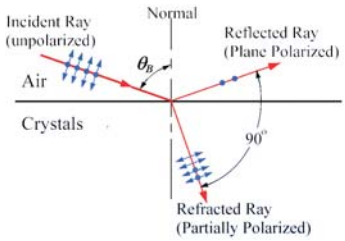
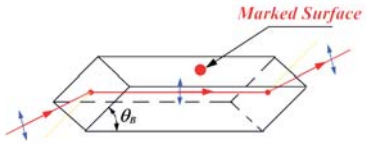
Every NLO crystal has a standard length (L) for frequency doubling lasers with pulse width longer than nanosecond (ns). For example, the standard crystal lengths for BBO and KTP are 7 mm and 5 mm, respectively. However, OPO and OPA need longer length, for example, > 12 mm for BBO, and the SHG and THG of ultrashort pulse lasers use thin crystals with length of less than 1 mm. Foctek's salesmen and engineers collected a series of standard crystal lengths for various applications. This information is provided free.

Brewster's angle NLO crystals

For laser beam propagates from Air to NLO crystal (with refractiveindices n). Brewster's angle is defined as θ_B=arctan(n). At Brewster's angle, the surface reflectance is zero for the light with polarization inside the plane defined by the direction of light propagation and the normal to the surface.

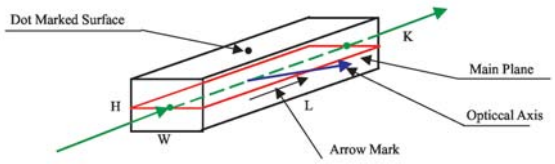


In order to have a low surface reflection, Brewster's angle cut (B-cut) NLO crystals are used. Without special notices, Foctek will fabricate the standard B-cut crystals according to the enclosed drawing. If customers design different sketch from our standard one, please notify Foctek by giving us a drawing



What is the Marked Surface:

The surface consists of Z, the optical axis and K, the light propagation direction is called as main plane. Foctek's NLO crystals are dot marked on the crystal surface which parallel the optical axis and main plane. As shown as the drawing. The dot marked surface is called marked surafce.



Meanwhile, if the coating is different on the input and output surface, there is an arrow mark on the

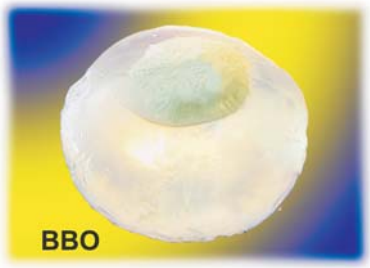
How to handle a NLO crystal

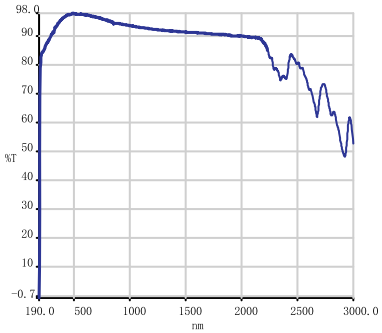
When you receive crystals from FOCTEK, please make sure that only qualified personnel are able to open inner plastic boxes at clean environment. When the plastic box of a NLO crystal is opened, please prevent finger print, oil and other substances from adhering to the polished or coated surfaces.
If the surfaces are contaminated, please blow the surfaces with air ball. If there is still pollution on the crystal surfaces, please clean the surfaces with cleaning liquid and soft silk. For BBO crystal, the mixing liquid of 50% high purity alcohol and 50% high purity ether is recommended as cleaning liquid. Please notify that the contaminated surfaces are very easy to be damaged.

Some NLO crystals have a low susceptibility to moisture, you are advised to provide dry atmosphere conditions for both use and preservation of them. When polished surfaces are fogged or damaged, please ask FOCTEK for repolishing and coating service.

BBO

BBO (beta-BaB_2O_4) is a nonlinear optical crystal with combination of number of unique features. Wide transparency and phase matching ranges, large nonlinear coefficient, high damage threshold and excellent optical homogeneity provide attractive possibilities for various nonlinear optical applications.



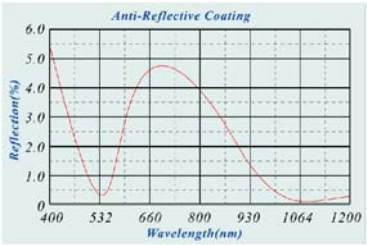


Capabilities:

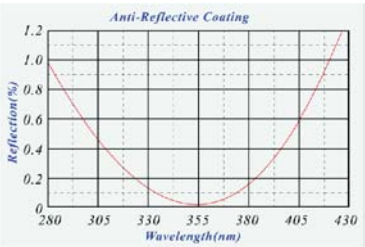
1) Aperture:	1x1 ~ 12x12mm
2) Length:	0.02 ~ 25mm
3) Phase Matching Angle θ and ϕ :	Determined by different kinds of homonic generartion.
4) Phase Matching Type	Type I or Type II
5) End Configuration:	Flat or Brewster or Specified

Typical specification and tolerance:

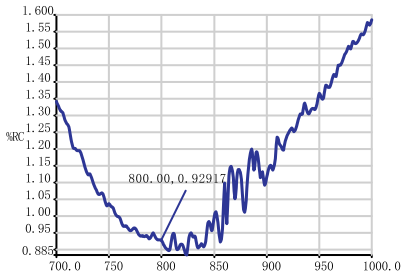
1) Angle Tolerance:	Δθ < ± 0.2°; Δϕ < ±0.2°
2) Dimension Tolerance:	(W ± 0.1mm) x (H ± 0.1mm) x (L + 0.2mm/-0.1mm)
3) Flatness:	<λ/8 @ 633nm
4) Scratch/Dig Code:	better than 10/5 Scracth/dig per MIL-O-13830A
5) Parallelism:	< 20 arc seconds
6) Perpendicularity:	< 5 arc minutes
7) Wavefront Distortion:	< λ/8 @ 633nm
8) Clear Aperture:	> 90% central area
9) Coating:	Protective Coating or Anti-Reflection



AR@1064nm R<0.2% + AR@532nm R<0.



AR@355nm R<0.2%



P-coating

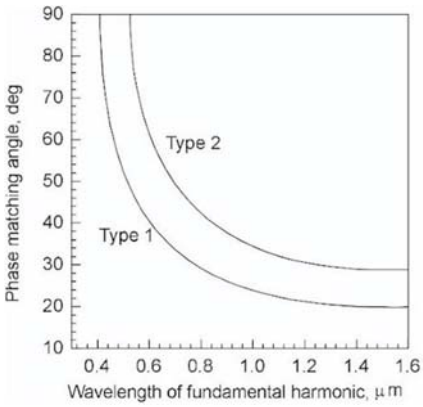
Physical and Optical Properties:

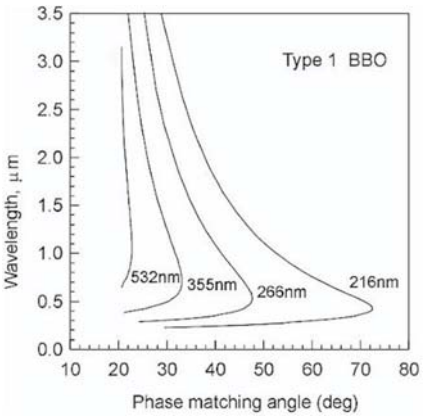
Crystal Structure	trigonal,space group R3c
Cell Parameters	A=b=12.532Å,c=12.717Å,Z=6
Melting Point	1095+/-5°C
Transition Temperature	925+/-5 °C
Optical Homogeneity	$\Delta n \approx 10^{-6}$/cm
Mohs Hardness	4.5
Density	3.85 g/cm^3
Absorption Coefficient	<0.1%/cm (at 1064nm)
Hygroscopic Susceptibility	low
Resistivity	>10^{11} ohm-cm
Relative Dielectric Constant	$\varepsilon^T_{11}/\varepsilon_0$:6.7, $\varepsilon^T_{33}/\varepsilon_0$:8.1 Tanδ < 0.001
Thermal Expansion Coefficients (in the range of 25°C-900°C	a, 4x10^{-6}/K c, 36x10^{-6}/K
Thermal Conductivity	⊥c, 1.2 W/m/K ; ∥c, 1.6W/m/K

Phase-Matchable SHG Range	189-1750nm
NLO Coefficients	d_{11}=5.8 x d_{36}(KDP) d_{31}=0.05 x d_{11}, d_{22} < 0.05 xd_{11}
Electro-Optic Coefficients	γ_{11}=2.7 pm/V , γ_{22},γ_{31} < 0.1γ_{11}
Half-Wave Voltage	48 KV (at 1064 nm)
Damage Threshold at 1.064 μm at 0.532 μm	 5 GW/cm^2 (10 ns); 10 GW/cm^2 (1.3ns) 1 GW/cm^2 (10 ns); 7 GW/cm^2 (250ps)
Transparency Range	189-3500 nm
Refractive Indices at 1.0642 μm at 0.5321 μm at 0.2660 μm	 n_e=1.5425, n_o=1.6551 n_e=1.5555, n_o=1.6749 n_e=1.6146, n_o=1.7571
Therm-Optic Coefficients	dn_o/dT=-9.3 x 10^{-6}/°C dn_e/dT=-16.6 x 10^{-6}/°C
Sellmeier Equations	$n_o^2(\lambda)=2.7359 + 0.01878/(\lambda^2 -0.01822)-0.01354\lambda^2$ $n_e^2(\lambda)=2.3753 + 0.01224/(\lambda^2 -0.01667)-0.01516\lambda^2$

As a result of large thermal acceptance bandwidth, high damage threshold and small absorption BBO well suits for frequency conversion of high peak or average power laser radiation.The large spectral transmission range as well as phase matchability, especially in UV range, makes BBO perfectly suitable for frequency doubling of Dye, Ar+-ion and Copper vapour laser radiation, effective cascade harmonic generation of wide spread Nd:YAG as well as of Ti:Sapphire and Alexandrite laser radiation. Both angle tuned Type 1 (oo-e) and Type 2 (eo-e) of phase matching can be obtained increasing a number of advantages for different applications.SHG phase matching angle dependence on input radiation wavelength is shown in fig. 1

Both Type 1 and Type 2 phase matching are used in OPO devices based on BBO crystals and designed for pump at different harmonics (up to fifth) of Nd:YAG lasers. Type 1 of interaction gives a larger tuning range and higher parametric amplification rate comparing to type 2 of interaction, while using type 2 interaction you're obtaining narrower bandwidth of output. Parametric gain in BBO is about10 times higher then in KDP in case of 355 nm pump for type 1 interaction. Up to 30% energy conversion efficiency has been obtained using BBO crystal of 12 mm length in OPO device synchronously pumped at 532 nm, which outputs at 406-3170 nm. Because of small acceptance angle and large walk off, the use of input laser radiation with good beam quality and low divergence is required for efficient conversion.





Standard BBO for SHG

Part No.	Size(mm)	θ	ϕ	Coating
BBO001	4x4x7	22.8°	0°	AR/AR@1064&532nm
BBO002	4x4x7	47.6°	0°	AR/AR@532&266nm
BBO003	4x4x10	22.8°	0°	AR/AR@1064&532nm
BBO004	4x4x10	47.6°	0°	AR/AR@532&266nm
BBO005	5x5x2	29.2°	0°	AR/AR@800&400nm
BBO006	5x5x1	29.2°	0°	AR/AR@800&400nm
BBO007	5x5x0.3-0.5	29.2°	0°	AR/AR@800&400nm
BBO008	5x5x0.1	29.2°	0°	AR/AR@800&400nm

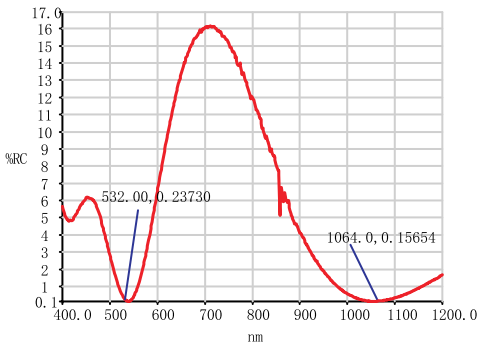
KTP

KTP ($KTiOPO_4$) is a nonlinear optical crystal, which possesses excellent nonlinear and electro-optic properties. It has large nonlinear optical coefficients and wide angular bandwidth and small walk-off angle, etc, which make it suitable for various nonlinear frequency conversion and wave guide application.

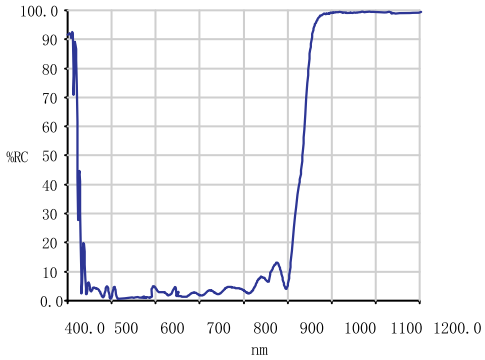
Due to very high effective nonlinearity (d_{eff}~8.3 x d_{36}(KDP) at 1.06μm) and excellent optical properties, KTP perfectly suits as lasing material in various applications. The phase matching range of KTP crystal lies in 0.99-3.3 μm region. This allows us to use KTP as an intracavity and extracavity frequency doubler for the most commonly used lasers, such as Nd:YAG, Nd:Glass and Nd:YLF

Capabilities:

1) Aperture:	1x1 ~ 10x10mm
2) Length:	0.05 ~ 20mm
3) Phase Matching Angle:	Determined by different homonic generartion (θ=90°; ϕ=23.5° for SHG 1064nm)
4) Phase Matching Type:	Type II
5) Typical Coating:	a) AR @1064nm R<0.1%; AR @ 532nm, R<0.25%(See Coating 18-1)
	b) HR @1064nm, R>99.8%; AR @532nm, R<0.5%(See Coating 18-2)
	Different coating specification is available upon customer request.



Coating 18-1



Coating 18-2

Typical Specification and Tolerance:

1) Angle Tolerance:	Δθ < ± 0.2°; Δϕ < ±0.2°
2) Dimension Tolerance:	(W ± 0.1mm) x (H ± 0.1mm) x (L + 0.2mm/-0.1mm)
3) Flatness:	< λ/8 @ 633nm
4) Scratch/Dig Code:	better than 10/5 Scracth/dig per MIL-O-13830A
5) Parallelism:	< 20 arc seconds
6) Perpendicularity:	< 5 arc minutes
7) Wavefront Distortion:	< λ/8 @ 633nm
8) Clear Aperture:	> 90% central area

Physical and Optical Properties:

Crystal Structure	Orthorhombic, point group mm^2
Melting Point	1172°C incongruent
Cell Parameters	a=6.404Å, b=10.616Å, c=12.814Å, Z=8
Curie Point	936°C
Mohs Hardness	~5
Density	3.01 g/cm^3
Color	colorless
Hygroscopic Susceptibility	no
Specific Heat	0.1643 cal/g.°C
Thermal Conductivity	0.13 W/cm/°K
Electrical Conductivity	3.5×10^{-8} s/cm (c-axis, 22°C, 1KHz)

Transmitting Range	350nm~4500nm			
Refractive Indices		n_x	n_y	n_z
	1064nm	1.7377	1.7453	1.8297
	532nm	1.7780	1.7886	1.8887
Absorption Coefficients	α < 1% / cm @ 1.064 μm			
Phase Matchable Range	0.984-3.4μm			
Therm-Optic Coefficients	dn_x / dT= 1.1×10^{-5}/°C, dn_y / dT= 1.3×10^{-5}/°C, dn_z / dT=1.6×10^{-5}/°C			
Nonlinear Optical Coefficients	d_{31}=2.54pm/V, d_{32}=1.35pm/V, d_{33}=16.9pm/V d_{24}=3.64pm/V, d_{15}=1.91pm/V, at 1.064μm $d_{eff}(II)\approx(d_{24}-d_{15})\sin2\Phi\sin2\theta-(d_{10}\sin^2\Phi+d_{24}\cos^2\Phi)\sin\theta$			
Electro-Optic Coefficients		Low frequency (pm/V)		High frequency (pm/V)
	r13	9.5		8.8
	r23	15.7		13.8
	r33	36.3		35.0
	r51	7.3		6.9
	r42	9.3		8.8
Dielectric Constant	ε_{eff}=13			
Sellmeier Equations	$n_x^2 = 3.0065 + 0.03901/(\lambda^2 - 0.04251) - 0.01327\lambda^2$ $n_y^2 = 3.0333 + 0.04154/(\lambda^2 - 0.04547) - 0.01408\lambda^2$ $n_z^2 = 3.3134 + 0.05694/(\lambda^2 - 0.05658) - 0.01682\lambda^2$			

Fig. 1 represents Type 2 SHG tuning curve of KTP in x-y plane. In x-y plane the slope d(Dk)/dq is small. This corresponds to quasi-angular noncritical phase matching, which ensures the double advantage of a large acceptance angle and a small walk off

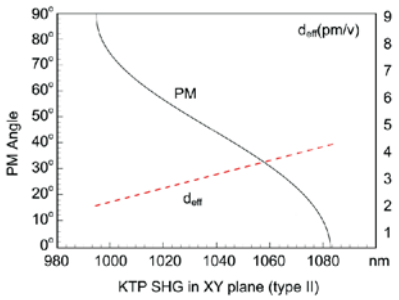


Fig.1

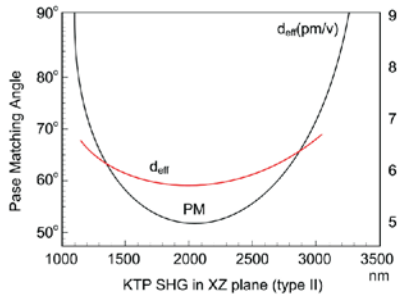


Fig.2

Fig. 2 represents Type 2 SHG tuning curve of KTP in x-z plane. in x-z plane the slope d(Dk)/dq is almost zero for wavelengths in the range 1.5-2.5 μm and this corresponds to quasi-wavelength noncritical phase matching, which ensures a large spectral acceptance. Wavelength noncritical phase matching is highly desirable for frequency conversion of short pulses.

Figures 3 and 4 show the phase matching angles for OPO/OPA pumped at 532 nm in x-y and x-z plane respectively. As a lasing material for OPG, OPA or OPO, KTP can most usefully be pumped by Nd lasers and their second harmonic or any other source with intermediate wavelength, such as a dye laser (near 600 nm).

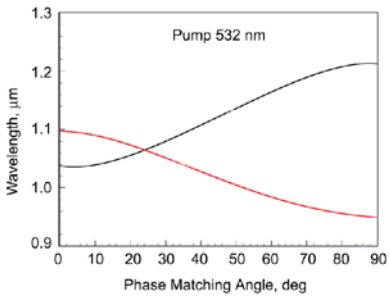


Fig.3

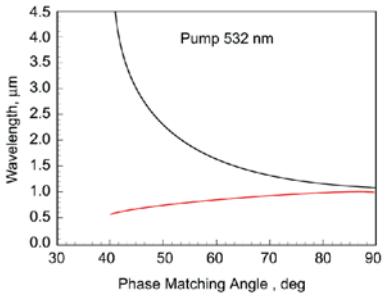


Fig.4

Standard KTP for SHG of 1064nm

Part NO.	Size (mm)	θ	Φ	Coating	
				S1	S2
KTP001	3x3x5	90°	23.5°	AR @ 1064nm R < 0.2% AR @ 532nm R < 0.5%	AR @ 1064nm R < 0.2% AR @ 532nm R < 0.5%
KTP002	3x3x5	90°	23.5°	HR@1064nm R > 99.8% AR @ 532nm R < 0.5%	AR @ 1064nm R < 0.2% AR @ 532nm R < 0.5%
KTP003	3x3x10	90°	23.5°	HR@1064nm R > 99.8% AR @ 532nm R < 0.5%	AR @ 1064nm R < 0.2% AR @ 532nm R < 0.5%

Notes:

To inquiry or order a finished KTP crystals, please specify the specification listed above, we kindly request engineering drawing to specify orientation. Please consult us for the designs if you're not sure about the phase matching angle for others' special application.

$LiNbO_3$

$LiNbO_3$ Crystal is widely used as frequency doublers for wavelength > 1 μm and optical parametric oscillators (OPOs) pumped at 1064 nm as well as quasi-phase-matched (QPM) devices. Due to its large Electro-Optic (E-O) and Acousto-Optic (A-O) coefficients.

FOCtek provides high quality and large size $LiNbO_3$ crystals for laser frequency doublers, OPOs and quasi-phase-matched doublers, as well as waveguide substrate and SAW wafers. High quality $LiNbO_3$ finished components with aperture of (2 - 15) x (2 - 15) mm^2 and length up to 50 mm for frequency doublers and optical parametric oscillators (OPOs), 50x50x1 mm^3 or Dia. 3" x 1 mm $LiNbO_3$ substrate for waveguide optics, and Dia. 3" SAW wafers are available with high volume and at low price.

Physical and Optical Properties:

Crystal Structure	Trigonal, space group R_{3c}
Cell Parameters	a = 5.15, c = 13.863, Z = 6
Melting Point	1255 +/-5 °C
Curie Point	1140 +/-5 °C
Mohs Hardness	5
Density	4.64 g/cm^3
Absorption Coefficient	~ 0.1%/cm @ 1064 nm
Solubility:	insoluble in H_2O
Relative Dielectric Constant	$\varepsilon^T_{11}/\varepsilon_0$: 85, $\varepsilon^T_{33}/\varepsilon_0$: 29.5
Thermal Expansion Coefficients at 25 °C	‖a, 2.0 x 10 $^{-6}$/K @ 25 °C ‖c, 2.2 x 10 $^{-6}$/K @ 25 °C
Thermal Conductivity	38 W /m /K @ 25 °C

Transparency Range	420 - 5200 nm
Refractive Indices	n_e = 2.146, n_o = 2.220 @ 1300 nm n_e = 2.156, n_o = 2.322 @ 1064 nm n_e = 2.203, n_o = 2.286 @ 632.8 m
Optical Homogeneity	~ 5 x 10^{-5} /cm
Sellmeier Equations: (λ in μm)	n_o^2 (λ) = 4.9048+0.11768/(λ^2 - 0.04750) - 0.027169 λ^2 n_e^2 (λ) = 4.5820+0.099169/(λ^2- 0.04443) - 0.021950 λ^2

NLO Coefficients	d_{33} = 34.4 pm/V, d_{31}= d_{15} = 5.95 pm/V, d_{22} = 3.07 pm/V
Electro-Optic Coefficients	γ^T_{33} = 32 pm/V, γ^S_{33} = 31 pm/V, γ^T_{31}= 10 pm/V, γ^S_{31} = 8.6 pm/V, γ^T_{22}= 6.8 pm/V, γ^S_{22}= 3.4 pm/V,
Half-Wave Voltage, DC Electrical field ‖z, light ⊥ z: Electrical field ‖x or y, light ‖ z:	 3.03 KV 4.02 KV
Damage Threshold	200 MW/cm^2 (10 ns)

Efficiency NLO Coefficients	d_{eff} = 5.7 pm/V or ~ 14.6 x d_{36} (KDP) for SHG@ 1300 nm; d_{eff} = 5.3 pm/V or ~ 13.6 x d_{36} (KDP) for OPO pumped at 1064 nm; d_{eff} = 17.6 pm/V or ~ 45 x d_{36} (KDP) for quasi-phase-matched structure

Birefringent Crystals

FOCtek provide a wide range of birefringent crystals: YVO_4, Calcite, α-BBO, $LiNbO_3$, quartz, etc. The crystals are widely used in the application of beam displacers, polarizing optics (Glan Laser, Glan Taylor, Glan Thompson, Wollaston and Rochon), optical isolators, circulators and interleaver, etc.

The comparation of refractive indices, birefringence, and walk off anlge for common crystals are listed below for reference. (Notes: ρ is walk off angle at crystal 45° cut)

YVO_4	1550nm:	n_o=1.9447	n_e=2.1486	Δn=0.2039	ρ=5.69°
Calcite:	1550nm:	n_o=1.6629	n_e=1.47722	Δn=-0.1564	ρ=-5.75°
α-BBO	1550nm:	n_o=1.64998	n_e=1.51199	Δn=-0.137996	ρ=-4.99°
$LiNbO_3$	1550nm:	n_o=2.21122	n_e=2.13806	Δn=-0.073156	ρ=-1.93°

Feature comparation of YVO_4, Calcite, α-BBO Birefringent crsytals

1) YVO_4 has better temperature stability and physical and mechnical properties than others.
2) Calcite is hard to obtain high optical quality because of its low susceptibility to moisture and low hardness, which make it easily scratched.
3) $LiNbO_3$ birefringence is smallest among them, although its mechanical and physical properties is similar to YVO_4.
4) α-BBO transparency range can cover far UV wavelength band from 189nm to 3500nm, it's especially Suitable for high power and UV polarizer application.

The main properties is listed follows

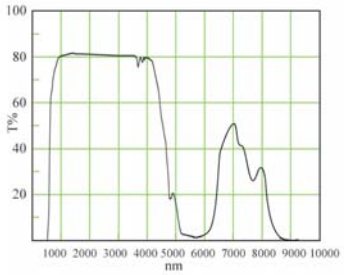
	YVO4	Calcite	α-BBO
Transparency	400—5000nm	350—2300nm	189—3500nm
Crystal class (Uniaxial)	Positive $n_o=n_a=n_b, n_e=n_c$	Negative $n_o=n_a=n_b, n_e=n_c$	Negative $n_o=n_a=n_b, n_e=n_c$
Mohs hardness	5	3	4.5
Thermal Expansion Coefficient	$\alpha_a=4.43\times10^{-6}$/k $\alpha_c=11.37\times10^{-6}$/k	$\alpha_a=24.39\times10^{-6}$/k $\alpha_c=5.68\times10^{-6}$/k	$\alpha_a=4\times10^{-6}$/k $\alpha_c=36\times10^{-6}$/k
Hygroscopic susceptibility	Non-Hygroscopic	Low to moisture	low

YVO_4

Undoped YVO_4 crystal is widely used in many beam displace applications because of its large birefringence. It also has good physical and favorable mechnical properties than others birefringent crystals, which make YVO_4 well suited for polarizer and compact fiber optical components, such as isolators, circulators and interleaver etc.

Capabilities:

1) Diameter: max. 25mm
2) Length: max. 30mm
3) Surface Quality: better than 20/10 scratch/dig Per MIL-0-13830A
4) Beam Deviation: <3 arc min
5) Optical Axis Orientation: +/-0.20°
6) Flatness: < λ/4 @633nm
7) Wavfront Distortion: < λ/2 @633nm
8) Coating: upon customer's Specification



Transmission VS wavelength

Physical and Optical Properties:

Transparency Range	400-5000nm
Crystal Symmetry	Zircon tetragonal,space group D4h
Crystal Cell	a=b=7.12Å;c=6.29Å
Density	4.22g/cm^3
Hygroscopic Susceptibility	Non-hygroscopic
Mohs Hardness	5 glass like
Thermal Optical Coefficient	$dn_a/dT=8.5\times10^{-6}$/K; $dn_c/dT=3.0\times10^{-6}$/K
Thermal Condutivity Coefficient	∥C: 5.23 w/m/k; ⊥C:5.10w/m/k
Crystal Class	Positive uniaxial with $n_o=n_a=n_b$, $n_e=n_c$
Refractive Indices Birefringence($\Delta n=n_e - n_o$) and Walk-Off angle at 45 deg(ρ)	n_o=1.9929, n_e=2.2154,Δn=0.2225, ρ=6.04°,at 630nm n_o=1.9500, n_e=2.1554,Δn=0.2054, ρ=5.72°,at 1300nm n_o=1.9447, n_e=2.1486,Δn=0.2039, ρ=5.69°,at 1550nm
Sellmeier equation (λ in μm)	$n_o^2 = 3.77834+0.069736/(\lambda^2-0.04724)-0.0108133\lambda^2$ $n_e^2 = 4.59909+0.110534/(\lambda^2-0.04813)-0.0122676\lambda^2$

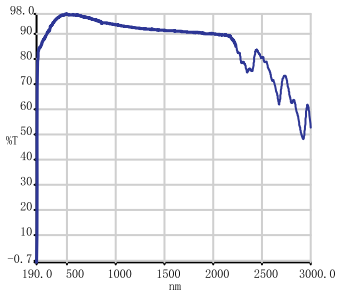
α-BBO

High temperature phase of BaB_2O_4 is an excellent birefringent crystal; it is characterized by large birefringent coefficient and wide transmission window from 189nm to 3500nm, particularly it is suitable to make the high power UV polarizer, due to its unique UV transparency and good mechanical properties.

The physical, chemical, thermal and optical properties of α-BBO crystals are similar to those of β-BBO, for instant high optical homogeneity extremely low absorption in the UV to IR range , low hygroscopic susceptibility, high damage threshold.

Capabilities:

1) Diameter: max 40~50mm
2) Length: max 25~35mm
3) Surface quality: better than 20/10
4) Beam deviation: < 3 arc min
5) Optical axis orientation: +/-0.50
6) Flatness: < λ/4 @633nm
7) wavefront distortion: <λ/2 @633nm
8) Coating: upon customer's specification



Transmission VS Wavelength

Physical and Optical Properties:

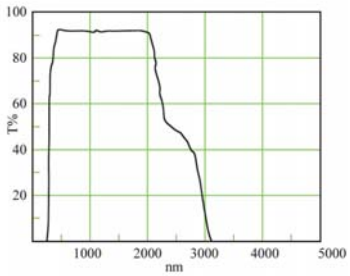
Transparency Range	189~3500nm
Density	3.85g/cm^3
Therm-Optic Coefficients	$dn_o/dT=-9.3\times10^{-6}$/°C $dn_e/dT=-16.6\times10^{-6}$/°C
Optical Homogeneity	$\Delta n \approx 10^{-6}$/cm
Mohs Hardness	4.5 glass like
Damage Threshold	1GW/cm^{2}at 1064nm 200MW/cm^2 at 532nm
Thermal Expansion Coefficients (25°C~900°C)	$\alpha_a=4\times10^{-6}$/K $\alpha_c=36\times10^{-6}$/K
Linear Absorption Coefficients	a<0.005cm^{-1}from 300nm to 2300nm
Refractive Indices Birefringence($\Delta n=n_e - n_o$) and Walk-Off angle at 45°C(ρ)	n_e= 1.53797, n_o=1.65790, Δn=-0.11993, ρ=-4.9532°,at 1064nm n_e= 1.55345 , n_o=1.67755, Δn=-0.12411, ρ=-5.0407°,at 532nm n_e= 1.61145 , n_o=1.76171, Δn=-0.15026, ρ=-5.6926°,at 266nm
Sellmeier equation (λ in μm)	$n_o^2 = 2.7471+0.01878/(\lambda^2-0.01822)-0.01354\lambda^2$ $n_e^2 = 2.37153+0.01224/(\lambda^2-0.01667)-0.01516\lambda^2$

Calcite

Calcite is a natural crystal that has high birefringence, wide spectral transmission and availability in reasonably sized rhombs. It's a negative uniaxial crystals and mostly used as visible and near IR polarizers.

Capabilities:

1) Diameter: max 30~40mm
2) Length: max 25~35mm
3) Surface Quality: better than 40/20 scratch/dig
4) Beam Deviation: < 3 arc minutes
5) Optical Axis Orientation: +/-0.50
6) Flatness: < λ/4 @633nm
7) Wavefront Distortion: < λ/2 @633nm
8) Coating: upon customer's Specification



Transmission Vs Wavelength

Notes:

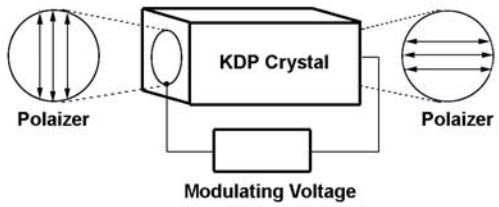
As the susceptibility to moisture is low so that , it's difficult to achieve excellent optical quality due to low hardness.

Physical and Optical Properties:

Transparency Range	350~2300nm
Partical Shape	Crystalline rhombihedral
Density	2.7 g/cm^3
Hygroscopic Susceptibility	Low susceptibility to moisture
Mohs Hardness	3
Thermal Expansion Coefficient	α_a=24.39 x 10^{-6}/k; α_c=5.68 x 10^{-6}/k
Crystal Class	Negative uniaxial with $n_o=n_a=n_b$, $n_e=n_c$
Refractive Indices Birefringence($\Delta n=n_e - n_o$) and Walk-Off angle at 45°C(ρ)	n_o=1.6557, n_e=1.4852 Δn=-0.1705, ρ=6.20° @630nm
	n_o=1.6380, n_e=1.4783 Δn=-0.1596, ρ=5.83° @1300nm
Sellmeier equation	$n_o^2 = 2.69705+0.0192064/(\lambda^2-0.01820)-0.0151624\lambda^2$ $n_e^2 =2.18438+0.0087309/(\lambda^2-0.01018)-0.0024411\lambda^2$

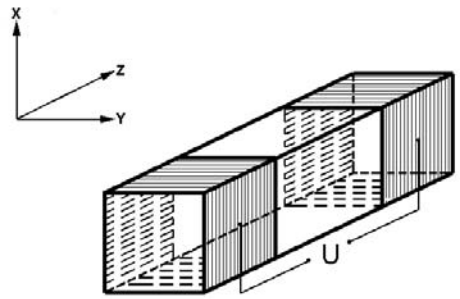
Electro-optic effect is the change in the refractive index resulting from the appliation of a DC or low frequency electric field. A field applied to an ansotropic electro-optic material can modify its refractive indices and thereby its effect on polarized light. The dependence of the refractive index on the applied electric field takes two forms: linear electro-optic effect, and quadratic electro-optic. Electro optics crsyals can be used for producing controllable optical devices such as Q-switch application.

If a linearly polarized light passes through an E-O crystal, the phase retardation (Γ) will be induced by Δn to $\Gamma = 2\pi\Delta nL$, where L is crystal length, for KD*P, as an example, $\Delta n=0.5 n_{30}r_{63}E/\lambda$, $\Gamma = \pi L n_{30}r_{63}E/\lambda$. It is clear that the phase of light will change together with electric field (E). This is called electro-optic phase modulation. If two crossed polarizers are placed at input and output ends of E-O crystal separately as shown in (Amplitude Modulator), the output intensity of light will be $I = I_0\sin_2(G/2)$, where I_0 is input intensity. That means the intensity or amplitude of light can also be modulated by electric field. This is **called amplitude modulation.**

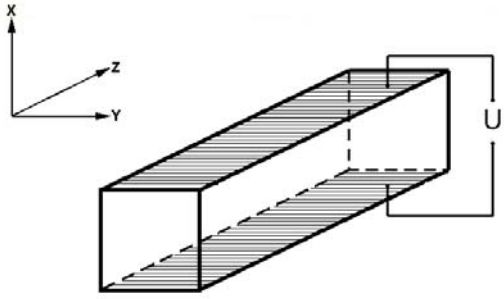


Amplitude Modulator

There are two kinds of E-O modulations. One is longitudinal E-O modulation if the directions of electric field and light propagation are the same (as shown in Longitudinal Modulation). The KDP isomorphic crystals are normally used in this scheme. If the directions of electric field and light propagation are perpendicular, it is called transverse E-O modulation (see Transverse Modulation). The $LiNbO_3$, $MgO:LiNbO_3$, $ZnO:LiNbO_3$, BBO and KTP crystals are usually employed in this scheme.



Longitudinal Modulation



Transverse Modulation

The half-wave voltage (V_π) is defined as the voltage which makes $\Gamma = \pi$, for example, $V_\pi=\lambda/(2nr_{63})$ for KD*P and $V_\pi=\lambda d/(2nr22L)$ for $LiNbO_3$, where λ is light wavelength and d is the distance between the electrodes.

FOCtek provide four kinds of electro-optic crystal BBO, KTP, $LiNbO_3$, $LiTaO_3$ with z-cut, AR coating, and Au-electrodes.

BBO

BBO crystals with Z-cut is an excellent electro-optic crystal combining good physical properties, it's suitable for high power applications. It launchs a super Q-switch for a cw diode pumped Nd:YAG laser with average power >50W. Please refer to Page 93 for more information about BBO crystal.

We can provide as large as 6x6x25mm BBO for high power aplication. The standard BBO for Q-Switch as:

Part No.	Size (mm)	Orientation	Coating
BBO101	3x3x18	Z-Cut	Z-face AR coating, X-face Au coating
BBO102	3x3x20	Z-Cut	Z-face AR coating, X-face Au coating

■**Please contact us for Quotation of volume quantity**

KTP

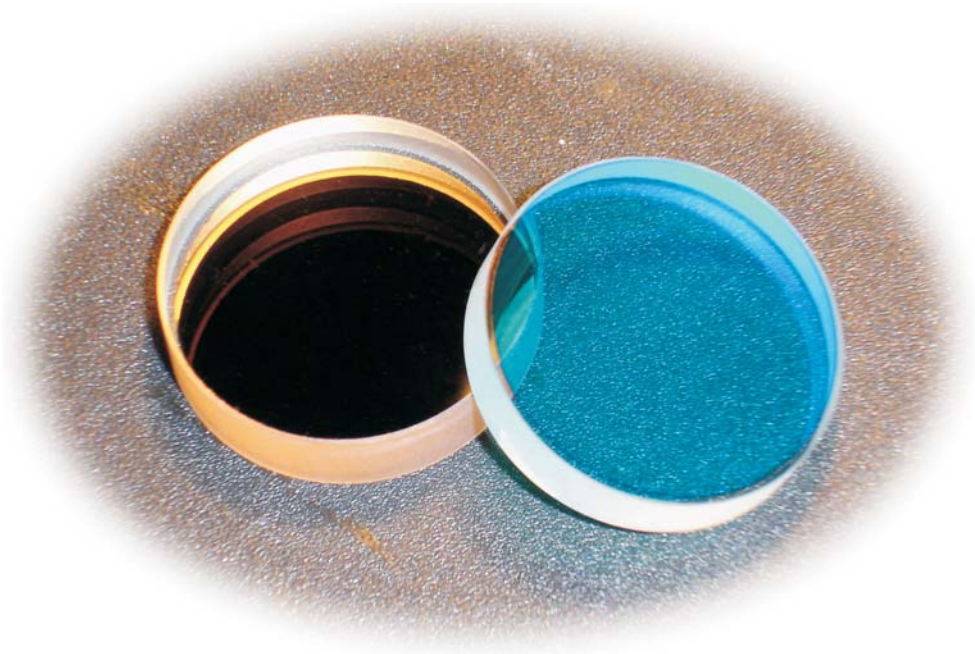
KTP has promising E-O and dielectric properties comparable to those of LiNbO3, which makes it extremely useful to various E-O devices. The following table gives the comparison of KTP and those crystals commonly used E-O modulator materials:

Material			Phase			Amplitude		
	ε	n	r pm/V	k 10^{-6}/°C	$n^7 r^2/\varepsilon$ $(pm/V)^2$	r pm/V	k 10^{-6}/°C	$n^7 r^2/\varepsilon$ $(pm/V)^2$
KTP	15.4	1.80	35.0	31	6130	27.0	11.7	3650
LiNbO3	27.9	2.20	31.0	82	7410	20.1	42	3500
KD*P	48.0	1.47	26.4	9	178	24.0	8	178
LiIO3	5.9	1.74	6.4	24	335	1.2	15	124

When these properties are combined with high damage threshold, low optical loss at high average power, wide optical bandwidth, thermal and mechanical stability, KTP crystals are expected to replace $LiNbO_3$ crystals as E-O modulators, especially for mode-locking diode laser pumped Nd:YAG and Nd:YLF lasers as well as Ti:Sapphire and Cr:$LiSrAlF_6$ lasers.

PART 5

OPTICAL COATING



COATING CENTER

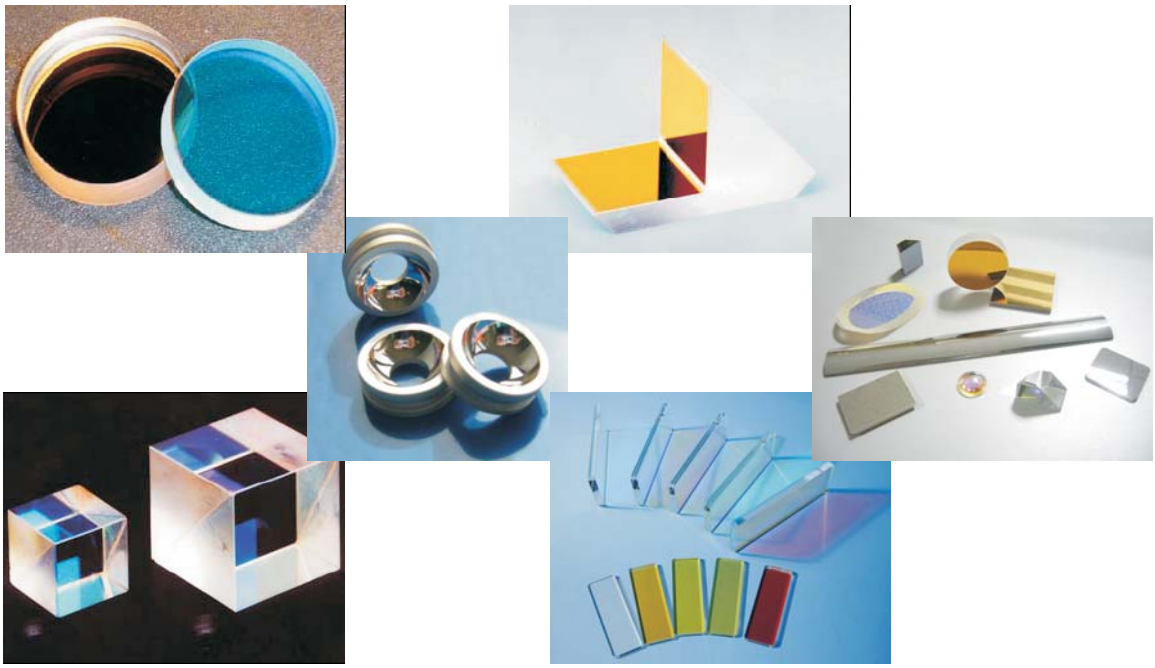
Leybold Coater


3 Optorun Coaters


Lambda 950 spectrophotometer

Total 10 Coaters, including three Optorun Coaters and one Lebold Coater

COATED OPTICAL COMPONENTS

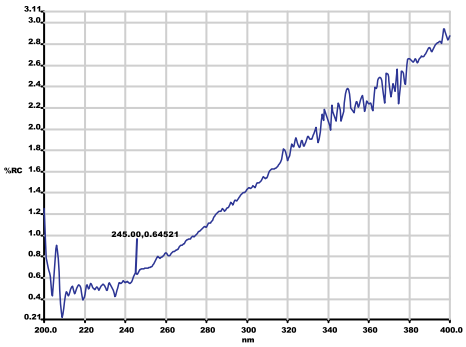


The Coating on the optical element is very important, which can improve the transmission, high reflection, etc. Foctek offers all kinds of anti-reflective (AR) coating, BBAR, V-coating, Dual Wavelength AR coating, high reflective (HR) coating, partial reflective (PR) coating, filter coating, dichroic coating, polarization beamsplitter coating and metal reflective coating, etc. according to customers' requirement. Foctek has the strong capability in coating design, we supply the coating design services for your special coating requirement.

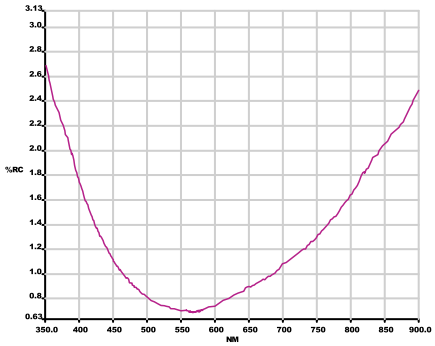
Foctek owns 10 coaters, which provide large coating capacity for our optical components. we measure the coating spectral curves of our coating products by Lambda 950(UV/VIS/NIR) spectrophotometer. The coating spectral curves measured by Lambda 950 can be provided with the delivery upon your request. The adhesion and hardness of the coatings are tested according to the Standard Mil Spec tests of Abrasion (Mil-C-675A), Adhesion (Mil-M-13508C), Hardness(MIL-M-13508C).

Anti reflection Coating

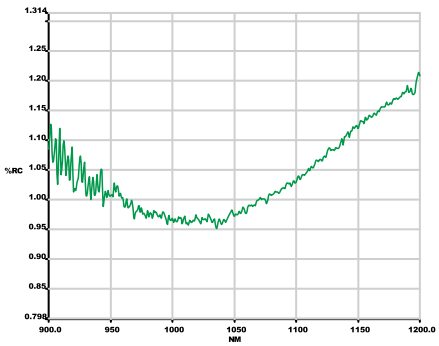
Single Layer MgF_2 AR Coating



Single layer MgF_2@245 nm

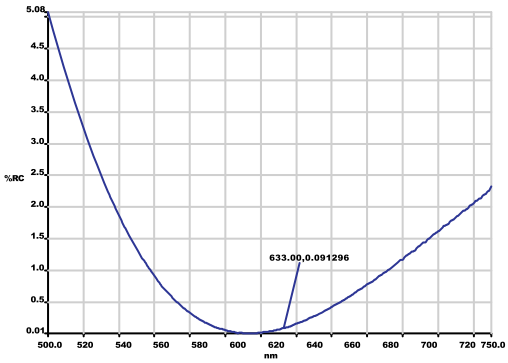


Single layer MgF_2@532 nm

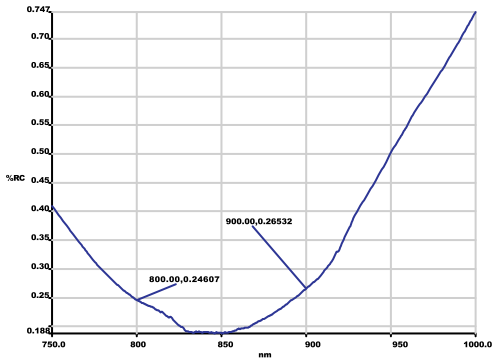


Single layer MgF_2@1064 nm

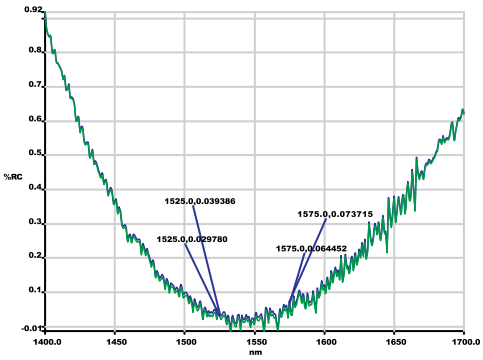
Multi-layer AR Coating



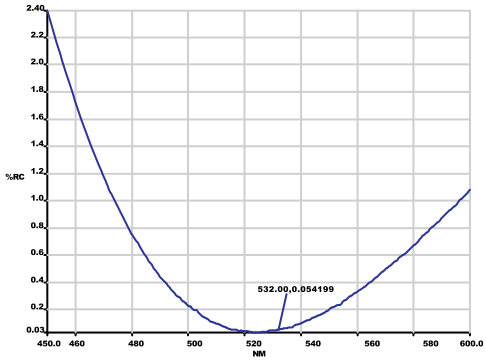
AR@633nm



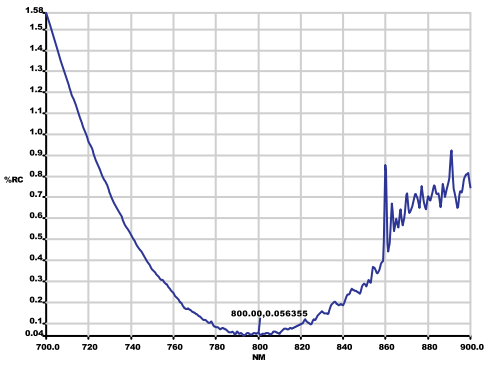
AR coating @ 850+/-50 nm, R<0.3%



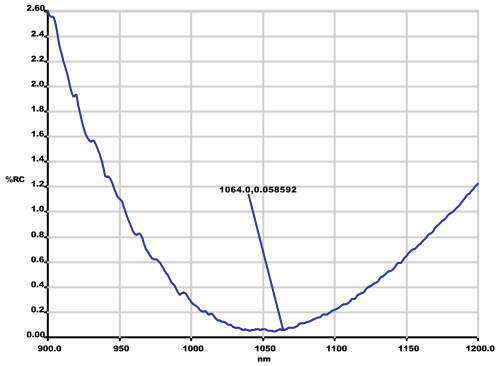
AR@1550±50 nm



AR@532 nm

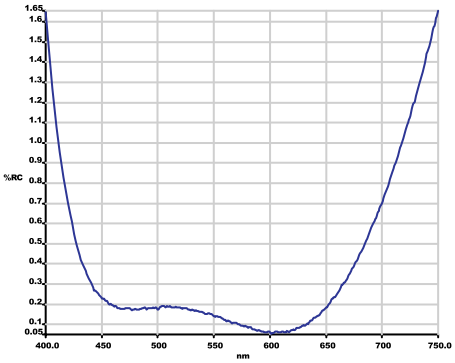


AR@800nm

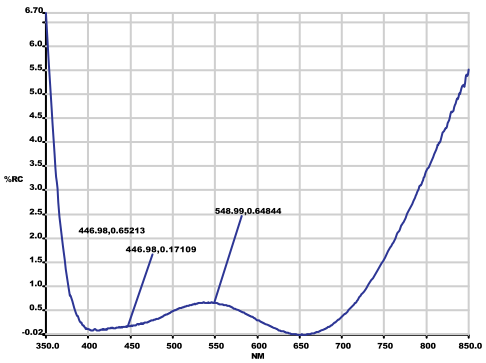


AR@1064 nm

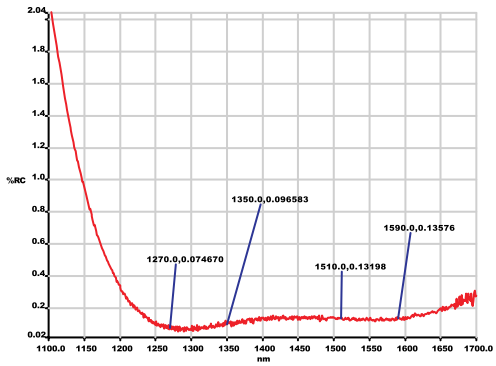
Broadband Multi-layer AR Coating



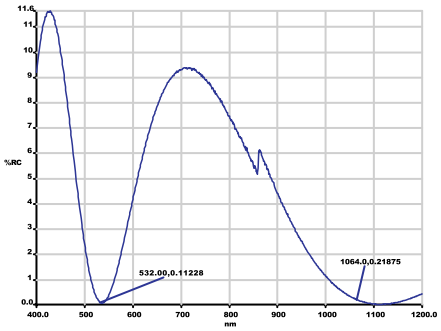
AR@450-650 nm Ravg<0.5%



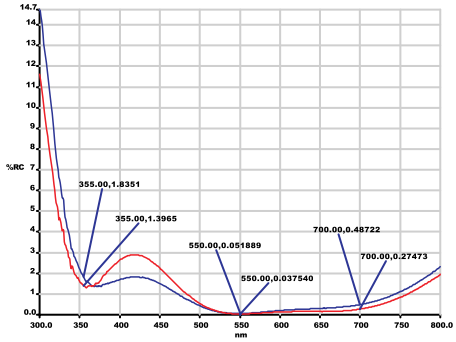
AR coating @ 400-700 nm



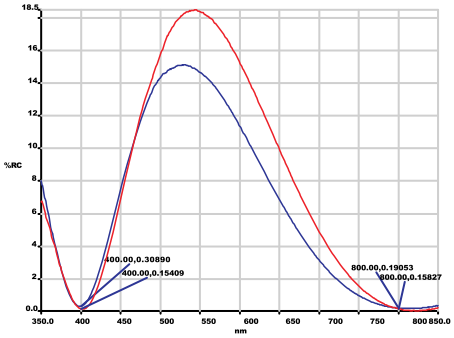
Dual Wavelength AR Coating



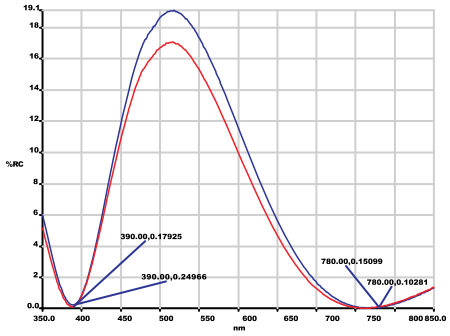
AR@1064&532 nm



AR@355nm,& AR@550~700nm

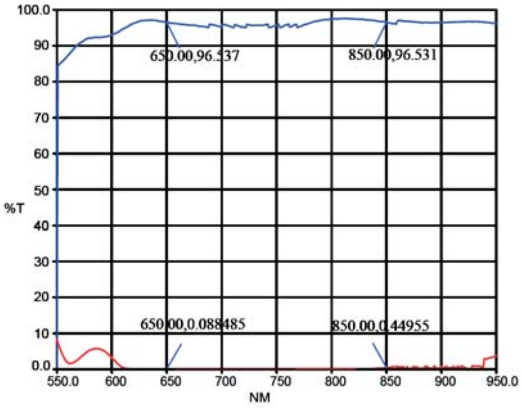


AR@800 & 400 nm

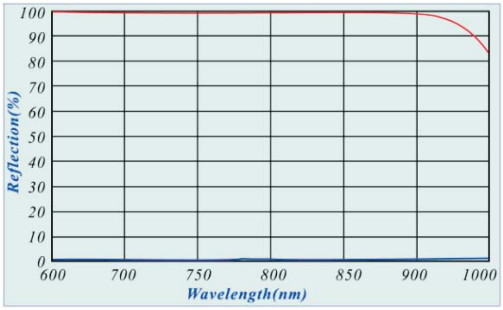


AR@780 & 390 nm

Polarization Beam splitter Coating

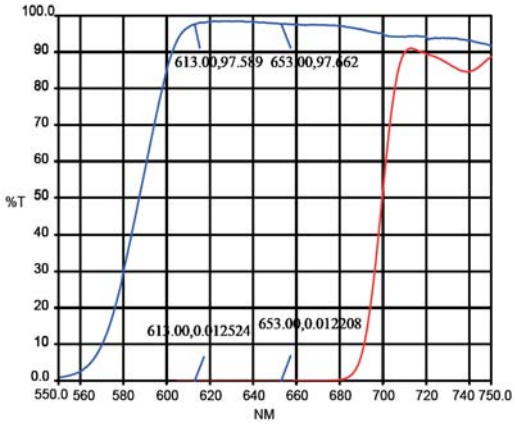


Tp>95%,Ts<1% @ 650-850nm

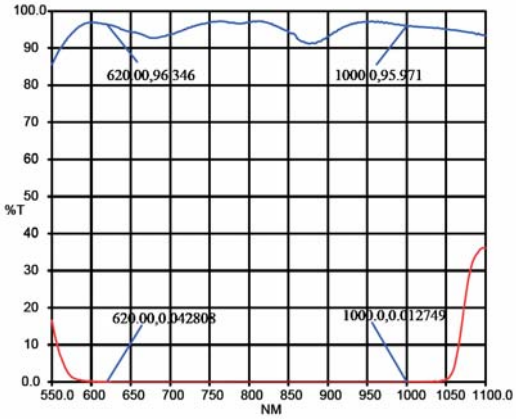


Rs>99%,Rp<5% @650-850nm

High Extinction PBS Coating



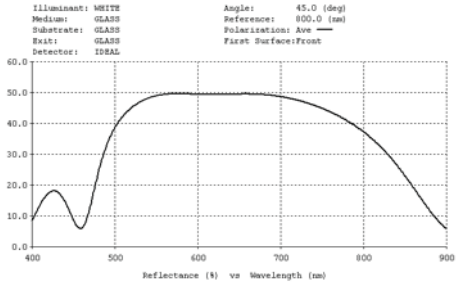
Tp>96%,Tp:Ts>3000:1 @ 633±20nm



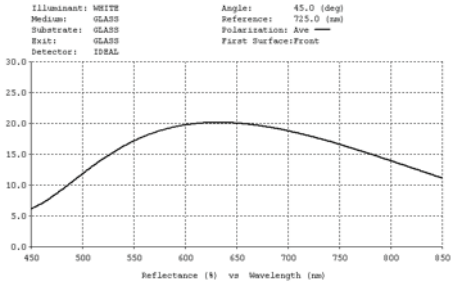
Tp>90%,Tp:Ts>1000:1 @ 620 -1000nm

Partial Reflection Coating

Single Wavelength Band PR Coating

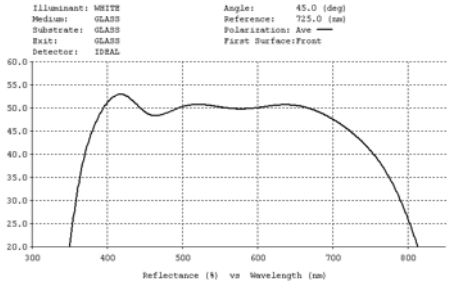


PR@633 nm, R/T=50%/50%±2%

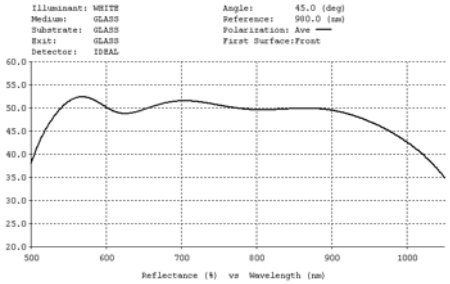


PR@633 nm, R/T=20%/80%±2%

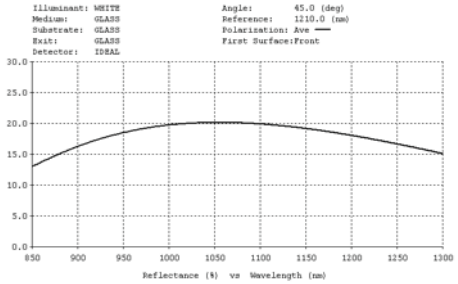
Broadband PR Coating



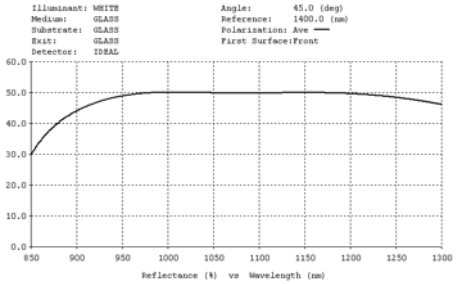
PR@ 400-700nm, R/T=50%/50%±5%



PR@ 600-900nm, R/T=50%/50%±5%



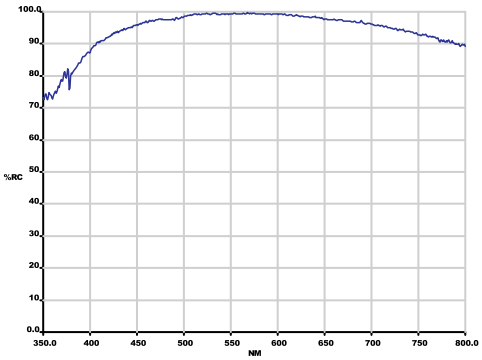
PR@ 900-1200nm, R/T=20%/80%±5%



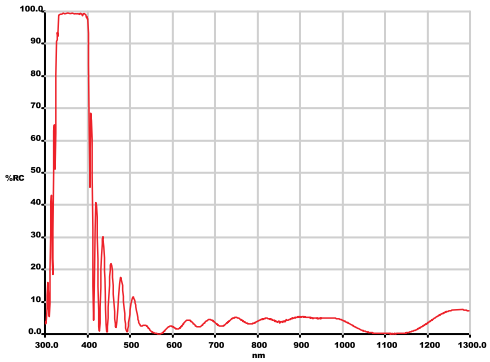
PR@ 950-1250nm, R/T=50%/50%±5%

High Reflection Coating

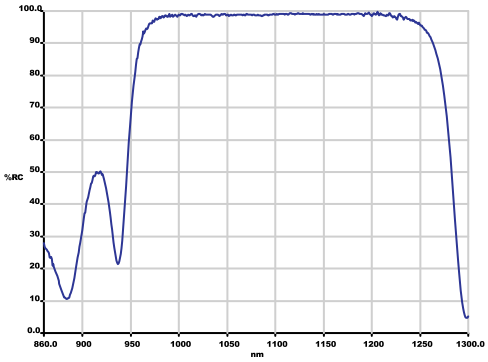
Dielectric High Reflective Coating



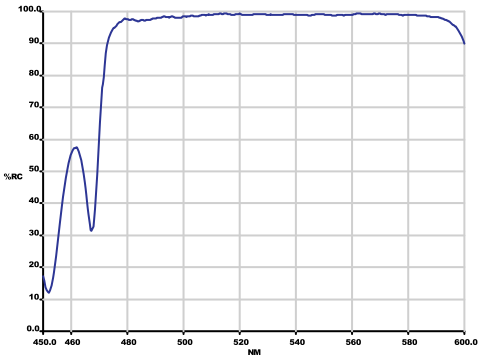
HR @ 450-750 nm



HR @ 355nm

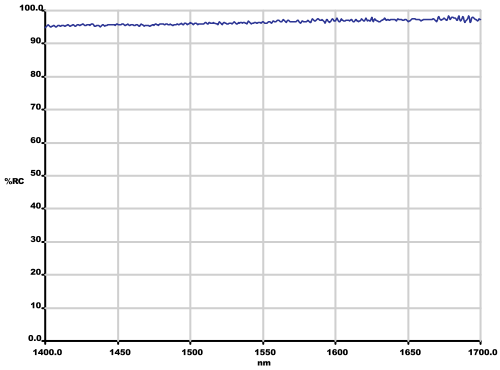


HR @ 1000-1200 nm

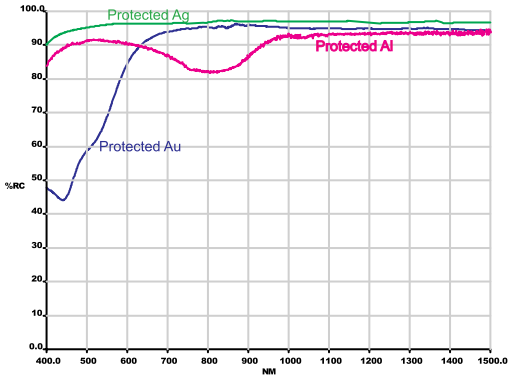


HR @ 532 nm

Metallic High Reflective Coating

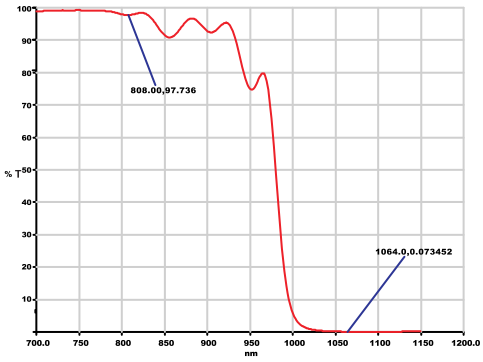


Protected Ag @ 1400-1700

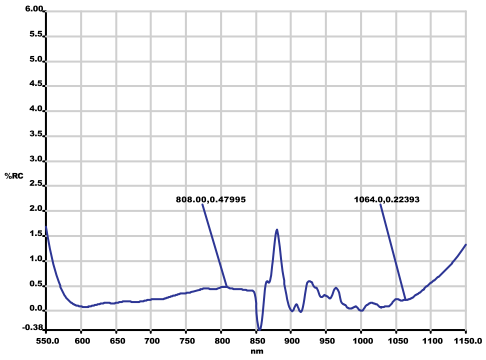


Protected Ag
Protected Au
Protected Al

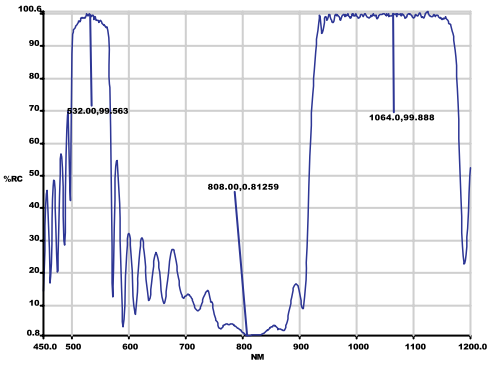
Diode Pumped Laser Optics Coatings



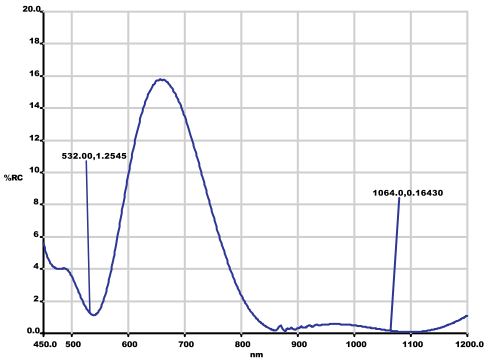
HR@1064 & HT@808 nm



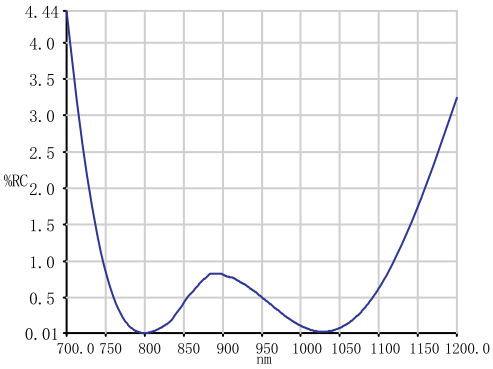
AR@1064 & HT@808 nm



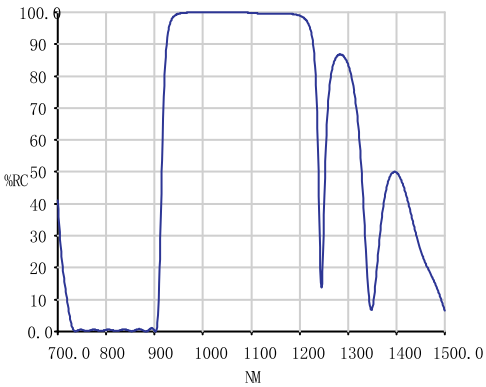
HR@ 1064&532 nm, HT@808 nm



AR@ 1064&HT@808&532 nm



AR@ 1064 nm&HT@808 nm



HR@ 1064 nm&HT@808 nm

PART 6

Holder

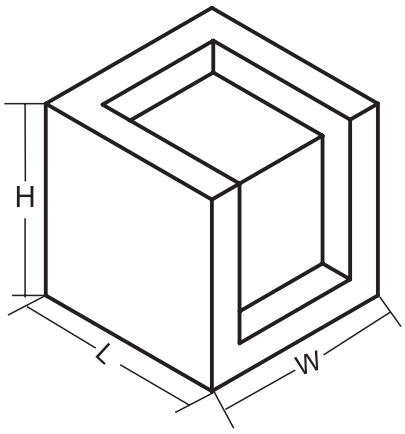
Cube Beamsplitter Holder

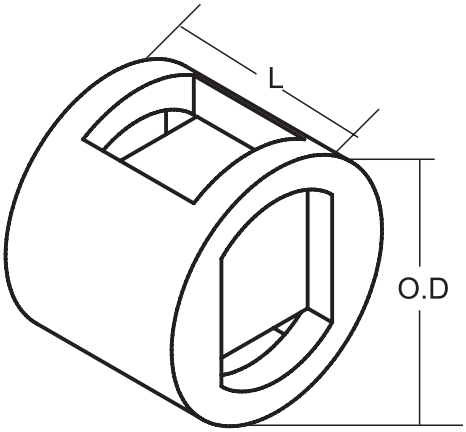
Quadrate Shape

P/N#	Cube Prism Size	$W^{+0}_{-0.2}$ (nm)	$H^{+0}_{-0.2}$ (nm)	$L^{+0}_{-0.2}$ (nm)	Unit Price
MCB1010	10.0×10.0×10.0	25.4	25.4	25.4	$15.0
MCB1012	12.7×12.7×12.7	25.4	25.4	25.4	$15.0
MCB1015	15.0×15.0×15.0	25.4	25.4	25.4	$15.0
MCB1020	20.0×20.0×20.0	30.0	30.0	30.0	$15.0
MCB1025	25.4×25.4×25.4	38.0	38.0	38.0	$15.0

Round Shape

P/N#	Cube Prism Size	$O.D^{+0}_{-0.2}$ (nm)	$L^{+0}_{-0.2}$ (nm)	Unit Price
MCB2010	10.0×10.0×10.0	Φ25.4	20.0	$15.0
MCB2012	12.7×12.7×12.7	Φ25.4	20.0	$15.0
MCB2015	15.0×15.0×15.0	Φ30.0	25.0	$15.0
MCB2020	20.0×20.0×20.0	Φ38.0	30.0	$15.0
MCB2025	25.4×25.4×25.4	Φ43.0	38.0	$15.0





Waveplate Holder

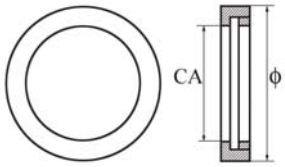
Ring Holder

Specifications:

Material: Black anodized aluminum

Diameter tolerance: +/-0.1mm

Thickness tolerance: +/-0.1mm



Holder

P/N#	ϕ (mm)	T (mm)	Aperture (mm)	CA (mm)	Unit Price
WH1508	15.0	6.0	8.0	7.0	$9.9
WH2508	25.4	6.0	8.0	7.0	$9.9
WH2510	25.4	6.0	10.0	9.0	$9.9
WH2512	25.4	6.0	12.7	11.5	$9.9
WH2515	25.4	6.0	15.0	13.5	$9.9
WH2520	25.4	6.0	20.0	18.5	$9.9
WH3015	30.0	6.0	15.0	13.5	$9.9
WH3020	30.0	6.0	20.0	18.0	$9.9
WH3025	30.0	6.0	25.4	22.8	$9.9

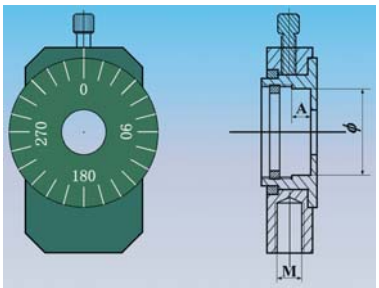
Rotating Holder

Specifications:

Material: Black anodized aluminum

Rotation tolerance: <5°

Diameter tolerance: +/-0.1mm



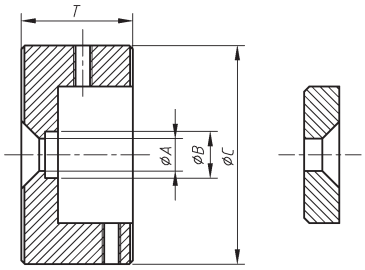
P/N#	Width (mm)	Height (mm)	Length (mm)	Diameter (ring holder)	Thickness (ring holder)	Unit Price
WRH25	40.0	60.0	10.0	25.4 mm	6.0~8.0 mm	$38
WRH30	45.0	63.0	10.0	30.0 mm	6.0~8.0 mm	$43

Noter: To use the roating holder, you should hold the waveplate in a ring holder first.

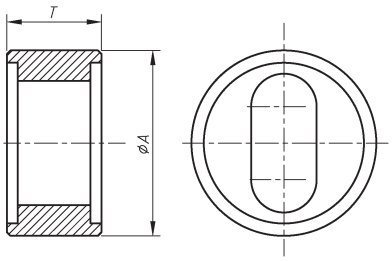
Crystal Holder

In order to prevent crystals from damaging or to be easily operated, FOCtek provide four kinds of mount of holder to install different dimension crystals. Please contact our sales for more information.

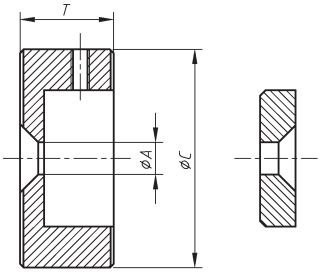
ΦC(mm)	T (mm)	Part No.	Crystal Aperture (mm)	Crystal Length (mm)	Unit Price
25.4	5.0	BH2001	4x4 - 10x10	0.1 - 2	$10.0
25.4	9.5	BH2002A	4x4 - 10x10	4 - 6	$10.0
25.4	9.5	BH2003	8x8 - 10x10	2 – 4	$10.0
25.4	13.5	BH2002B	4x4 - 10x10	6-10	$10.0



BH2001



BH2002A/BH2002B



BH2003

Note:

Delivery Time: 2 Weeks ARO(Typical)