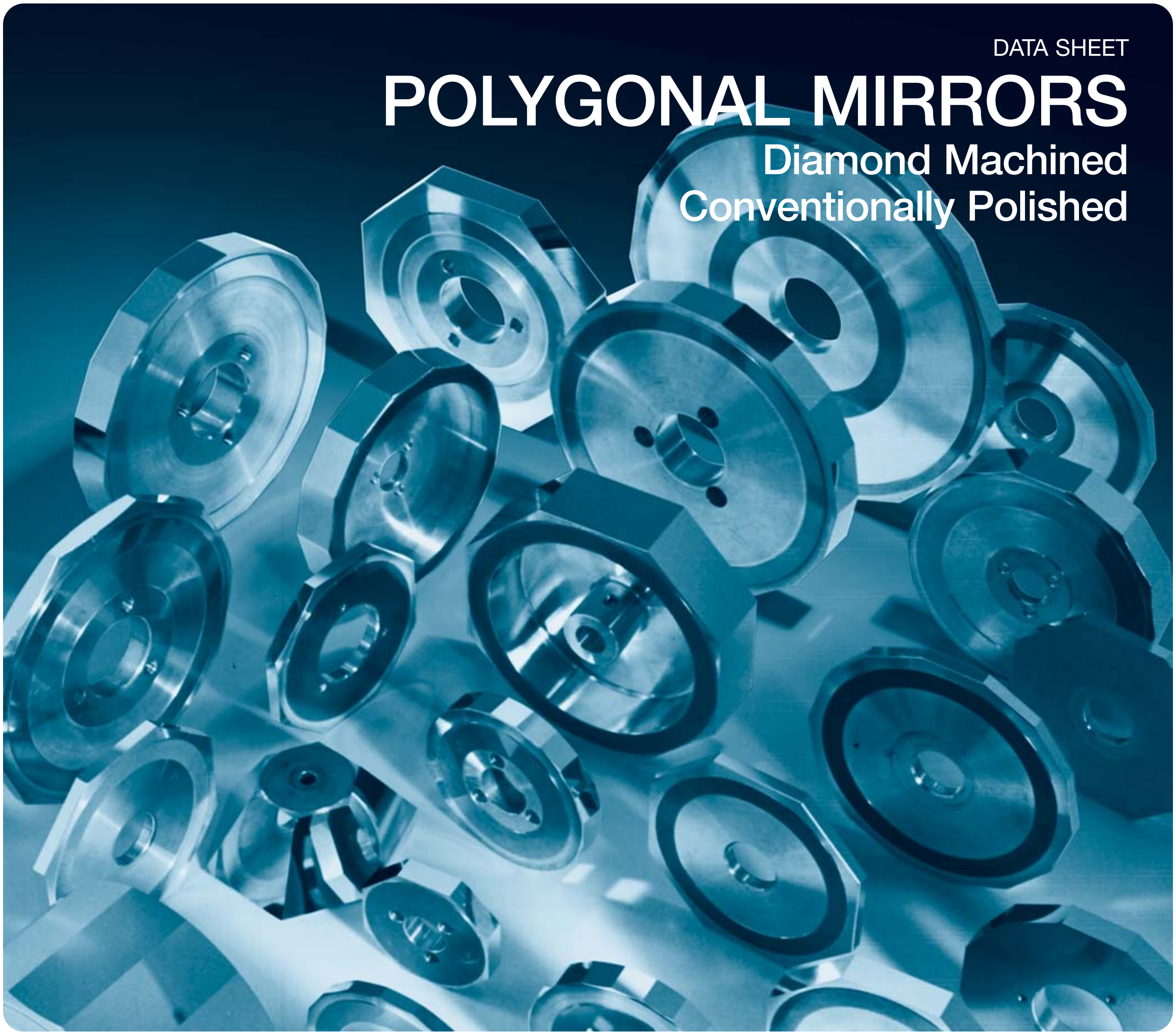
LINCOLN LASER®

DATA SHEET

POLYGONAL MIRRORS

Diamond Machined
Conventionally Polished



Lincoln Laser's polygon mirrors span the entire range from low-cost/high-volume components to the most sophisticated products available. Our manufacturing integrates state-of-the-art equipment, machine tools, and facilities and can successfully tackle the toughest fabrication challenges, including components with low scatter surfaces, high surface flatness, minimum pyramidal error, tight mechanical tolerances as well as specially optimized optical coatings.

Selecting the right Polygonal Mirror for your needs

Lincoln Laser offers a complete selection of diamond turned and conventionally polished mirrors for both standard and custom design applications. Lincoln Laser application engineers will assist you in selecting or designing the precise solution to your scanning requirements.

Diamond Machined Mirrors

General Properties

Diamond machined polygonal mirrors are manufactured from 5052 aluminum alloy.

- Flatness to λ/8 per inch.
- Low cost, automated manufacturing process.

General Areas of Application

Bar Code Scanning, Laser Printing, Graphic Arts, Laser Marking, Infrared Imaging, Inspection

Conventionally Polished Mirrors

General Properties

Conventionally polished polygonal mirrors are manufactured from electroless nickel plated 6061-T6 aluminum alloy.

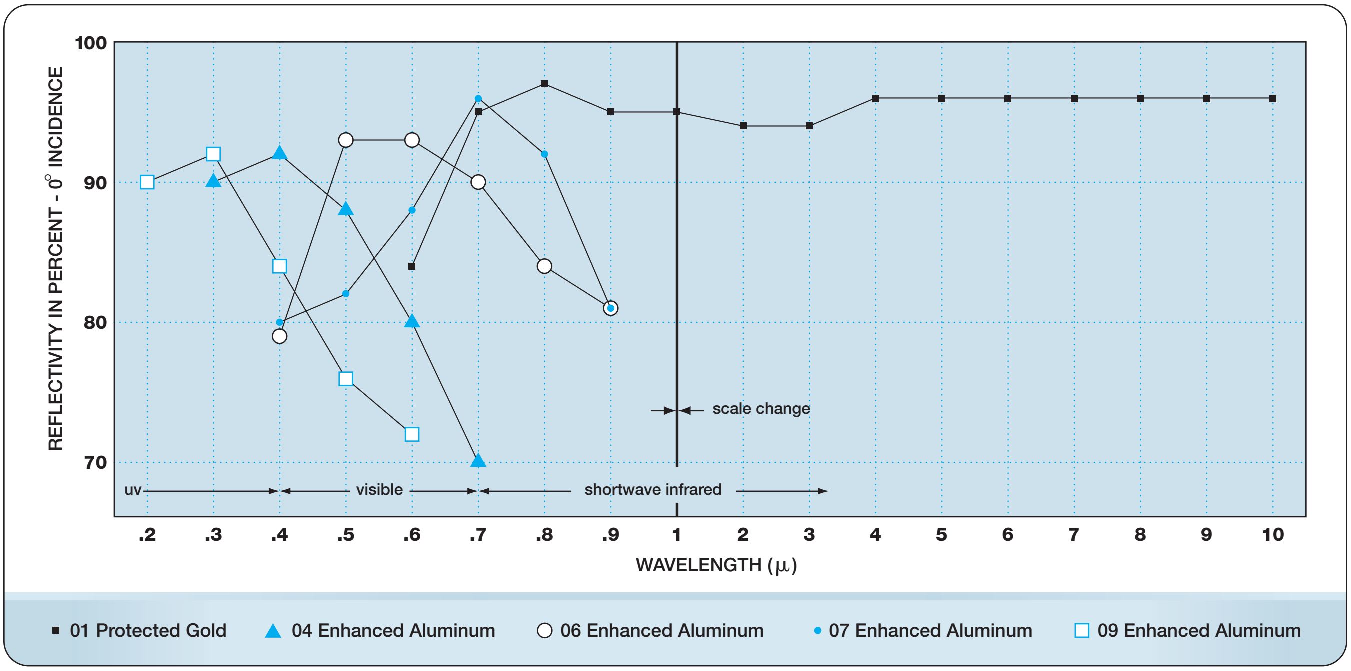
- Optical surfaces exhibit LOW SCATTER.
- Durable and scratch resistant, meets MIL C-675 STANDARD
- Flatness to λ/8 per inch
- Relatively higher cost – labor-intensive process.

General Areas of Application

Gray Scale Printing, Film Writing, Image Display, Web Inspection, Robotic Vision, Laser Inspection

REFLECTIVITY

Performance of Gold and Protected Aluminum Coatings



Enhancement Coatings

There are two major functions of enhancement coatings on polygonal mirrors: to improve the reflectance of the mirror and to improve its durability.

Unprotected diamond machined aluminum surfaces have a reflectance of 85% to 92% across most of the visible spectrum and are difficult to clean without scratching.

See chart above for reflectivity versus wavelength of standard coatings or contact Lincoln Laser for a complete list and specifications of available reflective coatings.

Optical Glossary

Clear Aperture – Defines the area on the facet where the optical specifications apply.

Surface Figure – This is a measure of the flatness of the surface and is specified in terms of wavelengths of light. The standard specification for our mirrors is λ/4 per inch. We can hold tighter tolerances if needed

Surface Roughness – This is a measure of the microstructure of the surface. It is specified in terms of Angstroms (Å) RMS. The standard specification for diamond turned surfaces is 80 Å; for conventionally polished surfaces, it is 20 Å.

Lay Direction – Lay is the direction of the predominant surface pattern generated by the diamond tool. Most mirrors can be manufactured with the lay direction either parallel or perpendicular to the datum. *If a diamond turned surface is selected, the lay direction must be specified.*

Reflectivity – A variety of reflective coatings are available. See Chart A for reflectivity versus wavelength for standard coatings.

System Glossary

To design the proper polygonal mirror for a given application, the following system specifications need to be determined.

C **Duty Cycle** – The ratio of the active scan time to total time. This can also be expressed as the ratio of the scan angle to the total available scan angle – where the maximum theoretical scan possible from a polygonal mirror is obtained from this formula: 720° /# of facets.

α° **Beam Feed Angle** – The angle measured in degrees between the input beam to the polygon and the center of the scan from the polygon.

λ **Wavelength** – The wavelength of the specific light source used, expressed in microns.

θ° **Scan Angle** – The full extent of active scan measured in degrees.

N **Number of Resolvable Points** – The total number of pixels needed in the scan plane, where a pixel diameter is $1/e^2$.

β **Angular Resolution** – The full angle of active scan, measured in degrees, divided by the number of resolvable points.

d(μ) **Spotsize in Scan Plane** – This is the beam diameter measured at the $1/e^2$ intensity point in the scan plane.

T (mm) **Throw Distance** – The distance between the polygon and the scan plane in a system without a scan lens.

F (mm) **Scan Lens Focal Length**

Y (mm) **Scan Length** – The total length of the scan line in the scan plane.

Polygon Size Calculation

Polygon size determination is a critical first step in the selection of a motorized scanner. The selection of the proper polygon for a given application requires some knowledge of the system parmeters. In all cases a few key parameters must be known: scan angle, beam feed angle, wavelength, and desired duty cycle.

Calculate Number of Facets

The number of facets to be used is a tradeoff that needs to be addressed. The formula for the number of facets is given by:

$n = 720(C)/\theta.$

where θ is the active optical scan angle and C is the duty cycle.

If this equation produces a non integer answer this means that there is no exact solution to provide the duty cycle desired at the same time as the optical scan angle requirement is satisfied. A next logical step is to fix the number of facets to an integer value near the result from the previous calculation and fix either the scan angle or the duty cycle and solve for the remaining variable.

$C = n\theta / 720$

Calculate the Beam Diameter Incident to the Facet

The following figures 1 and 2 illustrate two common design layouts. One with a scan lens and one without. The equations used to size the polygon depend on which design approach is used.

NOTE: If the output beam from the polygon is collimated do not use any of the following equations. Use instead the collimated beam diameter for D.

The following two formulas work regardless of use of a scan lens:

$D(mm) = .00127\ (\lambda)/[(\beta)\ (.017453)]$

where β is the angular resolution in degrees which is defined as the full optical angle of active scan divided by the number of resolvable points and λ is the wavelength in microns

$D(mm) = .00127\ (\lambda)\ (N)/[(\theta)\ (.017453)]$

where N is the number of resolvable points.
and λ is the wavelength in microns
and θ is the optical scan angle in degrees

Recall that N = scan length / d if N is not provided directly.

The polygon can be sized without a scan lens by using the following formula:

$D(mm) = 1.270\ (\lambda)\ (T)/d$

where T is the distance from the polygon to the scan plane in mm and d is the $1/e^2$ beam diameter in the scan plane in microns

If a scan lens has been selected then you can use the following formula:

$D(mm) = 1.270\ (\lambda)\ (F)/d$

where F is the focal length of the scan lens in mm
and λ is the wavelength in microns
and d is the $1/e^2$ beam diameter in the scan plane in microns

One final design decision is required before continuing the sizing is the amount of intensity variation during the scan that is allowable. The calculations assume a TEM00 gaussian beam that is truncated at either the $1/e^2$ or 1.5 x $1/e^2$ diameter. If the polygon is sized for a beam that is not truncated then using the $1/e^2$ diameter for D in the calculations will result in a 6.25% intensity drop off at the beginning and end of scan. If the polygon is sized for a $1.5\times 1/e^2$ diameter truncated beam then the intensity drop off will be approximately 0.5%.

Calculate the Beam Footprint on the Facet

The value D' now needs to be determined. This is the projected footprint on the polygon facet. It takes into account the truncation diameter and the cosine growth of the beam on the facet due to the beam feed angle. The formula for calculating the beam footprint is:

$D' = 1.5\ D/\cos(\alpha/2)$

This equation assumes nearly perfect intensity across the scan. If more drop off is allowed the 1.5 value can be lowered or eliminated completely.

Calculate the Length of the Facet

The length of the facet can be determined from the beam footprint using the following:

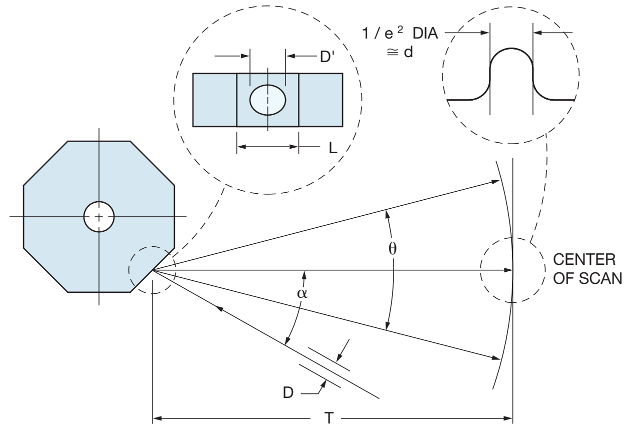


FIGURE 1: SCAN SYSTEM WITHOUT SCAN LENS

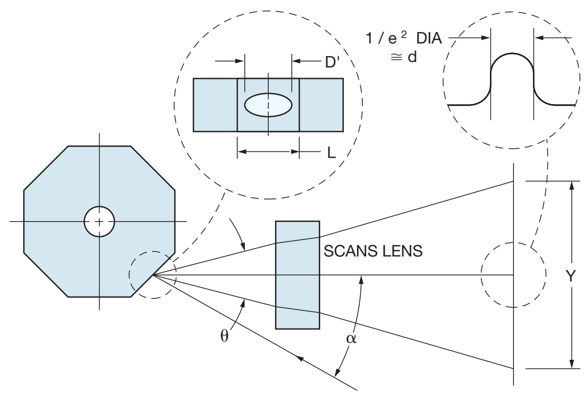


FIGURE 2: SCAN SYSTEM WITH SCAN LENS

$L(mm) = (D' + 1)/(1 - C)$

The value of 1mm in the numerator has been added to allow for facet ‘roll off’ at the edges.

Calculate the Polygon Diameter

The polygon diameter can now be calculated as follows:

$Diam_{inscribed} = L/[\tan(180/n)]$

This result is the inscribed polygon tip diameter in mm.

If the polygon diameter is too large then you have three options. The first is to reduce the duty cycle and suffer a higher speed and data burst rate. The second is to reduce the beam feed angle. The third is to allow more intensity variation across the scan by reducing the 1.5 multiplier which will reduce the facet length. After any of these changes go back and recalculate the polygon diameter and see if you have achieved your desired diameter.

Determine Polygon Thickness

The thickness of the polygon is not critical in most applications. If you are using an optical design that produces a line focus on the facet then the facet thickness is determined by what our housings can accommodate and staying below a 12:1 diameter to thickness ratio. If the design has a round beam incident to the facet then the minimum facet thickness is the beam diameter plus .120 inches for facet ‘roll off’ plus any alignment tolerance required. In most cases if you can minimize the polygon thickness the cost will be lower.

If you have any questions regarding this calculation please consult with our Applications Engineers.

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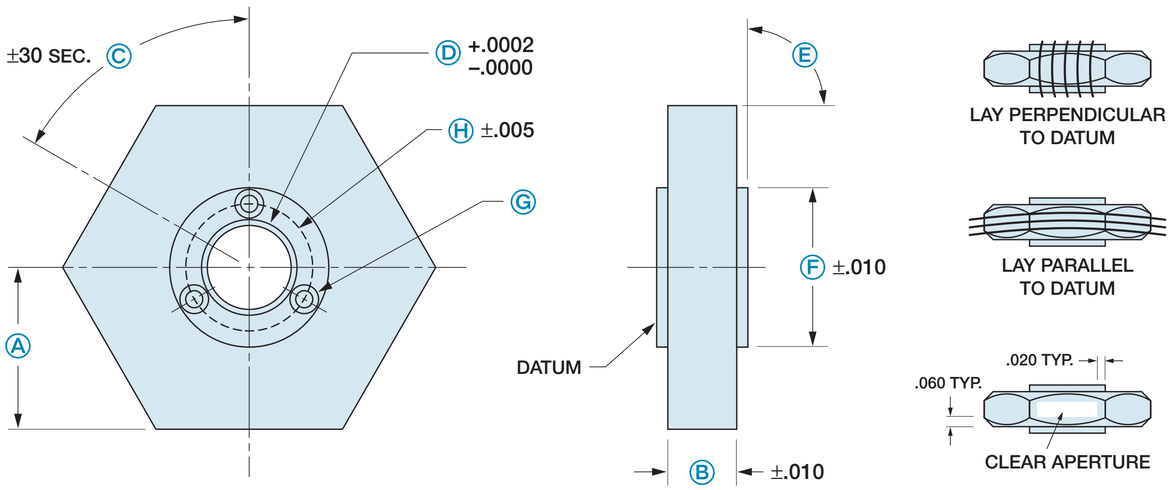
POLYGONAL MIRROR WORKSHEET

This worksheet is designed to help you specify your requirements



ALL DIMENSIONS IN INCHES

Mechanical Specifications

1.1 Number of facets needed: ______________________________

1.2 Ⓐ Facet to center distance: ______________________________
The facet to center distance may vary +/–.005 in.
Within a given polygon, all facets shall be equidistant within a standard of ±.001 in.

1.3 Ⓑ Facet thickness: ______________________________
For good part stability, a minimum aspect ratio of 12:1 (diameter to thickness) is required. Typically allow a minimum of .060 in. per side for chamfer and roll-off.

1.4 Ⓒ Facet-to-facet polar angle:_____ degrees, ± _____ seconds.

Lincoln Laser will specify items 1.5 - 1.9 if purchasing complete scanner assembly. For purchase of mirrors only, please complete all mechanical specifications.

1.5 Ⓓ Bore diameter: ______________________________
To accommodate existing tooling, 3 bore diameters are offered as standard: .5001 in. dia., .6253 in. dia., and 1.0001 in. dia.

1.6 Ⓔ Facet to datum angle: _______ degrees, _______ seconds.
With standard tolerancing, the mean angle may vary within 3 min. of arc, and within a given polygon, all the facets shall be the same angle within the specified tolerance:

± _______________ arc seconds.

1.7 Ⓕ Minimum datum diameter: ______________________________

1.8 Ⓖ Counter bored clearance hole for screwsize.

1.9 Ⓗ Bolt circle diameter: ______________________________

Optical Specifications

For surface roughness requirements below 50 Å RMS, polished nickel plated polygons must be utilized. For surface roughness requirements greater than 50 Å RMS, diamond machined aluminum polygons may be utilized.

2.1 Surface flatness: ______________________________

Wavelength: ________________ over optical clear aperture

of ________________(height) x ________________(width).

2.2 Surface reflectivity minimum: _______ % @ _______wavelength

over an angle of incidence of: ________ to _________ degrees.

2.3 Surface roughness: ______ Angstroms RMS at .6328 microns.

2.4 Lay (applicable to diamond machined polygons only):

- ☐ Approximately perpendicular to datum, OR
- ☐ parallel to datum, OR
- ☐ to be determined by Lincoln Laser.

Physical Specifications

3.1 Substrate material (standard is aluminum alloy):

____

3.2 Operating speed (RPM): ______________________________

3.3 Operating temperature: ______________________________

3.4 Operating attitude:

- ☐ Spin axis vertical, mirror up, OR
- ☐ Spin axis vertical, mirror down, OR
- ☐ Spin axis horizontal.