Esco feels that these tolerances are in line with the typical uses for these parts, we can manufacture custom products with different tolerances upon request. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

# Beamsplitters



## Coatings:

Whenever specifying a custom beamsplitter, it is important to know:

- Wavelength, or wavelength range
- Angle of incidence
- State of polarization

Esco can provide custom beamsplitter coatings for almost any combination of these conditions.

Three basic types of coatings can be used:

**1. All dielectric beamsplitter** coatings provide good R/T characteristics with negligible absorption. They are extremely sensitive to polarization and angle of incidence and are designed for use over a narrow spectral region.

**2. Metal** (Inconel) beamsplitter coatings are not sensitive to polarization or angle of incidence. They provide steady R/T characteristics over a wide spectral range but can absorb as much as 35% of the incident energy.

**3. Hybrid** beamsplitter coatings are a combination of metal and dielectric films and therefore share many of their properties. They tend to be less absorptive than metal coatings and have a wider spectral response than an all dielectric coating.

Polarizing beamsplitter coatings are narrowband coatings that separate the S and P states of the incident light. These coatings are extremely angle sensitive but highly effective with collimated beams.

AR coatings for the side faces of cubes or the rear surface of plates are always available and encouraged. For information concerning availability please contact Esco.

## Prisms



A prism is an optical element whose purpose is to deflect or deviate a beam of light. Literally dozens of basic prism types exist. Esco's standard product line consists of three elementary shapes:

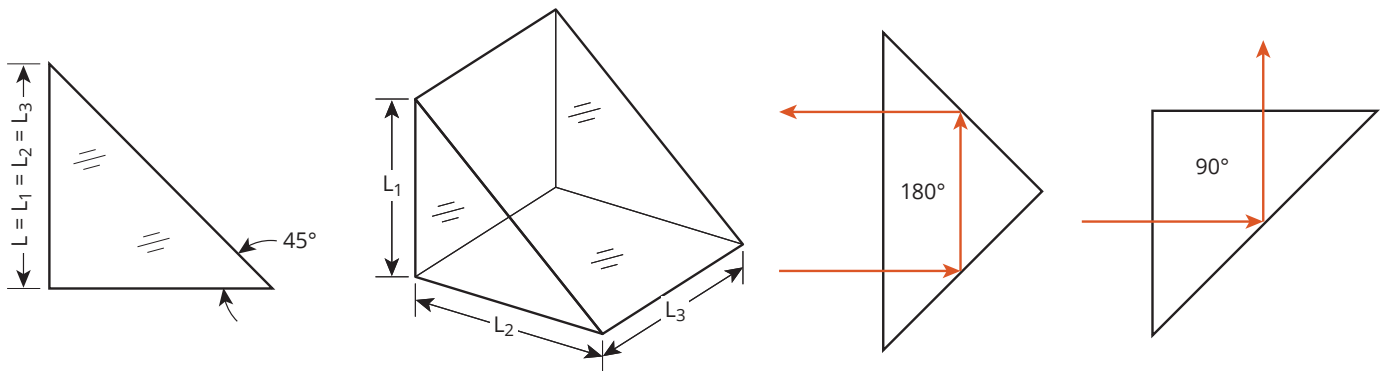
- Right angle prisms: Typically used to deflect beams either  $90^\circ$  or  $180^\circ$
- Equilateral prisms: Used to spectrally disperse polychromatic light.
- Laser prisms: Used to select a discrete wavelength from multi-wavelength lasers.

# Prisms



## Right Angle Prisms

In many situations involving collimated light, prisms are superior to mirrors for deflecting light. Prisms, because of their shape accuracy, require less positioning than mirrors. Light is always reflected within the plane parallel to the ground face of the prism. Also, because light is reflected by total internal reflection, prisms can be used to reflect high power laser beams that might otherwise damage sensitive coatings.



|                |                        | Commercial              | Laser Quality           |
|----------------|------------------------|-------------------------|-------------------------|
| Specifications | Dimensional Tolerance: | ±0.25 mm                | ±0.125 mm               |
|                | Angle Tolerance:       | ±10'                    | ±30"                    |
|                | Surface Accuracy:      | $\lambda/2$ per inch    | $\lambda/10$            |
|                | Surface Quality:       | 60 - 40, scratch-dig    | 20 - 10, scratch-dig    |
|                | Edges:                 | Fine ground and beveled | Fine ground and beveled |

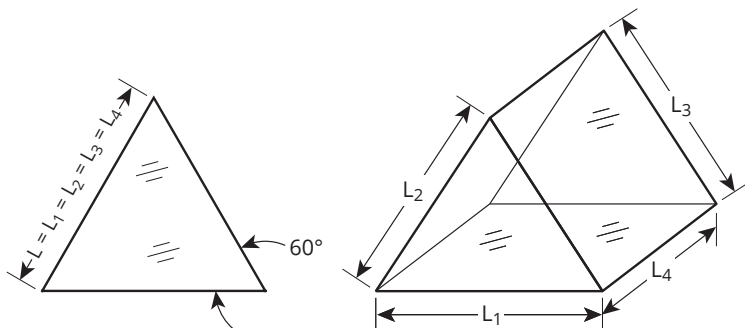
|                     |          | Commercial   |         | Laser Quality |         |
|---------------------|----------|--------------|---------|---------------|---------|
| Product Information | Size (L) | N-BK7/S-BSL7 | S1-UV   | N-BK7/S-BSL7  | S1-UV   |
|                     | 5.0      | I405050      | I105050 | I405151       | I105051 |
|                     | 10.0     | I410100      | I110100 | ---           | ---     |
|                     | 15.0     | I415150      | I115150 | I415151       | I115151 |
|                     | 20.0     | I420200      | I120200 | I420021       | I120201 |
|                     | 25.0     | I425250      | I125250 | I425251       | I125251 |
|                     | 38.1     | I438380      | I138380 | I438381       | I138381 |
|                     | 50.0     | I450500      | I150500 | I450501       | I150501 |



# Prisms

## Equilateral Prisms

These elements, also called dispersion prisms, are commonly used to separate multiple wavelengths of a polychromatic source. The direction of the exit beam is dependent on the wavelength, the angle of incidence and the shape of the prism. The equilateral shape of these prisms takes full advantage of the dispersive properties of the optical materials to provide maximum separation between wavelengths.



For visible light incident at a 60° angle of incidence to one face of an equilateral prism, the following angular separations between the h (404.7 nm) and r (706.5 nm) lines can be realized for the materials listed below.

|              |        |
|--------------|--------|
| S1-UV        | 1° 5'  |
| N-BK7/S-BSL7 | 1° 22' |
| SF10         | 7° 9'  |

|                        |                        | Commercial              | Laser Quality           |
|------------------------|------------------------|-------------------------|-------------------------|
| Product Specifications | Dimensional Tolerance: | ±0.25 mm                | ±0.125 mm               |
|                        | Angle Tolerance:       | ±10'                    | ±10'                    |
|                        | Surface Accuracy:      | λ1 per inch             | λ/10                    |
|                        | Surface Quality:       | 60 - 40, scratch-dig    | 20 - 10, scratch-dig    |
|                        | Edges:                 | Fine ground and beveled | Fine ground and beveled |

|                     |              | Commercial   |         |         | Laser Quality |         |         |
|---------------------|--------------|--------------|---------|---------|---------------|---------|---------|
| Product Information | Size (L x L) | N-BK7/S-BSL7 | SF10    | S1-UV   | N-BK7/S-BSL7  | SF10    | S1-UV   |
|                     | 20 x 20      | L420200      | L520200 | L120200 | L420201       | L520201 | L120201 |
|                     | 25 x 25      | L425250      | L525250 | L125250 | L425251       | L525251 | L125251 |
|                     | 30 x 30      | L430300      | L530300 | L130300 | L430301       | L530301 | L130301 |
|                     | 40 x 40      | L440400      | L540400 | L140400 | L440401       | L540401 | L140401 |
|                     | 45 x 45      | L445450      | L545450 | L145450 | L445451       | L545451 | L145451 |
|                     | 50 x 50      | L450500      | L550500 | L150500 | L450501       | L550501 | L150501 |

# Prisms



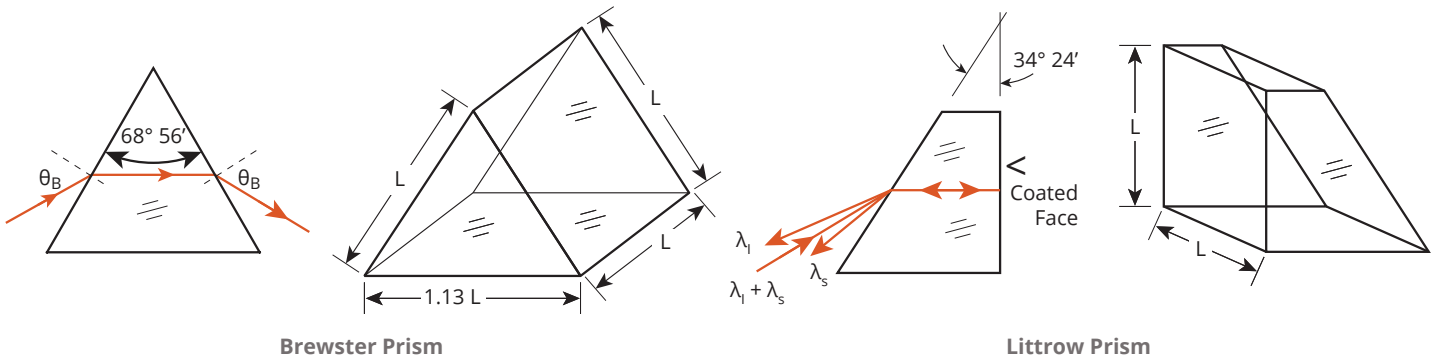
## Laser Prisms

### Brewster & Littrow Prisms:

These prisms are used to select a particular wavelength from a multi-wavelength laser. The apex angle of a Brewster laser prism is designed to deviate a ray of a particular wavelength by Brewster's angle, thus minimizing reflection losses when used with linearly polarized light. Only light that travels within the prism parallel to the base will be perfectly transmitted. Since other wavelengths will experience high losses, the Brewster prism can be used interacavity to suppress their gain.

A Littrow laser prism is the result of cutting a Brewster prism in half. The plane of the cut divides the apex angle and is perpendicular to the base of the prism. By adding a reflective coating to the new leg face, the Littrow is used like the Brewster prism, but the output exits back toward the source.

Each of these elements can be used to tune a variety of laser systems efficiently. Tuning is performed by tilting the prism in the path of the beam. The apex angle has been carefully chosen to allow maximum performance at any desired wavelength within the visible spectrum. For assistance with these or other similar custom products, please contact Esco at 1-800-922-ESCO (3726).



|                                                      |                                                      |
|------------------------------------------------------|------------------------------------------------------|
| <b>Material:</b>                                     | S1-UV Grade Fused Silica                             |
| <b>Surface Accuracy:</b>                             | $\lambda_{20}$ over clear aperture                   |
| <b>Surface Quality:</b>                              | 10-5, scratch dig                                    |
| <b>Clear Aperture:</b>                               | Central 80% diameter                                 |
| <b>Dimensional Tolerance:</b>                        | ±0.5 mm                                              |
| <b>Apex Angle Tolerance:</b>                         | ±5'                                                  |
| <b>Edges:</b>                                        | Fine ground and beveled                              |
| <b>Width of Bevel</b>                                | <5 mm                                                |
| <b>Coating:</b>                                      | Uncoated, specify optional coating on Littrow prisms |
| All dimensions are in mm unless otherwise specified. |                                                      |

| Type     | Size (L) | Apex Angle | P/N     |
|----------|----------|------------|---------|
| Brewster | 15       | 68° 56'    | I515015 |
| Brewster | 25       | 68° 56'    | I525025 |
| Littrow  | 15       | 34° 28'    | I615015 |
| Littrow  | 25       | 34° 28'    | I615015 |



# Prisms

## Custom Prisms

In addition to our standard lines of prisms, we are often called upon to design and manufacture a variety of custom elements. For more information on custom products or applications, please contact Esco.

### Sizes:

There is almost no size limitation for prisms that we can build. There is, however, usually a trade-off between size and angular accuracy. Please call Esco to discuss your particular application.

### Materials:

Fused Quartz/Fused Silica (all grades)

N-BK7/S-BSL7 Optical Glass

Other materials upon request

### Surface Quality:

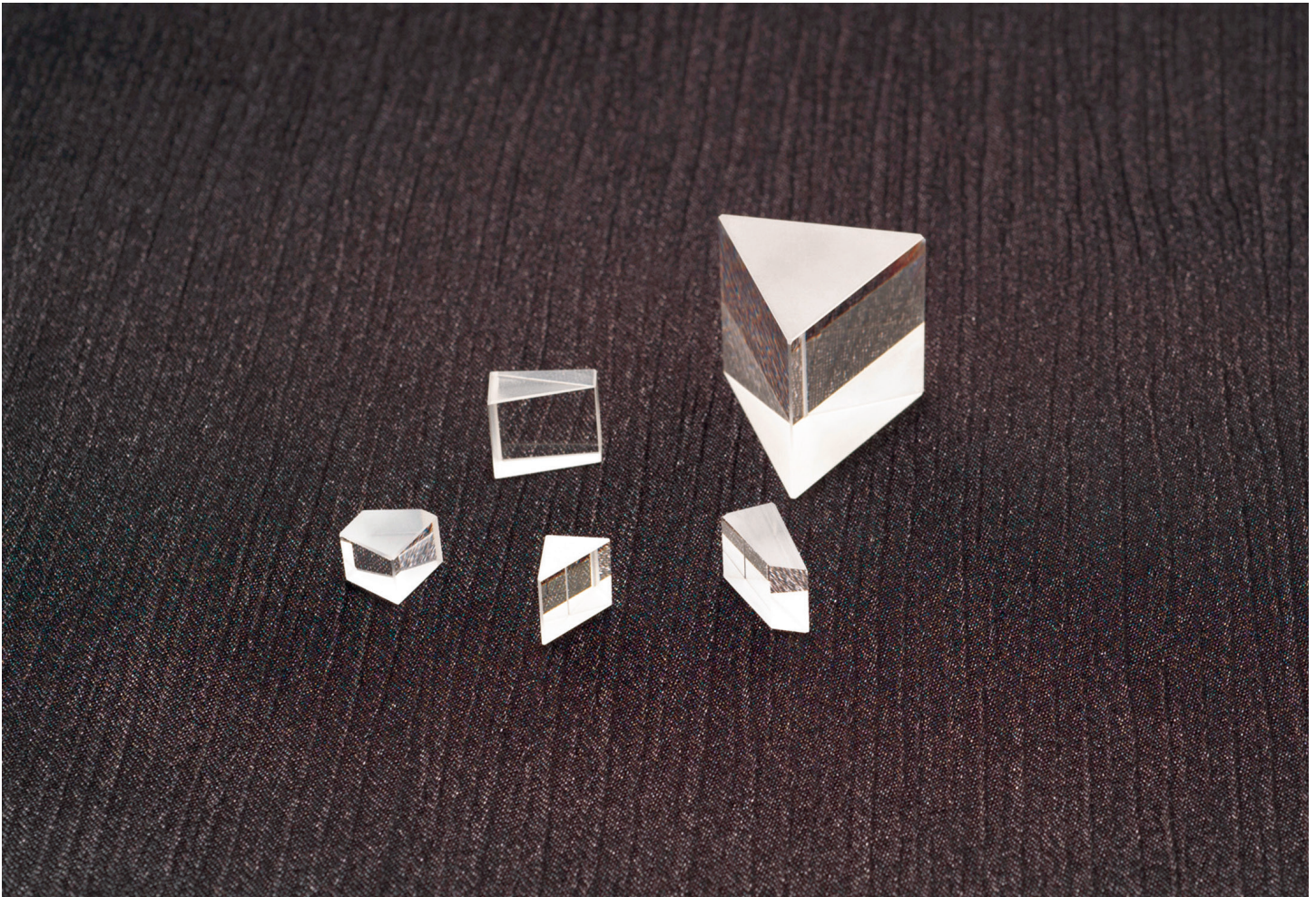
Some applications may require surface qualities better than that of commercially available products. Esco can supply elements with surface quality better than laser grade, 10-5 or surface accuracies better than  $\lambda/20$ . Please contact Esco for more information.

### Tolerances:

The dimensional tolerances shown above are the standard tolerances used for off-the-shelf elements. Although Esco feels these tolerances are in line with the typical uses for these parts, we can manufacture custom products with other tolerances upon request. For certain OEM applications, looser tolerances may lead to a cost savings, while many critical applications may require much tighter tolerances. To discuss your particular needs, please contact Esco.

### Coatings:

Unless otherwise specified, all standard Esco prisms are supplied uncoated. Coatings can, however, greatly enhance a prism's performance. To discuss your specific coating needs, please contact Esco

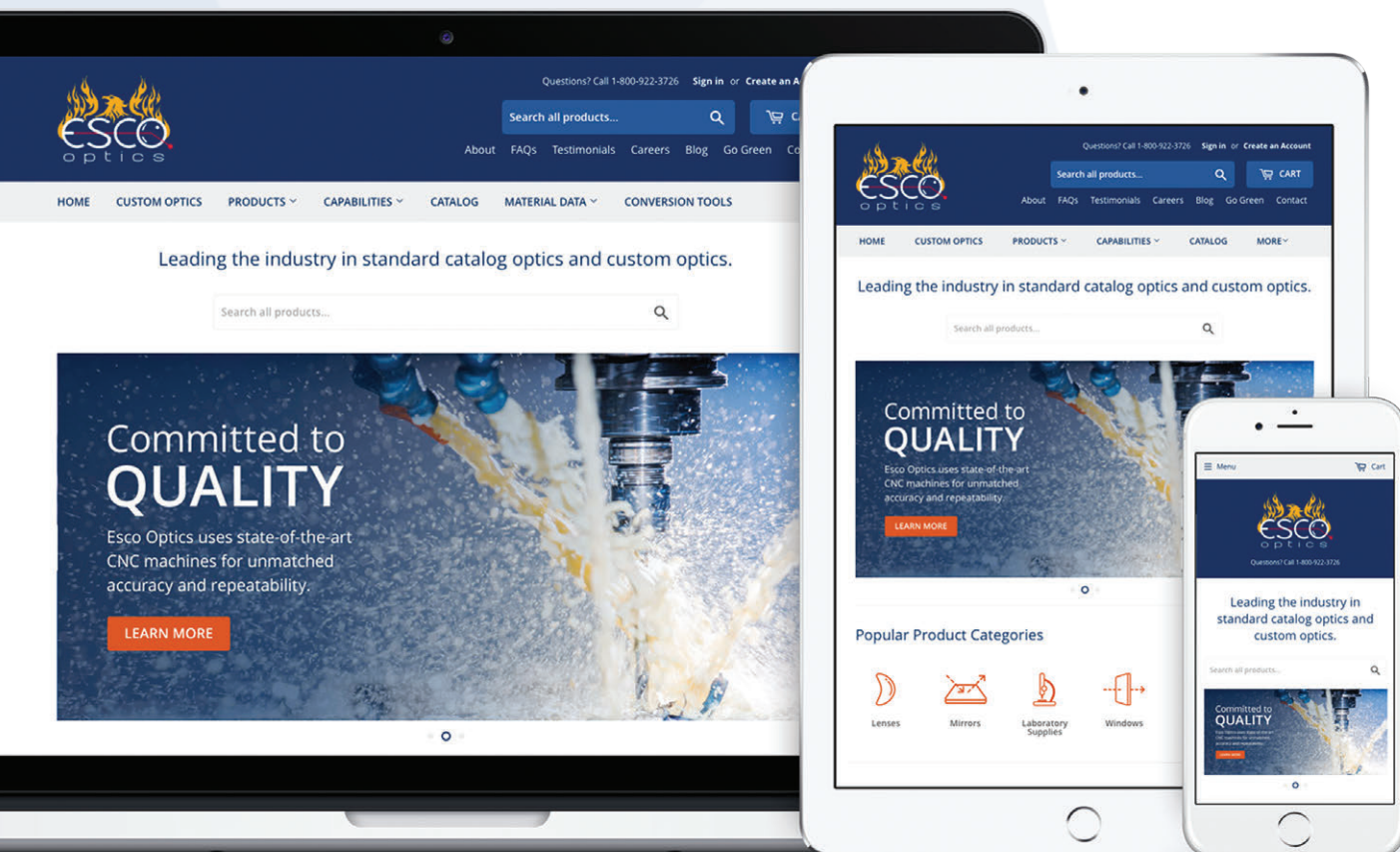


Custom and catalog prisms of any configuration can be supplied.



## Visit the new EscoOptics.com

Check out our recently launched website featuring an improved user experience, searchable product catalog, and mobile-friendly, responsive design!



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Our redesigned website better serves current and prospective customers through clear navigation, lightning fast search, and helpful conversion tools.

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## A Message From Our President

"We are excited to start the next chapter in Esco's long history. The misfortune of the 2014 fire has given rise to numerous backward blessings and has strengthened Esco to its core. The entire Esco Optics family is working hard to assure all of our customers the continuation of world class quality products and renewed partnerships in the coming years. With the support of our exceptional employees, our families, and our dearest friends in the industry, Esco is rising above this tragedy and continuing to excel at being a premier optics manufacturer in the United States."



Lee Steneken  
President



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