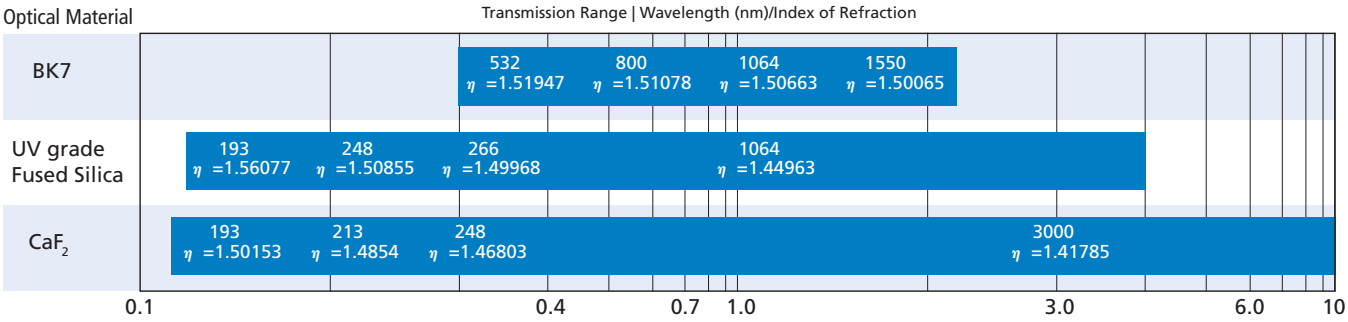
WAVELENGTH TRANSMISSION RANGE AND REFRACTIVE INDEX



FOCAL LENGTH FORMULAS FOR SINGLET LENSES

Type	Orientation	Focal Length f	Back Focal Distance BFD	Front Focal Distance FFD
General	$R_1 = R_1$ $R_2 = R_2$	$\left[(\eta-1)\times\left(\frac{1}{R_1}-\frac{1}{R_2}+\frac{t_c(\eta-1)^2}{\eta R_1 R_2}\right)\right]^{-1}$	$f\times\left[1-\frac{t_c(\eta-1)}{\eta R_1}\right]$	$f\times\left[1+\frac{t_c(\eta-1)}{\eta R_2}\right]$
Plano-Convex	$R_1 = R$ $R_2 = \infty$	$\frac{R}{\eta-1}$	$f\times\left[1-\frac{t_c(\eta-1)}{\eta R}\right]$	f
Plano-Concave	$R_1 = -R$ $R_2 = \infty$	$\frac{-R}{\eta-1}$	$f\times\left[1+\frac{t_c(\eta-1)}{\eta R}\right]$	f
Bi-Convex	$R_1 = R$ $R_2 = -R$	$\left[\frac{2(\eta-1)}{R}-\frac{t_c(\eta-1)^2}{\eta R^2}\right]^{-1}$	$f\times\left[1-\frac{t_c(\eta-1)}{\eta R}\right]$	$f\times\left[1-\frac{t_c(\eta-1)}{\eta R}\right]$
Bi-Concave	$R_1 = -R$ $R_2 = R$	$-\left[\frac{2(\eta-1)}{R}-\frac{t_c(\eta-1)^2}{\eta R^2}\right]^{-1}$	$f\times\left[1+\frac{t_c(\eta-1)}{\eta R}\right]$	$f\times\left[1+\frac{t_c(\eta-1)}{\eta R}\right]$

BASIC EQUATIONS

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

$$OD = \log_{10}\left(\frac{1}{T}\right)$$

Snell's Law:

$$\eta_1 \sin\theta_1 = \eta_2 \sin\theta_2$$

Fresnel reflection at 0°:

$$R = \left(\frac{\eta_2-\eta_1}{\eta_2+\eta_1}\right)^2$$

f Number:

$$f/\# = \frac{f}{D} = \frac{1}{2(NA)}$$

Mirror Focal Length:

$$f = \frac{\text{Radius of Curvature}}{2}$$

INTERNAL REFLECTION & CRITICAL ANGLE

$$\theta_c = \sin^{-1}(\eta_2/\eta_1), \text{ for } \eta_2 < \eta_1$$

$$r_p = \frac{(\eta_2/\eta_1)^2\cos\theta_1 - i\sqrt{\sin^2\theta_1-(\eta_2/\eta_1)^2}}{(\eta_2/\eta_1)^2\cos\theta_1 + i\sqrt{\sin^2\theta_1-(\eta_2/\eta_1)^2}}$$

$$r_s = \frac{\cos\theta_1 - i\sqrt{\sin^2\theta_1-(\eta_2/\eta_1)^2}}{\cos\theta_1 + i\sqrt{\sin^2\theta_1-(\eta_2/\eta_1)^2}}$$

$$t_p = t_s = 0$$

$$\delta = \phi_s - \phi_p = 2\tan^{-1}\left[\frac{\cos\theta_1\sqrt{\sin^2\theta_1-\eta^2}}{\sin^2\theta_1}\right],$$

where $\eta = \frac{\eta_2}{\eta_1}$

$$\theta_B = \tan^{-1}\left(\frac{\eta_2}{\eta_1}\right)$$

DIFFRACTION-LIMITED BEAM DIAMETER DIVERGENCE

$$M^2 = \frac{\pi}{\lambda} w_0\Theta_0 = \frac{\pi}{\lambda}\frac{d_0}{2}\frac{D_0}{2f}$$

Achievable focal spot diameter, d_0

$$d_0 = \frac{M^2\, 4\,\lambda f}{\pi D_0}$$

ETALONS

$$T = \frac{I_{trans}}{I_{inc}} = \frac{1}{1+\frac{4R}{(1-R)^2}\sin^2(\delta/2)}$$

$$FSR = \frac{\lambda^2}{2d}$$

$$FWHM = \frac{FSR}{F}$$

POLARIZATION

Malus's Law:

$$I = \frac{1}{2} c\, \epsilon_0 E_0^2 \cos^2\theta = I_0 \cos^2\theta$$

Faraday Rotation:

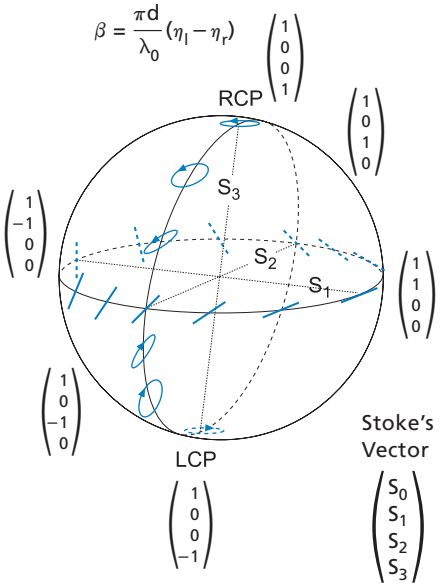
$$\beta = VBd,$$

β = angle of rotation

Optical Activity:

d-rotary is when $\eta_l > \eta_r$
l-rotary is when $\eta_r > \eta_l$

$$\beta = \frac{\pi d}{\lambda_0}(\eta_l - \eta_r)$$



LASER SELECTION GUIDE

Rayleigh length $z_R = \dfrac{\pi\omega_o^2}{\lambda}$

Sum Frequency Generation $\lambda\,\text{sum} = \dfrac{1}{\left(\dfrac{1}{\lambda_1} + \dfrac{1}{\lambda_2}\right)}$

Difference Frequency Generation $\lambda\,\text{difference} = \dfrac{1}{\left(\dfrac{1}{\lambda_1} - \dfrac{1}{\lambda_2}\right)}$

Brightness or Radiance of Laser Beam $B = \dfrac{P}{\pi\omega_o^2\,\pi\theta^2}$

FABRICATION TOLERANCES

Surface Tolerances	Precision	Laser Grade	Mfg Limit
Surface quality (scratch/dig)	40-20	10-5	5-2
Surface roughness (Å, R_A)	20	5	2.5
Spherical irregularity (waves, P-V @ 633 nm)	0.5	0.2	0.01
Spherical radius (fringes)	5	3	0.5
Flat irregularity (waves, P-V @ 633 nm)	0.5	0.1	0.04

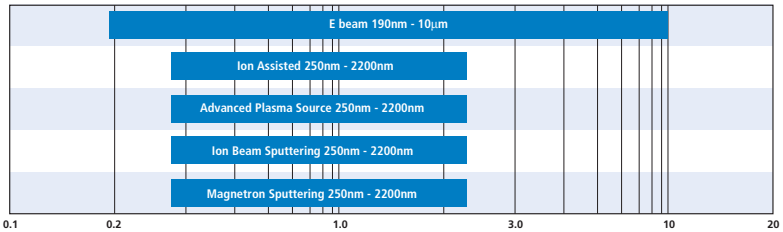
Dimensional Tolerances	Commercial	Precision	Mfg Limit
Diameter (mm)	+0.000/-0.250	+0.000/-0.025	+0.000/-0.005
Length & Width (mm)	±0.050	+0.000/-0.025	+0.000/-0.010
Thickness (mm)	±0.250	±0.050	±0.005
Centration (edge thickness difference, mm)	0.050	0.010	0.005
Wedge	<10 ± 5 arc min	≤1 arc sec	≤0.5 arc sec
Clear aperture (%)	85	90	100

The general tolerance specifications above provide a guideline regarding manufacturing capabilities for optics ranging in size from 3-100mm. The manufacturing limits are not absolute; tighter tolerances may be possible. Part specific tolerances may vary depending on component size, shape, and/or material. λ/100 surfaces are achievable. Call us for more details.

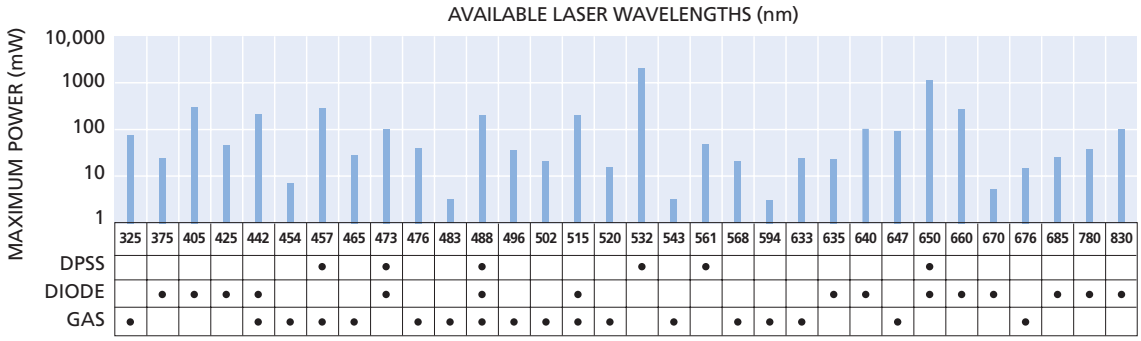
COATINGS

	E-beam	IAD	APS	IBS	Magnetron Sputtering
Laser Damage Threshold*	>20J/cm²	>40J/cm²	>40J/cm²	>20J/cm²	>40J/cm²
Scatter and Absorption (%)	<0.2	<0.15	<0.15	<1 PPM	<50 PPM
Surface Roughness (Å rms)	5	7	7	<1	<9
Wet/Dry Shift (range) (%)	<0.8	<0.3	0.00	0.00	0.00

*These values may be slightly higher or lower depending on deposition conditions and other process related parameters. Overall plasma processes have lower absorptions than conventional e-beam technologies. *Laser-Inducer Damage Threshold (LIDT) depends on Test Wavelength, Pulse Width, repetition rate and inspection method. This data is from 1064 nm, 10 ns, 20 Hz.*



AVAILABLE LASER WAVELENGTHS (nm)



Acronyms, Abbreviations, and Units

Ω	ohm
μsec	microsecond
μW	microwatt
A	ampere
A	analog
A/D	analog to digital
ac	alternating current
ACC	Automatic Current Control
ANSI	American National Standards Institute
AO	acousto-optic
APC	automatic power control
AR	antireflection
BFL	back focal length
BNC	Berkeley Nucleonics Corporation
CA	clear aperture
CAN	controller area network
CCD	charge-coupled device
CDRH	Center for Devices and Radiological Health
CFC	chlorofluorocarbons
CIE	International Commission on Illumination (Commission Internationale de l'Éclairage)
CLT	clear lightweight technology
CMOS	Complementary Metal Oxide Semiconductor
CVD	chemical vapor deposition
cw	continuous wave
D	digital
dB	decibel
dc	direct current
DIP	dual inline package
DOF	Depth of Field
DVO	diffuse viewing only
EFL	effective focal length
EMI	electromagnetic interference
EO	electro-optic
ESD	electrostatic discharge
ESPI	electronic speckle pattern interferometry
FC	fiber coupling
ft	foot
fsec	femtosecond
FSR	free spectral range
FWHM	full width at half maximum
g	gram
GΩ	gigaohm
HEBBAR™	high-efficiency broad-band antireflection
HEL	high-energy laser
HP	horizontal points
Hz	Hertz
IC	integrated circuit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMS	integrated modular system
in.	inch
IR	infrared
ISO	International Standards Organization
IVM	integrated vision module
kg	kilograms
kV	kilovolt
lb	pound
LCD	liquid crystal display
LED	light emitting diode
LSO	laser safety officer
mA	milliampere
mm	millimeter
MPE	maximum piezoelectric extension
msec	millisecond
MTF	modulation transfer function
MTTF	mean time to failure
N/A	not applicable
nA	nanoampere
NA	numerical aperture
NAS	nonaspheric side
NBS	National Bureau of Standards
ND	neutral density
NEP	noise-equivalent power
NIST	National Institute for Science and Technology
nm	nanometer
OD	Optical Density
OD	outside diameter
OEM	original equipment manufacturer
pA	picoampere
PC	personal computer
PCI	Peripheral Component Interconnect
PCMCIA	Personal Computer Memory Card International Association. Often called PC cards
pF	picofarad
p-p	peak-to-peak
PSD	power spectral density
PZT	piezo electric transducers
QCW	quasi continuous wave
RH	relative humidity
rms	root mean square
sec	second
SPC	statistical process control
T	transmissibility
TE	thermoelectric
TEC	thermoelectric cooler
TIR	total internal reflection
TSA	transverse spherical aberration
TTL	transistor-transistor logic
USB	universal serial bus
UV	ultraviolet
UVGSFS	UV-grade synthetic fused silica
V	volt
Vac	volts, alternating current
Vdc	volts, direct current
W	watt
YAG	yttrium aluminum garnet
ZIF	zero insertion force