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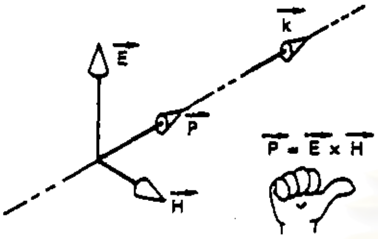
ภาคผนวก

Reference Guide

Light

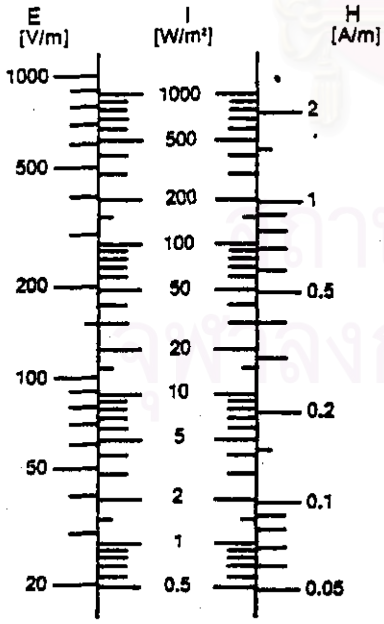
Light is a transverse electromagnetic wave. The electric and magnetic fields are perpendicular to each other and to the propagation vector *k*, as shown below.



Power density is given by **Poynting's vector**, *P*, the vector product of *E* and *H*. You can easily remember the directions if you "curl" *E* into *H* with the fingers of the right hand: your thumb points in the direction of propagation.

Intensity Nomogram

The nomogram below relates *E*, *H*, and *I* in vacuum. You may also use it for other area units, for example, [V/mm], [A/mm] and [W/mm²]. If you change the electrical units, remember to change the units of *I* by the product of the units of *E* and *H*: for example [V/m], [mA/m], [mW/m²] or [kV/m], [kA/m], [MW/m²].



Light intensity

Light intensity, *I* is measured in Watts/m², *E* in Volts/m, and *H* in Amperes/m. The equations relating *I* to *E* and *H* are quite analogous to OHMS LAW. For peak values:

$$E = \eta H, \quad H = \frac{E}{\eta}, \quad \eta = \frac{E}{H}$$

$$I = \frac{EH}{2}, \quad I = \frac{E^2}{2\eta}, \quad I = \frac{\eta H^2}{2}$$

$$E = \sqrt{2\eta I}, \quad H = \sqrt{\frac{2I}{\eta}}$$

$$\eta_0 = 377 \text{ ohms } (\Omega)$$

$$\eta = \frac{\eta_0}{n}$$

The quantity η_0 is the wave impedance of vacuum, and η is the wave impedance of a medium with refractive index *n*.

Wave quantity relationships

$$k = \frac{2\pi}{\lambda} = \frac{2\pi n}{\lambda_0} = \frac{2\pi n \nu}{c} = \frac{n\omega}{c}$$

$$\nu = \frac{c}{\lambda_0} = \frac{c}{n\lambda} = \frac{kc}{2\pi n} = \frac{\omega}{2\pi}$$

$$\lambda = \frac{c}{n\nu} = \frac{\lambda_0}{n} = \frac{2\pi}{k} = \frac{2\pi c}{n\omega}$$

k: wave vector [radians/m]
ν: frequency [Hertz]
ω: angular frequency [radians/sec]
λ: wavelength [m]
λ_0: wavelength in vacuum [m]
n: refractive index

Energy conversions

Wavenumber $(\nu)[\text{cm}^{-1}]$

$$= \frac{10^7}{\lambda_0}[\text{nm}]$$

Electron volts (eV) per photon

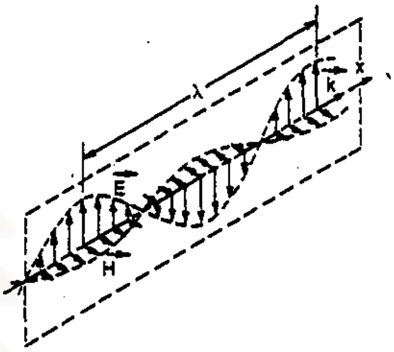
$$= \frac{1242}{\lambda_0}[\text{nm}]$$

Wavelength conversions

1 nm = 10 Angstroms(Å) = 10^{-9} m
= 10^{-7} cm = 10^{-3} micron

Plane polarized light

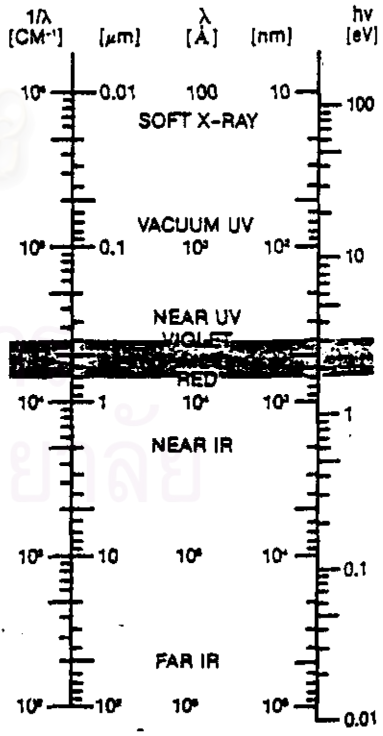
For **plane polarized light** the *E* and *H* fields remain in perpendicular planes parallel to the propagation vector *k* as shown below.



Both *E* and *H* oscillate in time and space as:

sin (ωt-kx)

The nomogram relates wavenumber, photon energy and wavelength.



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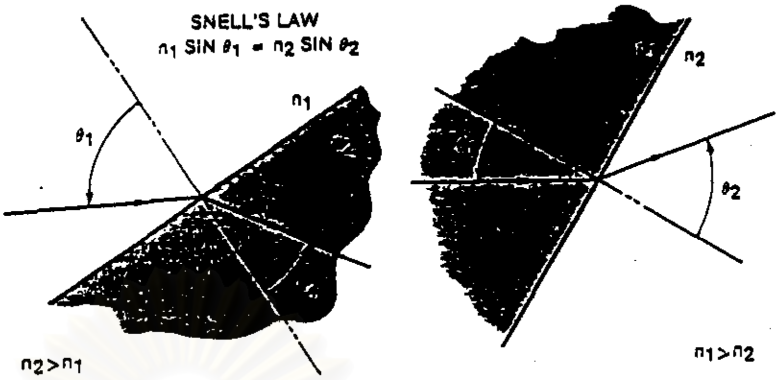
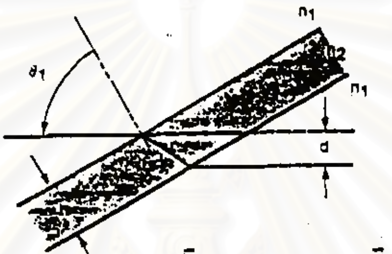
Snell's law

Snell's law tells how a light ray changes direction at a single surface between two media with different refractive indices. The angle of incidence, θ, is measured from the normal to the surface. A ray passing from low to high index is bent *toward* the normal: passing from high to low index it is bent *away from* the normal.

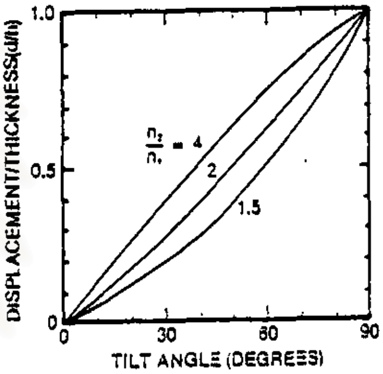


Displacement

A flat piece of glass can be used to *displace* a light ray laterally without changing its direction. The displacement varies with the angle of incidence; it is zero at normal incidence and equals the thickness of the flat at grazing incidence. The shape of the curve depends on the refractive index of the glass, as shown in the next column.

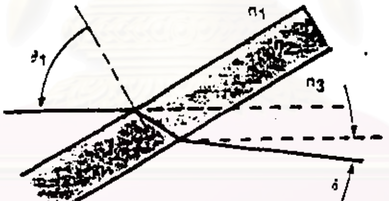


$$d = h\sin\theta_1\left[1-\frac{\cos\theta_1}{\sqrt{\left(\frac{n_2}{n_1}\right)^2-\sin^2\theta_1}}\right]$$



Deviation

Both displacement and deviation occur if the media on the two sides of the tilted flat are different - for example, a tilted window in a fish tank. The displacement is the same, but the angular deviation δ is given by the formula. Note that δ is independent of the index of the flat; it is the same as if a single boundary existed between media 1 and 3.



$$\delta = \theta_1 - \sin^{-1}\left(\frac{n_1}{n_3}\sin\theta_1\right)$$

$$\approx (n_3 - n_1)\tan\theta_1, \text{ if } n_3 \approx n_1$$

Example: The refractive index of air at STP is about 1.0003. The deviation of a light ray passing through a glass Brewster's angle window on a HeNe laser is then:

$\delta = (n_2 - n_1)\tan\theta$

At Brewster's angle, $\tan\theta = n_2$

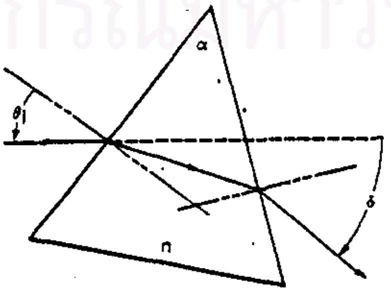
$\delta = (0.0003) \times 1.5 = 0.45$ mrad

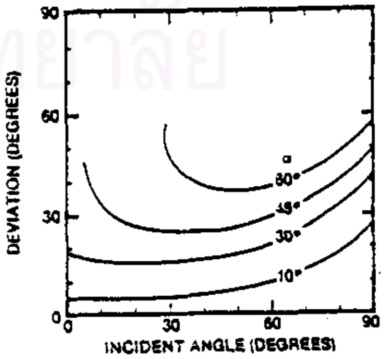
At 10,000 ft. altitude, air pressure is 2/3 that at sea level; the deviation is 0.30 mrad. This change may misalign the laser if its two windows are symmetrical rather than parallel.

Angular deviation of a prism

Angular deviation of a prism depends on the prism angle α, the refractive index, and the angle of incidence θ_i. Minimum deviation occurs when the ray within the prism is normal to the bisector of the prism angle. For small prism angles (optical wedges), the deviation is constant over a fairly wide range of angles around normal incidence. For such wedges the deviation is:

$\delta = (n - 1)\,\alpha$





ภาคผนวก ข.

Optical Fibers and Cables

		Operating Wavelength (nm)	Core dia. (µm)	Cladding dia. (µm)	Jacket dia. (µm)	Cable Sheath dia. (mm)	NA	Bandwidth (MHz-km)
Single Mode Fibers and Cables NEW	Fiber	488, 514	3.2	125	250	—	0.11	—
	Cable	488, 514	3.2	125	—	2.5	0.11	—
	Fiber	633	4	125	250	—	0.1	—
	Cable	633	4	125	—	2.5	0.1	—
	Fiber	850	5	125	250	—	0.1	—
	Cable	850	5	125	—	2.5	0.1	—
	Fiber	1060	6.7	125	250	—	0.11	—
	Cable	1060	6.7	125	—	2.5	0.11	—
	Fiber	1300, 1550	8	125	250	—	0.1	—
	Cable	1300, 1550	8	125	—	2.5	0.1	—
Polarization-Preserving Single Mode Fibers	Fiber	488, 514	1.5	125	250	—	0.1	—
	Fiber	633	2.75	125	250	—	0.1	—
	Fiber	850	3.25	125	250	—	0.1	—
	Fiber	1300, 1550	5.75	125	250	—	0.1	—
Multi-Mode Fibers and Cables NEW	Fiber	850, 1300	50	125	500	—	0.2	600
	Cable	850, 1300	50	125	900	2.9	0.2	400
	Fiber	850, 1300	62.5	125	500	—	.275	>200
	Cable	850, 1300	62.5	125	900	2.9	.275	200
	Fiber	850, 1300	100	140	500	—	0.3	300
	Cable	850, 1300	100	140	900	2.9	0.3	100
UV-NIR Transmissive Fiber Cable	Cable	—	200	250	1000	3.0	0.2	20
Hard Polymer Clad Fiber Cable	Cable	—	200	230	500	3.0	0.37	15

*For attenuation values at other wavelengths, call Newport.

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Dispersion (psec/km•nm)	Attenuation (dB/km)	-Model Numbers- Length (m)					
		10	20	50	100	200	500
425 @550 nm	<30	F-SA-10	F-SA-20	F-SA-50	F-SA-100	F-SA-200	F-SA-500
425 @550 nm	<30	FC-SA-10	FC-SA-20	FC-SA-50	FC-SA-100	FC-SA-200	FC-SA-500
285 @630 nm	<12	F-SV-10	F-SV-20	F-SV-50	F-SV-100	F-SV-200	F-SV-500
285 @630 nm	<12	FC-SV-10	FC-SV-20	FC-SV-50	FC-SV-100	FC-SV-200	FC-SV-500
120 @820 nm	<4	F-SF-10	F-SF-20	F-SF-50	F-SF-100	F-SF-200	F-SF-500
120 @820 nm	<4	FC-SF-10	FC-SF-20	FC-SF-50	FC-SF-100	FC-SF-200	FC-SF-500
38 @1060 nm	<2	F-SY-10	F-SY-20	F-SY-50	F-SY-100	F-SY-200	F-SY-500
38 @1060 nm	<2	FC-SY-10	FC-SY-20	FC-SY-50	FC-SY-100	FC-SY-200	FC-SY-500
3.5 @1285 nm	<0.5	F-SS-10	F-SS-20	F-SS-50	F-SS-100	F-SS-200	F-SS-500
3.5 @1285 nm	<0.5	FC-SS-10	FC-SS-20	FC-SS-50	FC-SS-100	FC-SS-200	FC-SS-500
—	<100	F-SPA-10	F-SPA-20	F-SPA-50	F-SPA-100	F-SPA-200	—
—	<12	F-SPV-10	F-SPV-20	F-SPV-50	F-SPV-100	F-SPV-200	F-SPV-500
—	<5	F-SPF-10	F-SPF-20	F-SPF-50	F-SPF-100	F-SPF-200	F-SPF-500
—	<2	F-SPS-10	F-SPS-20	F-SPS-50	F-SPS-100	F-SPS-200	F-SPS-500
—	2.4,1	F-MSD-10	F-MSD-20	F-MSD-50	F-MSD-100	F-MSD-200	F-MSD-500
—	5.4	FC-MSD-10	FC-MSD-20	FC-MSD-50	FC-MSD-100	FC-MSD-200	FC-MSD-500
—	3.1	F-MMD-10	F-MMD-20	F-MMD-50	F-MMD-100	F-MMD-200	F-MMD-500
—	5.3	FC-MMD-10	FC-MMD-20	FC-MMD-50	FC-MMD-100	FC-MMD-200	FC-MMD-500
—	4.5.2	F-MLD-10	F-MLD-20	F-MLD-50	F-MLD-100	F-MLD-200	F-MLD-500
—	4.5.2	FC-MLD-10	FC-MLD-20	FC-MLD-50	FC-MLD-100	FC-MLD-200	FC-MLD-500
—	9 @700 nm* 110 @300 nm	FC-2UV-10	FC-2UV-20	FC-2UV-50	FC-2UV-100	FC-2UV-200	—
—	6 @820 nm* 23 @514 nm	FC-HC-10	FC-HC-20	FC-HC-50	FC-HC-100	FC-HC-200	FC-HC-500

Newport

Available in April 1995

Newport.

Sensor Grade Fibers

Newport's sensor grade fibers include multimode and single-mode, bend-insensitive fibers, which have a high numerical aperture (NA) making them especially suited for applications requiring high coupling efficiencies or tight fiber bending radii. Also featured in this category are high-temperature, all-silica fibers, frequently used in medical and industrial fiber sensors. All sensor grade fibers are available in any length, and are stocked for immediate delivery.

Bend-Insensitive Fibers

Multimode, step-index sensor fibers are available in large core diameters of 110, 200, 400, 600 and 1000 µm. A high NA of 0.37 allows greater light coupling efficiencies, while also making these fiber optimal for applications requiring tight bending or coiling of fibers. Short-term (1 hour) bend radii for these fibers are 8, 15, 58, 87 and 121 mm, respectively. These fibers feature a pure silica core, enhancing their optical properties, and a bonded hard polymer cladding for additional strength and fatigue resistance. The operating temperature of bare sensor grade fibers ranges from -65°C to +125°C. Cabled fibers have a 900 µm outer jacket, surrounded by a layer of Aramid Yarn for added strength and protection. An outer polyurethane cable jacket, measuring 3 mm in diameter, provides additional environmental protection. Sensor grade cabled fibers have an operating temperature of -40°C to +85°C, and are identified by the -C suffix in their model number. Typical applications for these fibers include medical, industrial and avionics sensors and instruments.

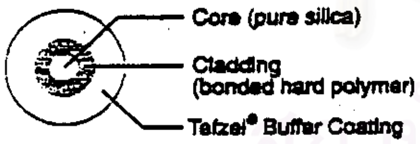
Single-mode sensor fibers, available with 820 and 1310 nm cutoff wavelengths, feature a high NA of 0.15, making them suitable for tightly wound fiber optic spools. At 1310 nm, their maximum bend induced attenuation is only 0.05 dB, due to 100 fiber turns on a 10 mm mandrel. Both 80 and 125 µm cladding diameters are available, with bend insensitivity increasing with smaller fiber diameter. These fibers are commonly used in fiber optic gyroscope assemblies or in fiber payout systems.

High-Temperature, All-Silica Fibers

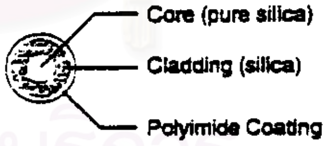
These high OH⁻, all-silica, fibers feature Spectran's Pyrocoat™ polyimide buffer coating. This coating extends the fibers' upper operating range to +375°C and increases its chemical and abrasion resistance, enabling its use in harsher environments. The fibers' pure silica core ensures enhanced optical properties, while the all-silica core/cladding combination decreases the fibers' recovery time after undergoing exposure to gamma radiation.

These multimode fibers are offered with 50, 100 and 200 µm core diameters, allowing short-term bend radii of 6, 11 and 22 mm, respectively. Typical applications for these fibers include medical and industrial sensors, spectroscopy and radiation analysis. High-temperature fibers are identified by the -T suffix in their model number.

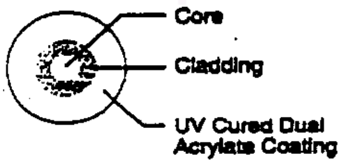
Multimode Sensor Fiber Construction



High-Temperature Sensor Fiber Construction



Single-Mode Sensor Fiber Construction



Newport optical fibers are available in any length and are stocked for immediate delivery.

Tefzel is a registered trademark of Dupont.

Sensor Grade Fibers

Multimode

Model	Operating Wavelength (nm)	Index Profile	NA	Core Diameter (µm)	Cladding Diameter (µm)	Coating Diameter (µm)	Min. Bend Radius 60 min./20 yrs (mm)	Bandwidth (MHz-km)	Remarks
F-MBA	500-1100	Step	0.37	110 ± 5	125 +1/-5	250 +50/-0	8/13	17	
F-MBA-C	500-1100	Step	0.37	110 ± 5	125 +1/-5	250 +50/-0	-	17	Cabled Fiber
F-MBB	500-1100	Step	0.37	200 ± 5	230 +0/-10	500 ± 50	15/24	17	
F-MBB-C*	500-1100	Step	0.37	200 ± 5	230 +0/-10	500 ± 50	-	17	Cabled Fiber
F-MBC	500-1100	Step	0.37	400 ± 10	430 +5/-10	730 ± 50	58/96	13	
F-MBD	500-1100	Step	0.37	600 ± 10	630 ± 10	1040 ± 40	87/142	9	
F-MBE	500-1100	Step	0.37	1000 ± 15	1035 ± 15	1400 ± 50	121/200	-	
F-MCA-T	250-1100	Step	0.22	50 ± 2	55 ± 2	68 ± 2	6/10	25	Temperature Insensitive
F-MCB-T	250-1100	Step	0.22	100 ± 2	110 ± 2	125 ± 2	11/19	25	Temperature Insensitive
F-MCC-T	250-1100	Step	0.22	200 ± 3	220 ± 3	240 ± 3	22/37	25	Temperature Insensitive

* Previously FC-2UV

Single-mode

Model	Operating Wavelength (nm)	Index Profile	NA	Mode Field Diameter (µm)	Cladding Diameter (µm)	Coating Diameter (µm)	Maximum Attenuation (dB/km)	Cut-Off Wavelength (nm)	Max. Added Attenuation due to 100 turns on 10 mm mandrel (dB)
F-SBA	820	Step	0.17	4.0	125 ± 2	245 ± 15	5.0	770 ± 30	0.05
F-SBB	820	Step	0.16	4.2	80 ± 2	135 ± 5	5.0	770 ± 30	0.05
F-SBC	1310	Step	0.17	6.3	125 ± 2	245 ± 15	1.0	1250 ± 50	0.05
F-SBD	1310	Step	0.17	6.3	80 ± 2	135 ± 5	1.0	1250 ± 50	0.05

Multimode Sensor Fiber Transmission

λ (nm)		dB/km
633	HeNe	8
820	LED	6
1064	Nd:YAG	12
1300	Diode Laser	30

High-Temperature Sensor Fiber Transmission

λ (nm)		dB/m
248	Krypton Fluoride	1.1
308	Excimer	0.27
488	Argon Blue	0.013
515	Argon Green	0.014
532	KTP	0.013
647	Krypton Red	0.008
850	LED	0.013

-C = Cabled

-T = temp. insensitive

-H = hermetic.

Newport Corporation, Irvine, California, has been certified compliant with ISO 9002 by the British Standards Institution. Certificate number FM 27207.

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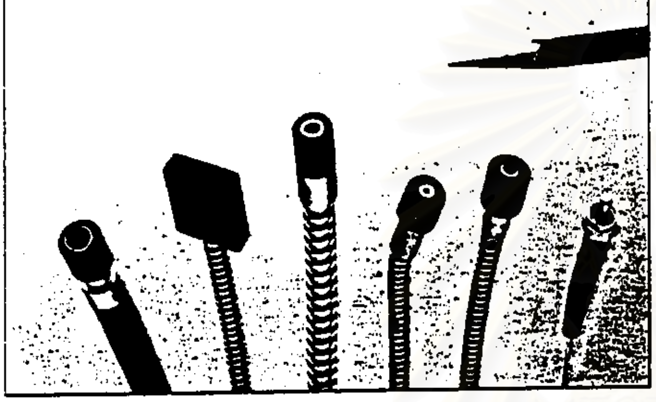
ORIEL PRODUCT LINE OVERVIEW



Various types of Fiber Optics

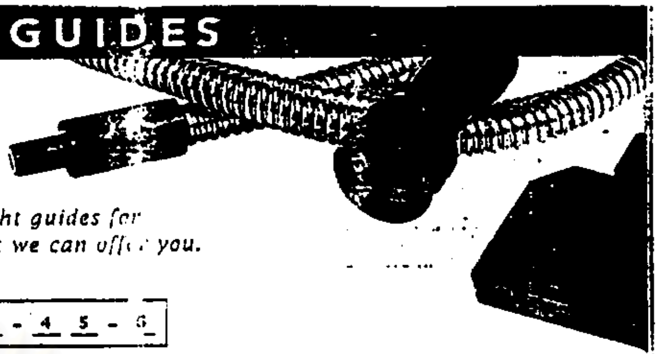
Table 1 Summary of Fiber Types

Type	Spectral Range (nm)	Diameter (mm)	Range of Lengths (m)	Principal Advantages	Pages
Glass Bundles*	400 - 1500	1.6 and 3.2	0.61 - 1.83	Low cost. large acceptance angle. Available in rectangular-circular, bifurcated and trifurcated models.	8-12 to 8-16
Standard Grade Fused Silica Bundles*	280 - 2200	1.6 and 3.2	0.61 - 0.92	Transmission of much of UV	8-12 to 8-14
High Grade Fused Silica Bundles*	240 - 2200	1.6 and 3.2	0.61 - 0.92	Better transmittance through the UV and VIS. Rectangular to circular and bifurcated models available. Special fluorescence probe available.	8-12 to 8-16
Liquid Light Guides**	270 - 750	3 and 5	1, 2	Large acceptance angle and core size.	8-17
UV-VIS Single Fibers	200 - 1000	0.2, 0.4, 0.6, 0.8, and 1	1 - 200	High transmittance of UV-NIR. Available with SMA connectors. High power handling capability	8-18 to 8-19
VIS-NIR Single Fibers	250 - 2000	0.2, 0.4, 0.6, 0.8, and 1	1 - 200	Excellent transmittance. Available with SMA connectors	8-18 to 8-19

*** Custom fiber bundles are available on request.**

**** 8 mm core diameters and longer lengths available on special order.**

LIGHT GUIDES



How do you get light exactly where you need it? With the right light guide, and Moritex will help you determine which one that is. We have standard light guides ranging from straight light guides to the more exotic. In addition, Moritex is happy to work with you to develop specialty light guides for OEM applications. In this section you will see exactly what we can offer you.

LIGHT GUIDE PART NUMBER KEY

M 1 2 3 - 4 5 - 6

1	LIGHT GUIDE TYPE
CODE	DESCRIPTION
S	Straight
W	Bifurcated
3	Trifurcated
4	Quad
R	Ring Light
K	Slit
P	Plate

2	FIBER TYPE
CODE	DESCRIPTION
G	Glass
P	Plastic
S	Silica

3	DEFINING FEATURE
GUIDE	FEATURE
Straight	bundle diameter
Tri	bundle diameter
Quad	bundle diameter
Ring	inner diameter
Slit	fiber line length
Plate	dimension square of lighted plate

4	LENGTH
shown in millimeters (mm)	

5	TUBING TYPES
CODE	DESCRIPTION
R	interlocking
S	stainless steel flexible
SR	stainless steel interlocking
V	stainless steel flexible PVC

6	SPECIAL FUNCTION
CODE	DESCRIPTION
L	L-shaped bifurcation
HR	heat resistant
RM	random configuration
SD	small diameter
UV	UV transmittable

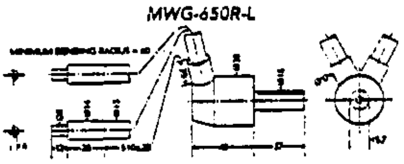
STRAIGHT LIGHT GUIDES

(SEE CHART BELOW)

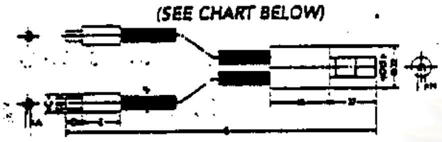
Straight light guides come in a variety of lengths. Some are available with locking outer tubing, others are completely flexible. The following chart will outline the features of these light guides.

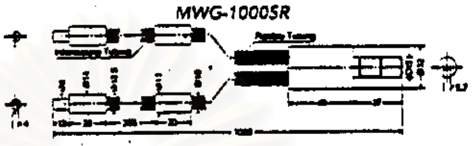
PART NUMBER	OUTPUT FERRULE DIAMETER		OUTPUT FERRULE LENGTH		LENGTH	TUBE DIAM.	BUNDLE DIAM.	MINIMUM BENDING RADIUS
	A	B	C	b	E	F	G	
MSG4-500R	8	14	12	28	500	12.5	4	60
MSG4-1100S	8	14	12	28	1100	10	4	30
MSG4-2200S	3	14	12	28	2200	10	4	30
MSP4-1100S	8	14	12	28	1100	10	4	30
MSG4-1100S-RM	8	14	12	28	1100	10	4	30
MSG4-2200S-RM	8	14	12	28	2200	10	4	30
MSG4-1100S-HR	8	14	12	28	1100	10	4	30
MSG5-1100S-HR	8	14	12	28	1100	10	5	30
MSG5-2200S-HR	8	14	12	28	2200	10	5	30
MSG6-1100S	8	14	12	28	1100	10	6	30
MSG6-2200S	8	14	12	28	2200	10	6	30
MSG6-1100S-RM	8	14	12	28	1100	10	6	30
MSG6-2200S-RM	8	14	12	28	2200	10	6	30
MSG8-1100S	14	20	40	20	1100	16	8	50
MSG8-2200S	14	20	40	20	2200	16	8	50
MSG8-1100S-HR	14	20	40	20	1100	16	8	50
MSG8-2200S-HR	14	20	40	20	2200	16	8	50
MSG10-1100S	14	20	40	20	1100	16	10	60
MSG10-2200S	14	20	40	20	2200	16	10	60
MSG3-1100S-SD	5	8	30	15	1100	7	3	25
MSS5-1000S-UV	8	14	12	28	1000	10	5	50

BIFURCATED LIGHT GUIDES



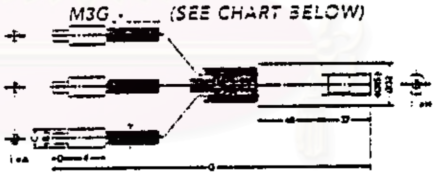
Bifurcated light guides allow one light source to provide two points of light. This type of light guide is ideal for applications requiring oblique lighting as well as applications which would benefit from having one light source illuminate two objects.



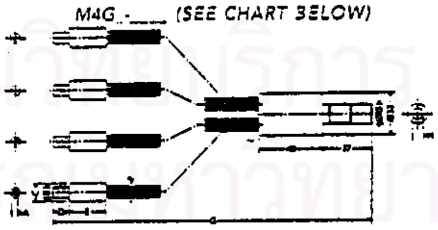


PART NUMBER	OUTPUT FERRULE DIAMETER A	B	C	OUTPUT FERRULE LENGTH D	E	TUBE DIAM. F	LENGTH G	BUNDLE DIAM. H	MINIMUM BENDING RADIUS
MWG-500R	4	8	14	12	28	12.5	500	5.7	60
MWG-1000S	4	8	14	12	28	10	1000	5.7	30
MWG-2000S	4	8	14	12	28	10	2000	5.7	30
MWG-1000V	4	8	14	12	28	11.5	1000	5.7	40
MWP-1000V	4	8	14	12	28	11.5	1000	5.7	40
MWG-1000SR	4	8	14	12	28	12.5	1000	5.7	60/30
MWG-1000S-SD	3	5	8	30	15	7	1000	4.25	25
MWG5-1000S-HR	5	8	14	12	28	10	1000	7	30
MWG5-2000S-HR	5	8	14	12	28	10	2000	7	30
MWG7-1000S	7	14	20	40	20	13	1000	10	50

MULTIFURCATED LIGHT GUIDES



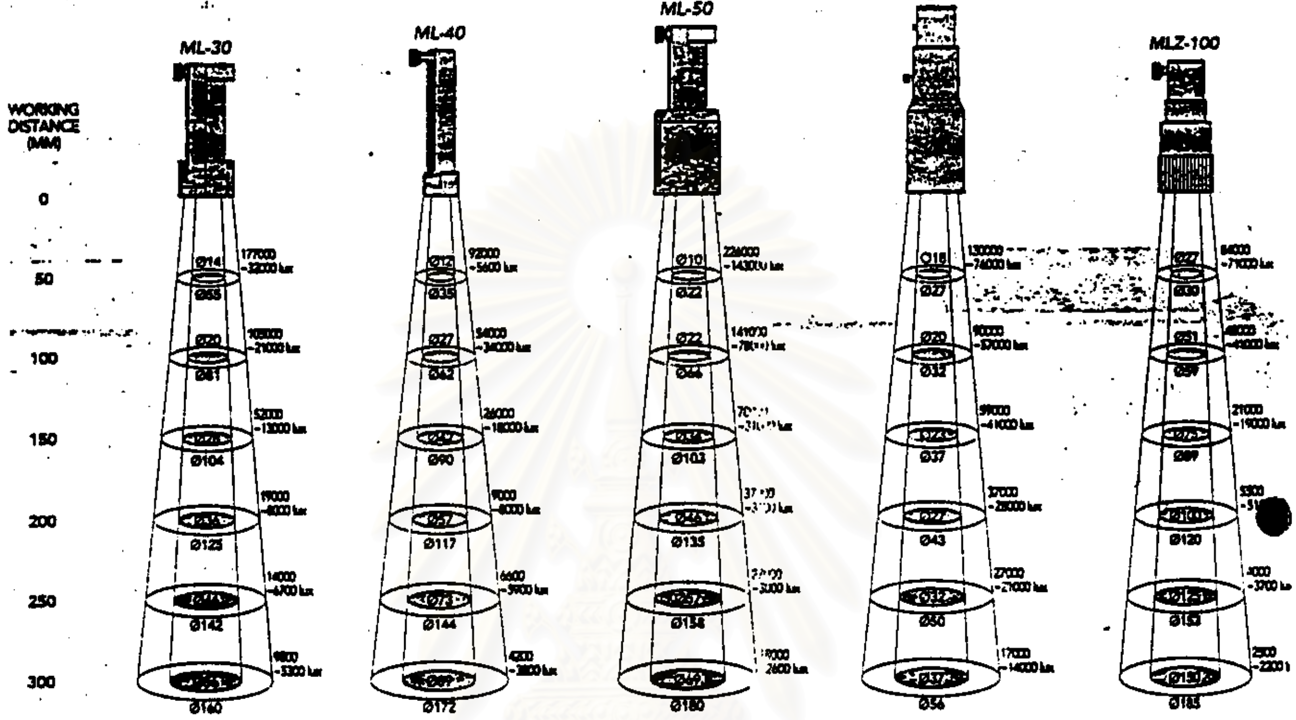
A multifurcated light guide has three or four terminating fiber bundles. These light guides allow you to use one light source to either illuminate one subject from many angles, or to illuminate multiple subjects simultaneously with a single light source.



PART NUMBER	OUTPUT FERRULE DIAMETER A	B	C	OUTPUT FERRULE LENGTH D	E	TUBE DIAM. F	LENGTH G	BUNDLE DIAM. H	MINIMUM BENDING RADIUS
M3G4-1000S	4	8	14	12	28	10	1000	6.9	30
M3G4-2000S	4	8	14	12	28	10	2000	6.9	30
M4G4-1000S	4	8	14	12	28	10	1000	8	30
M4G4-2000S	4	8	14	12	28	10	2000	8	30
M3G3-1000S-SD	3	5	8	30	15	7	1000	5.2	25
M3G3-2000S-SD	3	5	8	30	15	7	2000	5.2	25
M4G3-1000S-SD	3	5	8	30	15	7	1000	6	25
M4G3-2000S-SD	3	5	8	30	15	7	2000	6	25

LIGHT GUIDE LENS CHARACTERISTICS

Each lens is capable of providing different fields of view and light intensities as the distance between the lens and subject change. The following chart shows the characteristics of each lens over a range of working distances from 0 to 300mm.



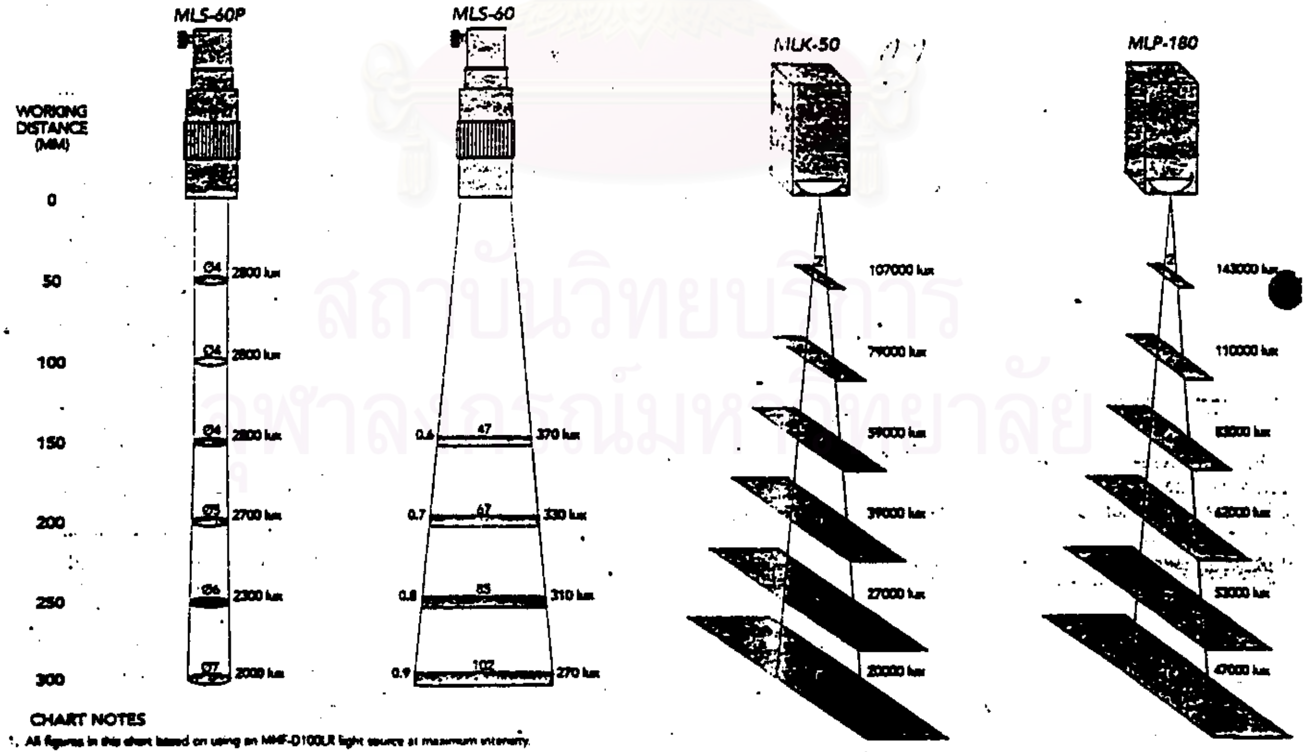


CHART NOTES

1. All figures in this chart based on using an MHF-D100LR light source at maximum intensity.
2. An MSG4-1100S was used during the testing of ML-30, ML-40, ML-50, ML-70, MLZ-100 and MLS-60/60P.
3. An MKG-50-1500S was used during the testing of MLK-50.
4. An MKP-180-1500S was used during the testing of MLP-180.

OPTIONAL LIGHT GUIDE FEATURES

HEAT RESISTANT LIGHT GUIDES The normal heat resistance ranges for multi-component glass fiber, quartz fiber, and plastic fiber light guides are -40°C to 180°C, -40°C to 180°C, and -40°C to 80°C respectively. However, on request, Moritex can manufacture light guides with increased resistance to cold and heat.

MOISTURE RESISTANT LIGHT GUIDES Standard Moritex light guides are not manufactured to withstand high humidity. At 130°C, 100% humidity, 2kg/cm pressure, a light guide will have a light capacity of less than 5% after 20 hours. As an option, Moritex can manufacture light guides using autoclaveable fibers. Under similar conditions, these light guides will have a light capacity over 90% after 100 hours.

HEAVY DUTY LIGHT GUIDES For extremely demanding applications, Moritex has designed optional heavy duty light guides. The specially-designed internal structure and fiber coating of these light guides help improve the light guides' durability by more than 10 times that of a standard light guide.

CHEMICAL RESISTANT LIGHT GUIDES For applications where chemical resistance is important, Moritex can provide light guides with special structures and components which increase chemical resistance.

EXTENDED LENGTH LIGHT GUIDES Quartz fiber should be specified for light guides over 5m long.

GENERAL LIGHT GUIDE CHARACTERISTICS

OPTICAL FIBER DATA

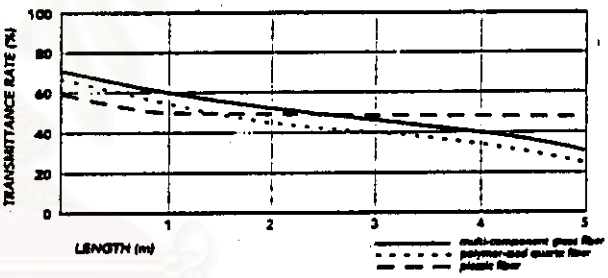
Material	Multi-Component Glass Fiber	Plastic Fiber		Quartz Fiber
Fiber Diameter	¹50μ	250μ, 500μ, 750μ, 1000μ, 2000μ		220μ
Core Diameter	45μ	3-5μ less than fiber diameter		200μ
Entrance Angle	~70° (30°)	~60°		~25°
Heat Resistance	Standard 180°C Special Order 300°C	Standard	80°C	Standard 180°C Special Order 300°C
Durability	▲	●		■
Visible Light Transmittance	▲	▲		●

● Excellent ▲ Satisfactory ■ Not Recommended

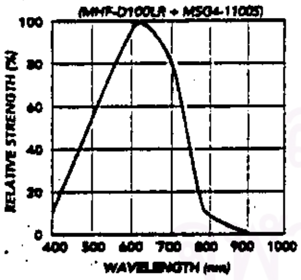
1 Fiber bundle data. (Raw fiber data not available.)

2 Please consult Moritex for more details.

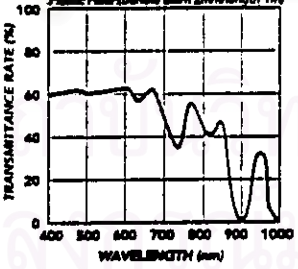
LIGHT GUIDE LENGTH AND TRANSMITTANCE RATE



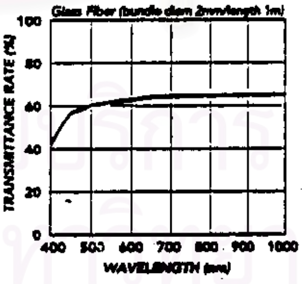
SPECTROSCOPIC FEATURES
(LIGHT GUIDE WITH HALOGEN LIGHT SOURCE)
(MHF-D100LR + MSG4-1100S)



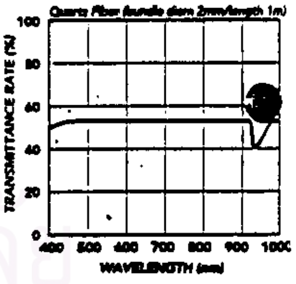
LIGHT GUIDE SPECTROSCOPIC TRANSMITTANCE A
Plastic Fiber (bundle diam 2mm/length 1m)



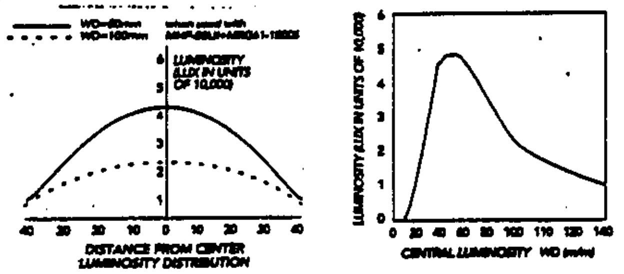
LIGHT GUIDE SPECTROSCOPIC TRANSMITTANCE B
Glass Fiber (bundle diam 2mm/length 1m)



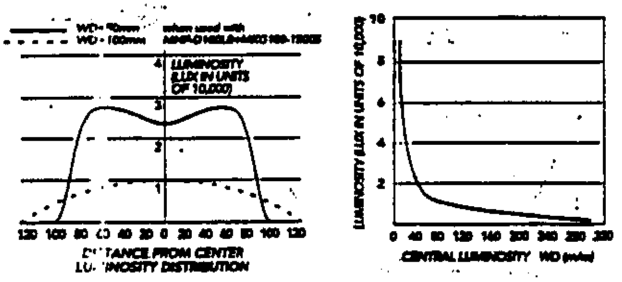
LIGHT GUIDE SPECTROSCOPIC TRANSMITTANCE C
Quartz Fiber (bundle diam 2mm/length 1m)



RING LIGHT GUIDE LUMINOSITY DISTRIBUTION EXAMPLE



LINE LIGHT GUIDE LUMINOSITY DISTRIBUTION EXAMPLE



ภาคผนวก ง.

Concave Fused Silica Lenses

Newport concave fused silica lenses are manufactured to rigid optical and mechanical standards from high purity Dynasil 1100 silica. The superior transparency of Dynasil 1100 lenses recommends their use with excimer lasers to 193 nm and with infrared sources to 2.7 microns. All lens surfaces are polished to optical test plate standards to eliminate wavefront irregularities. Tight surface polish tolerances reduce stray light and eliminate unwanted diffraction effects. As with other Newport optics, concave fused silica lenses are manufactured to standardized focal lengths and diameters. Optics mount quickly and easily into Newport hardware without the added expense and complexity of adapter rings. Due to the wide transparency range of fused silica, lenses are stocked uncoated with a variety of anti-reflective coatings available as options. For further information on coatings please contact Newport.

Optical Performance: Usable range: 185-2700 nm.

Cleaning: See page N-30.

Safe Energy Level: 5 J/cm^2 10 ns pulse, 5 MW/cm^2 uncoated.

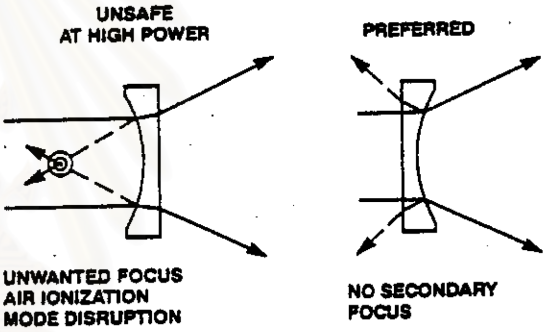
Application Notes

The purity and durability of fused silica are desirable characteristics in damage resistant optics. However, high power laser beams make certain requirements on optical layout that contradict traditional rules. One such example is a high power Galilean beam expander made from single fused silica lenses. As in the Keplerian expander, the expansion ratio is the ratio of output to input focal lengths. F_{OUT}/F_{IN}. The lenses are separated by the difference of focal lengths F_{OUT}-F_{IN}. Plano-convex and plano-concave lenses are chosen to reduce aberration. Standard procedure would require the curved surfaces face incoming and outgoing parallel rays.

5x GALILEAN EXPANDER

With high power lasers, a beam incident on a concave surface will be focused to a point outside the instrument. Air heating and ionization at the unwanted focal point are possible with attendant mode disruption or material damage.

In the above 5X expander, the **SPC034** input lens has a radius, R, of -22.95 mm. Due to Fresnel reflection, an uncoated concave surface will reflect ≈3.5% and act as a mirror of focal length F, where F = R/2 = 11.48 mm.



Due to the concave surface, the incident beam waist radius, r, will be focused to a new waist radius, r_0:

$$r_0 = \lambda F/\pi r$$

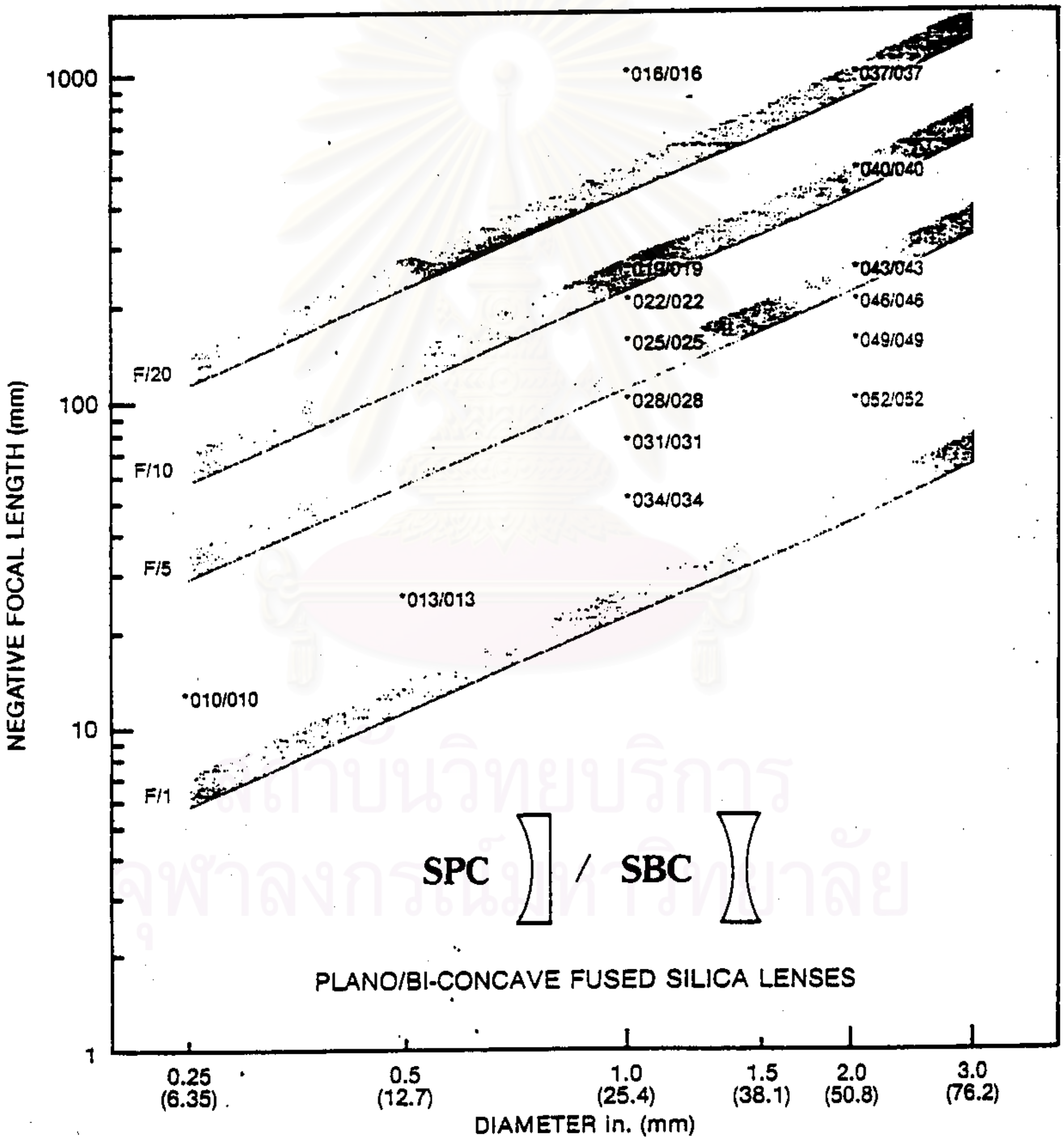
In the above, λ is the laser wavelength and F is the focal length. As an example, a high power pulsed Nd:YAG (λ = 1064 nm = 1.064 x 10^{-3} mm) laser might deliver 1 J/cm^2 in a 10 ns, 100 MW/cm^2 pulse. A beam waist of r = 5 mm would be typical when operating in the TEM$_{00}$ mode. From the above, the focused spot has a radius r_0 of 7.7 x 10^{-4} mm (.77 microns). The power density has been increased by the ratio of the radii squared, or ≈60000! If 100 MW/cm^2 are incident on the input lens, 3.5%, or 3.5 MW/cm^2, would be reflected. Refocusing would yield power densities of 2.1 x 10^{11} W/cm^2, well above the air ionization threshold of 10^{11} W/cm^2. Sparking and mode disruption would occur in this application.

To avoid this problem, the input lens should be reversed so that no concave surface faces a parallel beam. Safe operation of the expander is assured at the expense of a small increase in aberration.

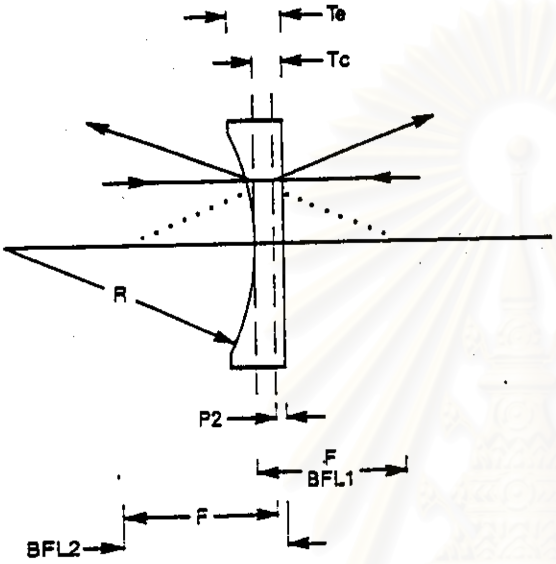
Concave Fused Silica Lenses

Lens Selection Guide

Newport offers plano-concave and bi-concave fused silica lenses in the standardized focal lengths and diameters displayed below. The selection guide may be used to rapidly determine suitable lenses for an application based on diameter, focal length and f-number. The first set of three digits refers to available plano-concave lenses, the second to bi-concave lenses. A full part number may be obtained by appending the three digit number from the selection guide to SPC for a plano-concave lens and SBC for a bi-concave lens. For example, a 1 inch (25.4 mm) diameter, f/5 lens is desired. The nearest plano-concave part number would be SPC+025=SPC025. An equivalent bi-concave lens is SBC+025=SBC025.



Plano-Concave Fused Silica Lenses



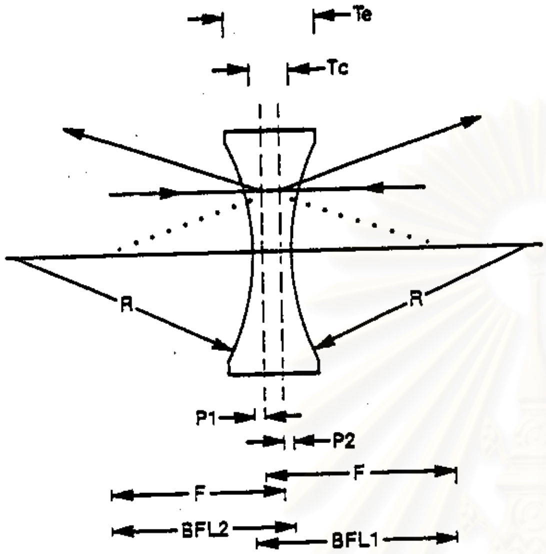
Specifications:

F (Focal Length):	±1%
Scratch/Dig:	40-20
R:	Nominal value to achieve focal length
Tc:	±0.1 mm/ ±.004 in.
Te:	Nominal value only
Diameter:	+0 -.1 mm/ -0 -.004 in.
Clear Aperture:	>90% of diameter

For quick, easy mounting with a minimum of hardware, Newport optics are manufactured to a standardized series of diameters. All the lenses on this page mount into a Newport LCM-2 lens holder. Please see page D-30 for more information.

Part Code	Dia. (mm)	F (mm)	f/	R (mm)	Tc (mm)	Te (mm)	BFL1 (mm)	BFL2 (mm)	P1 (mm)	P2 (mm)
SPC010	6.35	-12.50	-1.9	-5.73	2.50	3.26	-12.50	-14.21	0.00	-1.71
SPC013	12.70	-25.00	-1.9	-11.47	2.50	4.02	-25.00	-26.71	0.00	-1.71
SPC016	25.40	-1000.00	-39.3	-459.19	2.50	2.64	-1000.00	-1001.71	0.00	-1.71
SPC019	25.40	-250.00	-9.8	-114.75	2.50	3.07	-250.00	-251.71	0.00	-1.71
SPC022	25.40	-200.00	-7.8	-91.99	2.50	3.21	-200.00	-201.71	0.00	-1.71
SPC025	25.40	-150.00	-5.9	-69.04	2.50	3.45	-150.00	-151.70	0.00	-1.71
SPC028	25.40	-100.00	-3.9	-45.90	2.50	3.94	-100.00	-101.71	0.00	-1.71
SPC031	25.40	-75.00	-2.9	-34.42	2.50	4.45	-75.00	-76.71	0.00	-1.71
SPC034	25.40	-50.00	-1.9	-22.95	2.50	5.54	-50.00	-51.71	0.00	-1.71
SPC037	50.80	-1000.00	-19.6	-459.19	2.50	3.07	-1000.00	-1001.71	0.00	-1.71
SPC040	50.80	-500.00	-9.8	-229.69	2.50	3.64	-500.00	-501.71	0.00	-1.71
SPC043	50.80	-250.00	-4.9	-114.75	2.50	4.80	-250.00	-251.71	0.00	-1.71
SPC046	50.80	-200.00	-3.9	-91.99	2.50	5.39	-200.00	-201.71	0.00	-1.71
SPC049	50.80	-150.00	-2.9	-69.04	2.50	6.40	-150.00	-151.71	0.00	-1.71
SPC052	50.80	-100.00	-1.9	-45.90	2.50	8.59	-100.00	-101.71	0.00	-1.71

Bi-Concave Fused Silica Lenses



Specifications:

F (Focal Length):	±1%
Scratch/Dig:	40-20
R:	Nominal value to achieve focal length
Tc:	±0.1 mm/ ±.004 in.
Te:	Nominal value only
Diameter:	+0 -.1 mm/ +0 -.004 in.
Clear Aperture :	>90% of diameter

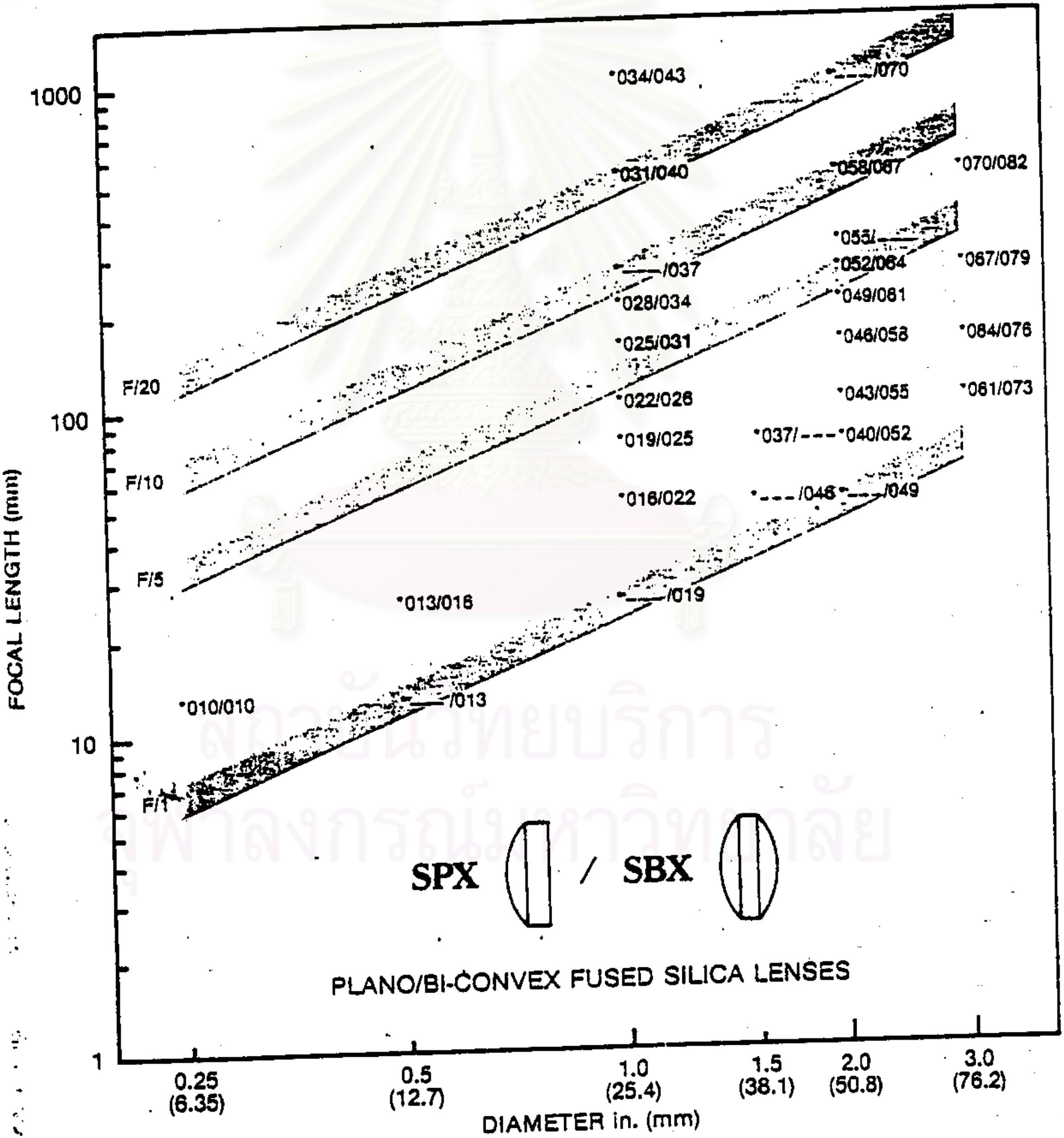
The diameter of any stock lens can be easily reduced to meet your specifications. Please contact a Newport applications engineer for information.

Part Code	Dia. (mm)	F (mm)	f/	R (mm)	Tc (mm)	Te (mm)	BFL1 (mm)	BFL2 (mm)	P1 (mm)	P2 (mm)
SBC010	6.35	-12.50	-1.9	-11.85	2.50	3.19	-13.32	-13.32	0.82	-.82
SBC013	12.70	-25.00	-1.9	-23.33	2.50	3.92	-25.84	-25.84	0.84	-.84
SBC016	25.40	-1000.00	-39.3	-918.37	2.50	2.64	-1000.85	-1000.85	0.85	-.85
SBC019	25.40	-250.00	-9.8	-229.69	2.50	3.06	-250.85	-250.85	0.85	-.85
SBC022	25.40	-200.00	-7.8	-183.99	2.50	3.21	-200.85	-200.85	0.85	-.85
SBC025	25.40	-150.00	-5.9	-138.09	2.50	3.44	-150.85	-150.85	0.85	-.85
SBC028	25.40	-100.00	-3.9	-91.99	2.50	3.92	-100.85	-100.85	0.85	-.85
SBC031	25.40	-75.00	-2.9	-69.04	2.50	4.40	-75.85	-75.85	0.85	-.85
SBC034	25.40	-50.00	-1.9	-46.29	2.50	5.36	-50.85	-50.85	0.85	-.85
SBC037	50.80	-1000.00	-19.6	-918.37	2.50	3.06	-1000.85	-1000.85	0.85	-.85
SBC040	50.80	-500.00	-9.8	-459.19	2.50	3.63	-500.85	-500.85	0.85	-.85
SBC043	50.80	-250.00	-4.9	-229.69	2.50	4.77	-250.85	-250.85	0.85	-.85
SBC046	50.80	-200.00	-3.9	-183.99	2.50	5.35	-200.85	-200.85	0.85	-.85
SBC049	50.80	-150.00	-2.9	-138.09	2.50	6.31	-150.85	-150.85	0.85	-.85
SBC052	50.80	-100.00	-1.9	-91.99	2.50	8.25	-100.85	-100.85	0.85	-.85

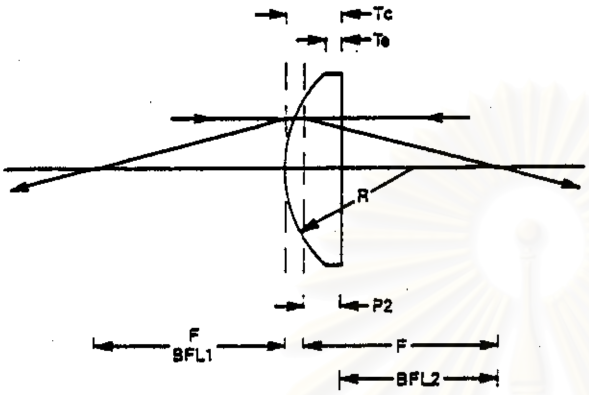
Convex Fused Silica Lenses

Lens Selection Guide

Newport offers plano-convex and bi-convex fused silica lenses in the standardized focal lengths and diameters displayed below. The selection guide may be used to rapidly determine suitable lenses for an application based on diameter, focal length and f-number. The first set of three digits refers to available plano-convex lenses, the second to bi-convex lenses. Dashes (---) indicate a lens is unavailable. A full part number may be obtained by appending the three digit number from the selection guide to SPX for a plano-convex lens and SBX for a bi-convex lens. For example, a 2 inch (50.8 mm) diameter, 100 mm focal length lens is desired. The plano-convex part number would be SPX+043=SPX043. An equivalent bi-convex lens is SBX+055=SBX055.



Plano-Convex Fused Silica Lenses



Specifications:

F (Focal Length):	±1%
Scratch/Dig:	40-20
R:	Nominal value to achieve focal length
Tc:	±0.1 mm / ±.004 in.
Te:	Nominal value only
Diameter:	+0 -.1 mm/ +0 -.004 in.
Clear Aperture:	>90% of diameter

In order to take full advantage of the transparency of fused silica, Newport offers these lenses uncoated. AR coatings may be applied at a nominal charge. Please contact Newport for information.

Part Code	Dia. (mm)	F (mm)	f/	R (mm)	Tc (mm)	Te (mm)	BFL1 (mm)	BFL2 (mm)	P1 (mm)	P2 (mm)
SPX010	6.35	12.70	2.0	5.82	3.94	3.00	12.70	9.99	0.00	-2.70
SPX013	12.70	25.40	2.0	11.65	4.88	3.00	25.40	22.05	0.00	-3.34
SPX016	25.40	50.20	1.9	23.04	6.81	3.00	50.20	45.52	0.00	-4.67
SPX019	25.40	75.60	2.9	34.70	5.40	3.00	75.60	71.89	0.00	-3.70
SPX022	25.40	100.00	3.9	45.76	4.79	3.00	100.00	96.71	0.00	-3.28
SPX025	25.40	150.00	5.9	68.69	4.18	3.00	150.00	147.13	0.00	-2.86
SPX028	25.40	200.00	7.8	91.80	3.88	3.00	200.00	197.33	0.00	-2.66
SPX031	25.40	500.00	19.6	229.50	3.35	3.00	500.00	497.70	0.00	-2.29
SPX034	25.40	1000.00	39.3	458.46	3.17	3.00	1000.00	997.82	0.00	-2.17
SPX037	38.10	75.60	1.9	34.70	8.69	3.00	75.60	69.63	0.00	-5.96
SPX040	50.80	75.60	1.4	34.70	14.05	3.00	75.60	65.96	0.00	-9.63
SPX043	50.80	100.00	1.9	45.76	10.66	3.00	100.00	92.68	0.00	-7.31
SPX046	50.80	150.00	2.9	68.69	7.85	3.00	150.00	144.61	0.00	-5.38
SPX049	50.80	200.00	3.9	91.80	6.58	3.00	200.00	195.48	0.00	-4.51
SPX052	50.80	250.00	4.9	114.75	5.84	3.00	250.00	245.99	0.00	-4.00
SPX055	50.80	300.00	5.9	137.70	5.36	3.00	300.00	296.32	0.00	-3.67
SPX058	50.80	500.00	9.8	229.50	4.41	3.00	500.00	496.97	0.00	-3.02
SPX061	76.20	100.00	1.3	45.76	23.30	3.00	100.00	84.02	0.00	-15.97
SPX064	76.20	150.00	1.9	68.69	14.50	3.00	150.00	140.06	0.00	-9.94
SPX067	76.20	250.00	3.2	114.75	9.51	3.00	250.00	243.48	0.00	-6.51
SPX070	76.20	500.00	6.5	229.50	6.18	3.00	500.00	495.76	0.00	-4.23

BK-7 Glass Lenses

PLANO-CONVEX

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
KPX076	25.40	X	X
KPX079	38.10	X	X
KPX082	50.20	X	X
KPX085	62.90	X	
KPX088	75.60	X	X
KPX091	88.30	X	
KPX094	100.00	X	X
KPX097	125.00	X	
KPX100	150.00	X	X
KPX103	175.00	X	
KPX106	200.00	X	X
KPX109	250.00	X	
KPX112	300.00	X	X
KPX115	400.00	X	
KPX118	500.00	X	X
KPX121	750.00	X	
KPX124	1000.00	X	X

BI-CONVEX

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
KBX043	19.00	X	
KBX046	25.40	X	X
KBX049	38.10	X	
KBX052	50.20	X	X
KBX055	62.90	X	
KBX058	75.60	X	X
KBX061	88.30	X	
KBX064	100.00	X	X
KBX067	125.00	X	
KBX070	150.00	X	
KBX073	175.00	X	
KBX076	200.00	X	X
KBX079	250.00	X	
KBX082	500.00	X	X
KBX088	1000.00	X	

PLANO-CONCAVE

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
KPC028	-200.00	X	
KPC031	-150.00	X	X
KPC034	-100.00	X	
KPC037	-75.00	X	
KPC040	-50.00	X	X
KPC043	-25.00	X	X

BI-CONCAVE

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
KBC031	-200.00	X	
KBC034	-150.00	X	
KBC037	-100.00	X	
KBC040	-75.00	X	
KBC043	-30.00	X	
KBC046	-25.00	X	X

Fused Silica Lenses

PLANO-CONVEX

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
SPX016	50.20	X	X
SPX019	75.60	X	X
SPX022	100.00	X	X
SPX025	150.00	X	X
SPX028	200.00	X	X
SPX031	500.00	X	X
SPX034	1000.00	X	X

BI-CONVEX

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
SBX019	25.40	X	X
SBX022	30.20	X	X
SBX025	75.60	X	X
SBX028	100.00	X	X
SBX031	150.00	X	
SBX034	200.00	X	
SBX037	250.00	X	
SBX040	500.00	X	
SBX043	1000.00	X	

PLANO-CONCAVE

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
SPC016	-1000.00	X	
SPC019	-250.00	X	
SPC022	-200.00	X	
SPC025	-150.00	X	X
SPC028	-100.00	X	X
SPC031	-75.00	X	
SPC034	-50.00	X	X

BI-CONCAVE

Part No.	F (mm)	Included in Master Kit	Included in Intro. Kit
SBC016	-1000.00	X	
SBC019	-250.00	X	
SBC022	-200.00	X	
SBC025	-150.00	X	
SBC028	-100.00	X	
SBC031	-75.00	X	
SBC034	-50.00	X	X

Ordering Information

BK-7 Master Lens Kits (44 lenses)

Model	Description
LKIT-1	Master Kit, uncoated BK-7 glass
LKIT-1AR.14	AR coated for visible laser applications 430-700 nm
LKIT-1AR.16	AR coated for NIR laser diode applications 650-1000 nm
LKIT-1AR.18	AR coated IR laser diode applications 1000-1550 nm
LKIT-1AR.33	AR coated for Nd:YAG lasers at 1064 nm

BK-7 Introductory Lens Kits (20 lenses)

Model	Description
LKIT-2	Introductory Kit, uncoated, BK-7 glass
LKIT-2AR.14	AR coated for visible laser applications 430-700 nm
LKIT-2AR.16	AR coated for NIR laser diode applications 650-1000 nm
LKIT-2AR.18	AR coated for IR laser diode applications 1000-1550 nm
LKIT-2AR.33	AR coated for Nd:YAG lasers at 1064 nm

Fused Silica Master Lens Kits (30 lenses)

Model	Description
LKIT-FS1	Master Kit, uncoated UV grade fused silica
LKIT-FS1AR.10	AR coated for UV laser applications 250-430 nm
LKIT-FS1AR.14	AR coated for visible laser applications 430-700 nm

Fused Silica Introductory Lens Kits (15 lenses)

Model	Description
LKIT-FS2	Introductory Kit, UV grade fused silica
LKIT-FS2AR.10	AR coated for UV laser applications 250-430 nm
LKIT-FS2AR.14	AR coated for visible laser applications 430-700 nm

2. FOP (Fiber Optic Plate)

2-1. Principle

In 1854, John Tyndall, of England, reported that, as water was blown out of a tube, light was transmitted along with it. This was the beginning of research on light guides using transparent materials to conduct light. In 1954, H. H. Hopkins reported that light guides could be bundled together to convey images. An FOP is a collection of light guides, or light capillaries, which takes an image and conveys it as optical information. When light is transmitted, refraction occurs at the boundary between two materials with different refractive indexes, as stated by Snell's law.

2-1-1. Construction of the FOP

Basically, the FOP is constructed of the three types of glass listed below.

1) Core glass = Most of the light passes through this glass.

2) Clad glass = Light is reflected from the boundary between the clad and core glasses.

3) Absorbent glass = This glass absorbs any whatever light that was not reflected.

The clad glass is wrapped around the core glass to form the basic fiber, called a single fiber (SF). In the basic FOP configuration, single fibers are aligned in a hexagonal closest-packed structure and surrounded by absorbent glass. (See Fig. 27)

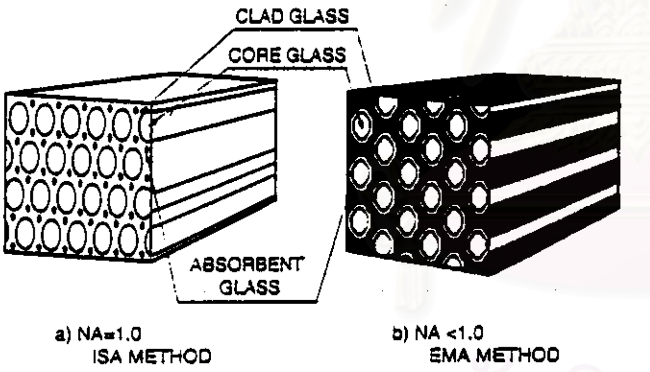


Fig. 27 Construction of the FOP

There are three ways in which the absorbent glass can be added. One is the ISA method shown in Fig. 27- a. Another is the EMA method shown in Fig. 27-b and the third is the Dead Single method shown in Fig. 28. If the numerical aperture (NA) is less than 1, the EMA-method is used since more stray light penetrates the clad glass. Hamamatsu mainly uses the ISA and EMA, except for special cases. The Dead Single is considered to be a type of blemish. Recently, the term "EMA" is frequently used for the absorbent glass, regardless of whether or not the EMA-method is actually used.

2-1-2. NA (Numerical Aperture)

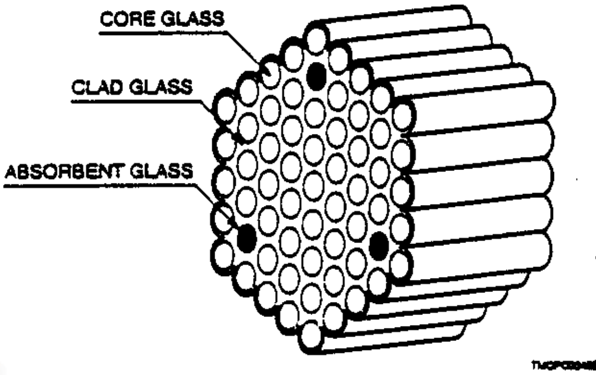


Fig. 28 Dead Single Type

The absorbent glass is arranged in each multi fiber as same number and same pattern. The absorbent glass diameter is as large as single fiber.

At the reflecting surface of the boundary between the core and the clad glasses, any light with an angle exceeding the critica angle penetrates the clad glass. This critical angle is determined by the difference between the refractive indices of the two glasses. As shown in Fig. 29, this also determines the angle a which the light enters the fiber (the light-receiving angle). The relation between the refractive index and angle is shown below

$$NA = n\sin\theta = \sqrt{n_0^2 - n_1^2}$$

n: Refractive index of air

n_0: Refractive index of the core glass

n_1: Refractive index of the clad glass

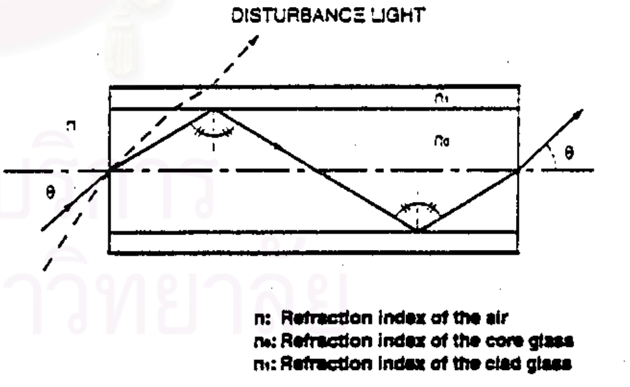


Fig. 29 Path of light in single fiber

"nsinθ" is called the NA (numerical aperture), and θ is the maximum light-receiving angle of the fiber. Since the angle at which light enters the fiber is the same as the angle at which it leaves the fiber, light is output with no increase of the θ value. By Hamamatsu, four standard models with NA values of 1.0, 0.88, 0.55, and 0.35 are available. The maximum light-receiving angle under atmospheric conditions (n = 1) and the refractive index for each of these are noted in Table A.

4) Chicken wire

Chicken wire which are differentiated from blemishes, are the continuous defects which occur along the border between multi-fibers (or multi-multi-fibers) and have a width equal to that of two or more single fibers (for example, 12 μm with a single fiber of 6 μm). Most of these are caused by partial breaks in the multi-fiber (or multi-multi-fiber). The methods for evaluating these flaws and their sizes are the same as those used for blemishes. Fig. 34 shows a photograph of a typical chicken wire flaw.

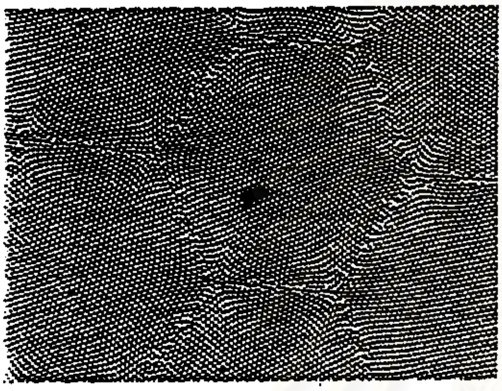


Fig. 33 Photo of a Blemish

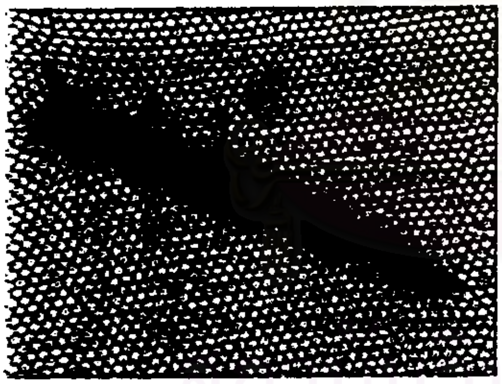


Fig. 34 Photo of a Typical Chicken Wire Flaw

5) Distortion

This is an image defect which occurs during the pressing of the FOP (see section 1-3, "How the FOP is Constructed") when a fiber is out of position or bent. There are two types: gross distortion and shear distortion. Frame runout can also be broadly categorized as a type of distortion; this happens in the cutting process when a bias angle occurs. It also differs from gross distortion and shear distortion in that it tends to occur over the entire FOP. Fig. 35 shows the patterns for the various types of distortion.

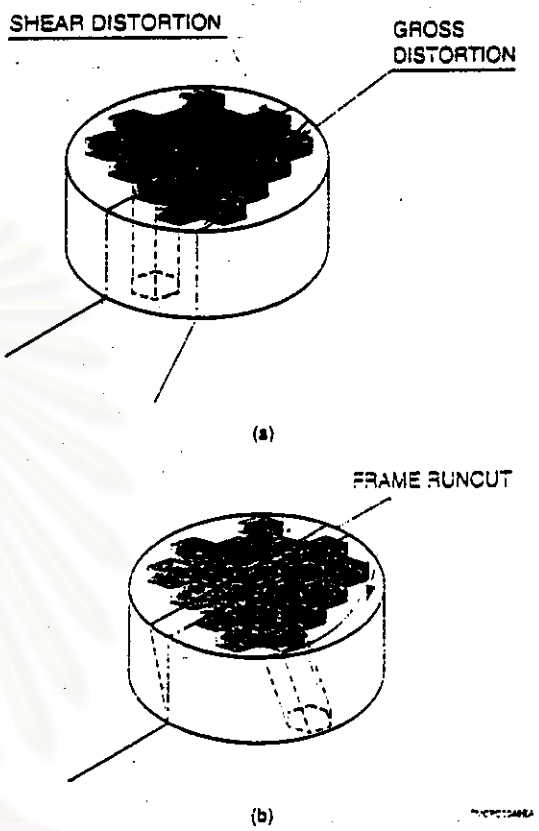


Fig. 35 Patterns for the Various Types of Distortion

2-2-2. X-ray Characteristics

As with an FOS, the FOP does not merely transmit the image, but absorbs any of the X-ray which was not converted to visible light, thus reducing the risk of damage to a CCD or other sensors with applications in which luminescent material is attached to the FOP and an X-ray image is converted to a visible light image .

1) X-ray absorption

Fig. 36 shows the X-ray absorption curve when the tube voltage of the X-ray is varied. Fig. 37 shows the X-ray absorption curve in relation to the FOP thickness at a given X-ray energy of 60 keV (Am). The XRS FOP (X-ray Radiation Shield FOP) shown in the figure is one in which lead or another heavy element has been inserted to improve absorption of X-rays. As can be seen from the figure, the XRS FOP has the desired effect for applications such as medical treatment at low X-ray energies. Because the XRS FOP includes lead, it is not appropriate for use as a photo cathode (alkali metal), but there are no significant differences in the other characteristics, as shown in Table C. Thus, it can be handled in the same way as standard FOPs.

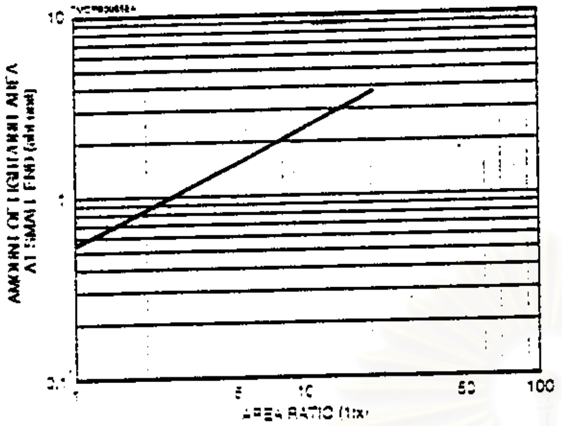


Fig. 42 Area Ratio of Tapered FOP vs. Amount of Light

2-3-2. Slanted FOPs

A slanted FOP is one which is processed in such a way that the ends of the FOP at which the light is input and output are, as shown in Fig. 43, at an angle to the direction of the fiber axis. By shaping the FOP this way, the input image can not only be enlarged or reduced in one direction (horizontally or vertically), but the angle can be selected to restrict the angle at which light is input and/or output.

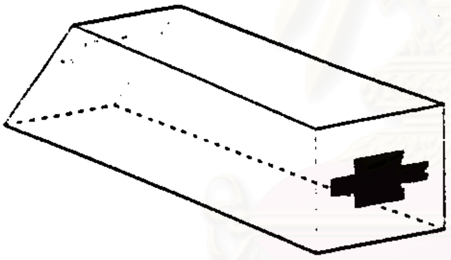


Fig. 43 Slanted FOP

Fig. 44 Light Pass in Slant FOP

1) Slant angle and angle of input/output light

As shown in Fig. 44, when the FOP is slanted, the fiber can transmit light only when the incident angle of the light is larger than + θ (if smaller than θ, or - θ, the light penetrates). + θ is determined by the refractive index of the glass used in the FOP. If this line of thinking is carried to its logical extension, then if, as shown in Fig. 45, an angle is determined at which light is transmitted only when + θ = 90, then based on Snell's law we have the following:

$$n_0 \sin\beta = n \sin 90^\circ$$

$$n_0 \sin\gamma = n_1 \sin 90^\circ$$

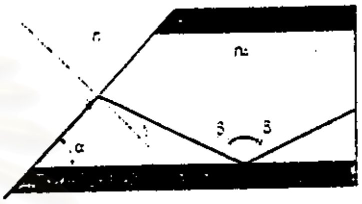
n: Refractive index of air (=1)

n_0: Refractive index of the core glass

n_1: Refractive index of the clad glass

$n_0 > n_1$

Also, because of the following relation:



n: Refraction index of the air
n₀: Refraction index of the core glass
n₁: Refraction index of the clad glass
n=1 n₀>n₁

Fig. 45 Logical Extension for Slant Angle

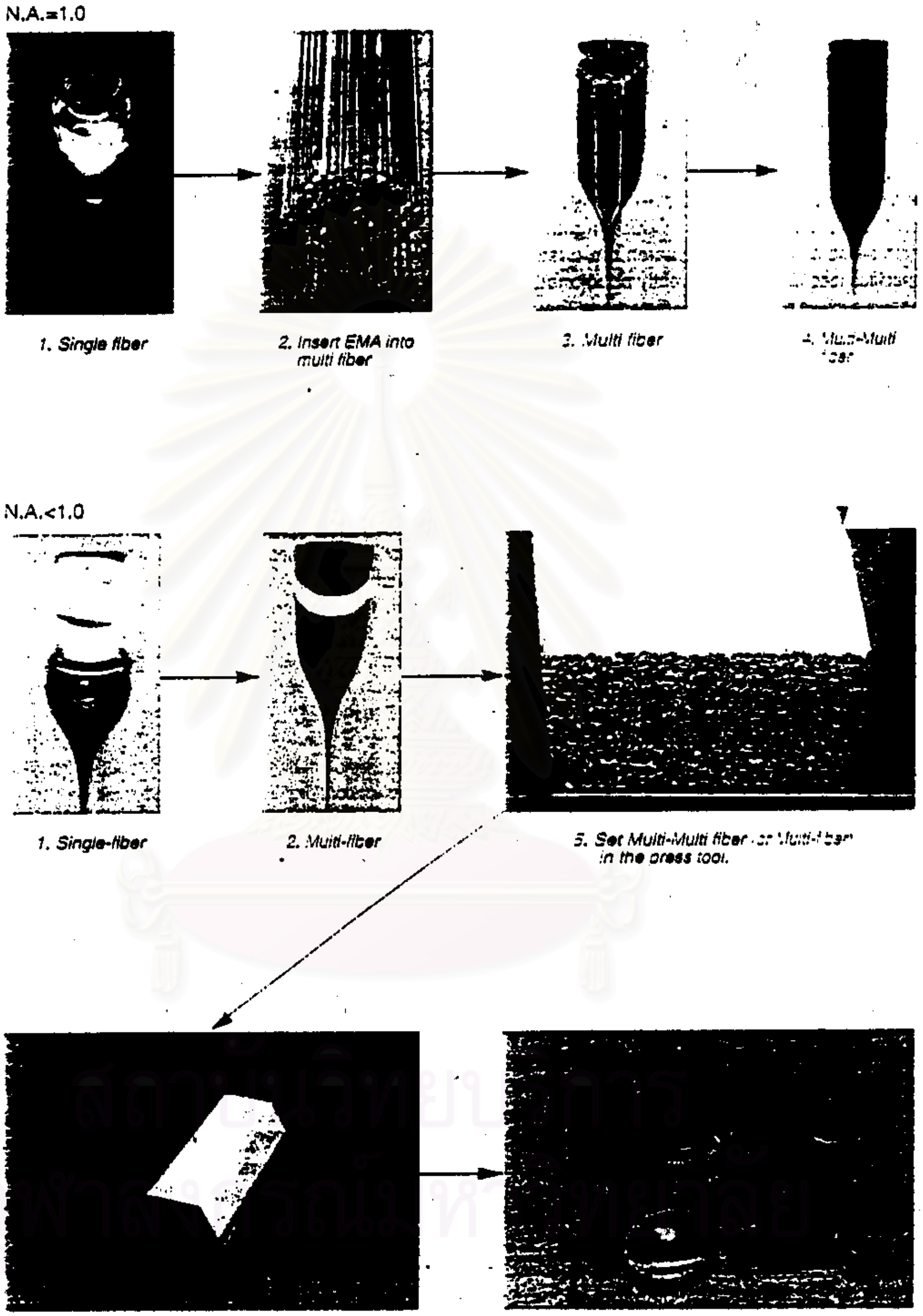
$$\alpha + (90^\circ - \gamma) + (90^\circ - \beta) = 180^\circ$$

substituting the various refractive indices for the values in Table A enables α to be determined based on Table D.

Table D Angle α at which only + θ (= 90°C) incident light is transmitted

N.A.	Angle of Slant
0.35	36.96
0.55	31.54
0.88	25.20
1.0	21.89

If α is smaller than the value given in the above table, not all of the light can be input to the fiber. However, if the refractive index is larger than that of air when the incident light comes in contact with the incident plane, light can be input for that section only. Applying this principle results in the finger print application shown in Fig. 52.



N.A.=1.0

1. Single fiber

2. Insert EMA into multi fiber

3. Multi fiber

4. Multi-Multi fiber

N.A.<1.0

1. Single-fiber

2. Multi-fiber

5. Set Multi-Multi fiber or Multi-fiber in the press tool.

6. Ingot

7. Final product after slice and polish.

Fig. 31 FOP Process

ประวัติผู้เขียน

นายธีรพงษ์ ประทุมศิริ เกิดเมื่อวันที่ 8 มีนาคม 2502 ที่อำเภอบ้านโป่ง จังหวัดราชบุรี ได้รับปริญญาครุศาสตร์อุตสาหกรรมบัณฑิต สาขาไฟฟ้าสื่อสาร จากสถาบันเทคโนโลยีราชมงคล วิทยาเขตเทเวศร์ เมื่อปี พ.ศ. 2534 ปัจจุบันรับราชการในตำแหน่งครู(ชำนาญการ) ระดับ 6 สาขาวิศวกรรมไฟฟ้าสื่อสาร ภาควิชาวิศวกรรมไฟฟ้า คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย