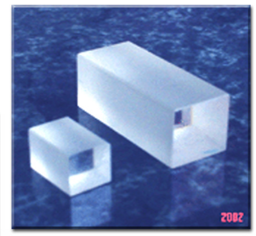
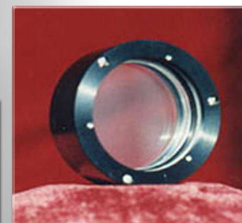
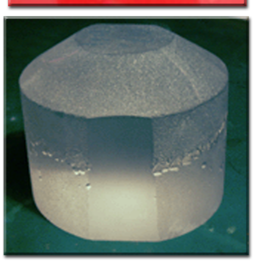
United Crystals

Catalog 2012







NLO Crystals & Devices
Laser Crystals & Devices
Optical Crystals & Devices
Polarizers & Wave Plates
Infrared & Ultraviolet Devices

www.unitedcrystals.com

Contents

Wave Plates

Appendix

Introduction

United Crystals Inc. is the leading manufacturer of nonlinear optical (NLO), laser, electro-optical (E-O) and optical crystals and devices with headquarter in Qingdao, China. We've provided multi-million pieces of LBO, KTP, BBO, DKDP, KDP, $LiIO_3$, ADP, $LiNbO_3$, LiTaO3, $AgGaS_2$, $AgGaSe_2$, Nd:YVO_4, YVO_4, Nd:YAG, YAG devices with high quality all over the world in the past decade, especially to North America and Europe. Please visit our web site to get the most updated information.

In addition to NLO crystals and Laser crystals, our product lines include various polarizers made of Calcite and α-BBO, as well as Quartz and Mica wave plates.

Right now, we also provide high quality ultraviolet and infrared optical materials, like CaF2, MgF2, LiF,BaF2 and ZnS, ZnSe, and their optical components.

Our senior scientist team has more than 30 years of crystal growth, device design and manufacturing experiences; and the company possesses the most advanced crystal growing and device manufacturing technologies in the world. The mass production capability and cutting-edge technologies enable United Crystals to produce high quality crystal and devices to meet the demands of both R&D and industrial customers.

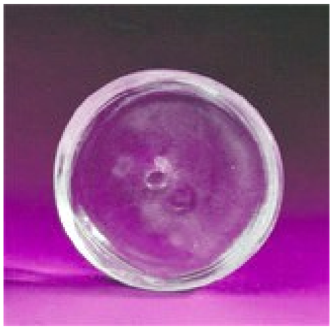
United Crystals Inc. makes every effort to provide high quality crystals and devices at the affordable price. The advanced technologies, mass production, well-organized management, and low labor cost make our products always the most competitive in the world.

New York branch is the sales and support division. Our sales and customer service engineers have strong background in theory and experiments of crystals, lasers and optics. We are always ready to reply your inquiries and offer you excellent services. Whatever crystals, optics, laser devices or technical services you need, please contact our representatives or United Crystals Inc. directly.

You can always get the latest updates, and all useful information from our website, http://www.unitedcrystals.com

Beta-Barium Borate (β-BaB_2O_4)

The combination of the nonlinear optical properties and the electro-optical properties makes Beta-Barium Borate (known as BBO) crystal one of the best candidates for both NLO applications and E-O applications.



BBO has shown the excellent performance in the second, third, fourth, even fifth harmonic generation of Nd doped laser systems, as well as in tunable Ti:Sapphire and Alexandrite, Dye, Ultrashort Pulse, Argon Ion and Copper-Vapor laser systems. BBO is also widely used in OPO and OPA applications to produce a widely tunable coherent radiation from the UV to IR.

Picture 1: BBO Crystal grown in United Crystals

In addition to its NLO applications, BBO is also used as EO crystal inside various modulators.

BBO Basic Properties:

Crystal symmetry:	Trigonal, space group R3c
Cell parameters:	a=b=12.532Å, c=12.717Å, Z=7
Melting point:	1095°C
Transition point:	925°C
Mohs hardness:	4.5
Density:	3.85 g/cm^3
Color:	colorless
Hygroscopic susceptibility:	low
Specific heat:	0.49 cal/g•°C
Thermal conductivity:	1.2 W/m/°K (⊥ to C), 1.6 W/m/°K (// to C)

BBO Optical Properties

Transmitting Range:	196nm ~ 2200nm		
Phase Matching Range:	189nm ~ 1750nm		
Refractive Indices:	@1064nm	1.6551(n_o)	1.5425(n_e)
	@532nm	1.6749(n_o)	1.5555(n_e)
	@266nm	1.75711(n_o)	1.6146 (n_e)
Sellmeier Equations: (λ in μm)	$N_o^2 = 2.7359+0.01878/(\lambda^2 -0.01822)-0.01354\lambda^2$		
	$N_e^2 = 2.3753+0.01224/(\lambda^2 -0.01667)-0.01516\lambda^2$		
Thermo-Optic Coefficient:(10^{-6}/°C)	$dn_o/dT=-9.3$	$dn_e/dT=-16.6$	
Absorption Coefficient:	a<0.1%/cm @1064nm		
Nonlinear Optical Coefficients and Equation:	$d_{11}=5.8d_{36}$(KDP)	$d_{31}=0.05d_{11}$	$d_{22}<0.05d_{11}$
	$d_{eff}(I)=d_{31}\sin\theta + (d_{11}\cos3\phi - d_{22}\sin3\phi)\cos\theta$ $d_{eff}(II)=(d_{11}\sin3\phi + d_{22}\cos3\phi)\cos^2\theta$		
Half-wave voltage:	48KV(at 1064 nm)		

Electro-Optic Coefficients:	γ_{11} = 2.7 pm/V, γ_{22}, γ_{31}< 0.1γ_{11}
Damage Threshold at 1064 nm at 532 nm:	5 GW/cm^2 (10 ns); 10 GW/cm^2 (1.3 ns); 1 GW/cm^2 (10 ns); 7 GW/cm^2 (250ps)

Applications:

In Nd:YAG and Nd:YLF laser systems:

BBO is an efficient NLO crystal for the second, third and fourth harmonic generation of Nd:YAG lasers, and the best NLO crystal for the fifth harmonic generation at 213nm. Conversion efficiencies of more than 70% for SHG, 60% for THG and 50% for 4HG, and 200mW output at 213nm (5HG) have been obtained, respectively. The comparisons of BBO with KD*P in a Nd:YAG laser and the basic nonlinear optical properties from SHG to 5HG are listed in Table 1 and Table 2.

Table 1. Comparison of Harmonic generations between BBO and DKDP

	1064nm(mJ)	SHG (mJ)	THG (mJ)	4HG (mJ)	5HG (mJ)
BBO	220	105	39	18.5	5
	600	350	140	70	20
DKDP	600	270	112.5	45	/

Table 2. Relative NLO properties for type I BBO crystal

	SHG	THG	4HG	5HG
Effective NLO Coefficient (d_{36} (KDP))	5.3	4.9	3.8	3.4
Acceptance Angle (mrad-cm)	1.0	0.5	0.3	0.2
Walk-off Angle (degree)	3.2	4.1	4.9	5.5

BBO is also an efficient crystal for the intra-cavity SHG of high power Nd:YAG lasers. Following are the phase matching angles for various harmonic generations.

1064nm SHG --> 532nm: Type I, θ=22.8°, ϕ=0°
1064nm THG --> 355nm: Type I, θ=31.3°, ϕ=0°; Type II θ=38.6°, ϕ=30°
1064nm 4HG --> 266nm: Type I, θ=47.6°, ϕ=0°
1064nm 5HG --> 213nm: Type I, θ=51.1°, ϕ=0°

In tunable laser systems:

1.Dye lasers

Efficient UV output (205nm-310nm) with a SHG efficiency of over 10% at wavelength of ≥206nm was obtained in type I BBO, and 36% conversion efficiency was achieved for a XeC1-laser pumped Dye laser with power 150KW which is about 4-6 times higher than that in ADP. The shortest SHG wavelength of 204.97 nm with efficiency of about 1% has been generated.

With type I sum-frequency of 780-950 nm and 248.5 nm (SHG output of 495 nm dye laser) in BBO, the shortest UV outputs ranging from 188.9nm to 197 nm and the pulse energy of 95 mJ at 193 nm and 8 mJ at 189 nm have been obtained, respectively.

670-530nm SHG --> 335-260nm: Type I, θ=40°, ϕ=0°
600-440nm SHG --> 300-220nm: Type I, θ=55°, ϕ=0°
444-410nm SHG --> 222-205nm: Type I, θ=80°, ϕ=0°

2.Ultrashort Pulse Laser

Frequency doubling and tripling of ultra short pulse lasers are the applications in which BBO shows superior properties to KDP and ADP crystals. We can provide as thin as 0.1mm BBO for this purpose. A laser pulse as short as 10fs can be efficiently frequency-doubled with a thin BBO, in terms of both phase-velocity and group-velocity matching.

Picture 2: BBO ultrashort pulse device

3.Ti:Sapphire and Alexandrite lasers

UV output in the region 360nm -390nm with pulse energy of 105 mJ (31% SHG efficiency) at 378 nm, and output in the region 244nm-259nm with 7.5 mJ (24% mixing efficiency) have been obtained for type I SHG and THG of an Alexandrite laser in BBO crystal.

720-800nm SHG --> 360-400nm: Type I, θ=31°, ϕ=0°
720-800nm THG --> 240-265nm: Type I, θ=48°, ϕ=0°

More than 50% of SHG conversion efficiency in a Ti:Sapphire laser has been obtained. High conversion efficiencies have been also obtained for the THG and FHG of Ti:Sapphire lasers.

700-1000nm SHG --> 350-500nm: Type I, θ=28°, ϕ=0°
700-1000nm THG --> 240-330nm: Type I, θ=42°, ϕ=0°
700-1000nm FHG --> 210-240nm: Type I, θ=66°, ϕ=0°

4. Argon Ion and Copper-Vapor lasers

By employing the intra-cavity frequency-doubling technique in an Argon Ion laser with all lines output power of 2W, maximum 33mW at 250.4 nm and thirty-six lines of deep UV wavelengths ranging from 228.9 nm to 257.2 nm were generated in a Brewster-angle-cut BBO crystal.

Up to 230mW average power in the UV at 255.3 nm with maximum 8.9% conversion efficiency was achieved in the SHG of a Copper-Vapor laser at 510.6 nm.

514nm SHG --> 257nm: Type I, θ=51°, ϕ=0°, Brewster-cut
488nm SHG --> 244nm: Type I, θ=55°, ϕ=0°, Brewster-cut

In OPA, OPO Applications

The OPO and OPA of BBO are powerful tools for generating a widely tunable coherent radiation from the UV to IR. The tuning angles for type I and II of BBO OPO and OPA have been calculated, and available upon request.

1.OPO pumped at 532 nm

The OPO output ranging from 680 nm to 2400 nm with the peak power of 1.6MW and up to 30% energy conversion efficiency was obtained in a 7.2 mm long type I BBO. The input pump energy was 40 mJ at 532nm with pulse-width 75ps. The BBO crystal cut angle for this application is: Type I, θ=21°, ϕ=0°.

2.OPO and OPA pumped at 355 nm

Pumped by Nd:YAG laser, BBO's OPO can generate wavelength tunable from 400nm to 2000nm with a maximum of 30% and more than 18% conversion efficiency.

Type II BBO can be used to decrease linewidth near the degenerate points. A linewidth as narrow as 0.05nm was obtained with the usable conversion efficiency of 12%. However, a longer (>15mm) BBO should normally be used to decrease the oscillation threshold when employing the type II phase-matching scheme.

Pumping with a Pico second Nd:YAG at 355nm, a narrow-band(<0.3nm), high energy (>200μJ) and wide tunable (400nm to 2000nm) pulse has been produced by BBO's OPAs. This OPA can reach as high as more than 50% conversion efficiency, and therefore is superior to common Dye lasers in many respects, including efficiency, tunable range, maintenance, and easiness in design and operation. Furthermore, coherent radiation from 205 nm to 3500 nm can be also generated by BBO's OPO or OPA plus a BBO for SHG. The crystal cut angle for 355nm pumped OPO is: θ=30° and ϕ=0° for Type I, θ=37°and ϕ=30° for Type II.

3.Others

A tunable OPO with signal wavelengths between 422 nm and 477 nm has been generated by angle tuning in a type I BBO crystal pumped by the fourth harmonic of a Nd:YAG laser (at 266 nm) has been observed to cover the whole range of output wavelengths 330 nm-1370nm. The crystal cut angle for 355nm pumped OPO is: Type I, θ=39°, ϕ=0°.

Pumped by a 1mJ, 80fs Dye laser at 615 nm, the OPA with two BBO crystals yields more than 50μJ (maximum 130μJ), <200fs ultra short pulse, over 800 nm-2000 nm.

Electro-Optical Applications:

BBO crystal is also widely used as electro-optical modulators. Please reference the Pockels Cell part of this catalog.

United Crystals' Standard Specifications on BBO Devices:

Dimension tolerance: (W ± 0.1 mm) x (H ± 0.1 mm) x (L + 0.2 mm/-0.1mm)
Transmitting wave-front distortion: less than $\lambda/4$ @ 633nm
Clear aperture: > 90% central area
Flatness: <$\lambda/8$ @ 633nm
Scratch/Dig code: 10/5 to MIL-O-13830A
Parallelism: better than 10 arc seconds
Perpendicularity: better than 5 arc minutes
Angle tolerance (degree): Dθ < ± 0.5, Dϕ < ± 0.5
AR coating: R< 0.2% at 1064nm and R<1.0% at 532nm
Protective coating: available upon request

Note:

BBO is not very hard, so polished surfaces need more precautions.
BBO has a low susceptibility to moisture, so please keep BBO devices in a dry circumstance.
Other applications of BBO devices are also available upon request.

KDP and its Isomorphic Crystals (KD*P and ADP)

KDP and its isomorphic single crystals, KD*P (DKDP) and ADP are widely used as non-linear optical and Electro-optic crystals, as well as Acoustic-Optic crystals.

For nonlinear optical applications, they are good candidates for the second, third and fourth harmonic generators for Nd:YAG and Nd:YLF lasers. These crystals are grown by water solution method and can be grown into very large size. Therefore, the low-cost and large-size nonlinear optical components are available. In the following Tables, we list the main properties and refractive indices of KDP and its isomorphic crystals.

Picture 1: DKDP Crystal Grown in United Crystals

Deuterated KDP, known as DKDP or KD*P, is the good candidate for Electro-optic devices, such as Pockels Cells, and Q-switches and modulators in solid laser systems due to its lower half-wave voltage than KDP and ADP.

ADP is also the good candidate in the acoustic-optical and X-ray applications

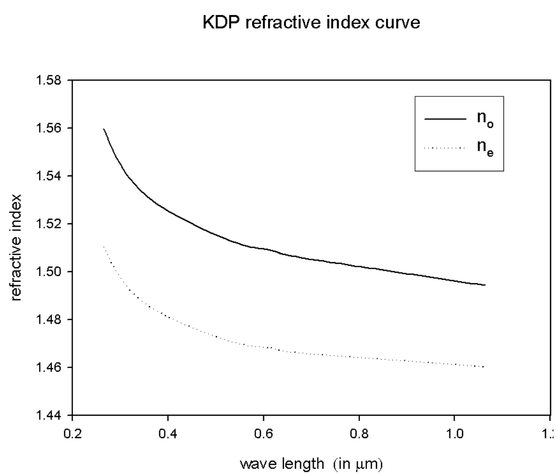
The Basic Properties of KDP and its Isomorphic Crystals

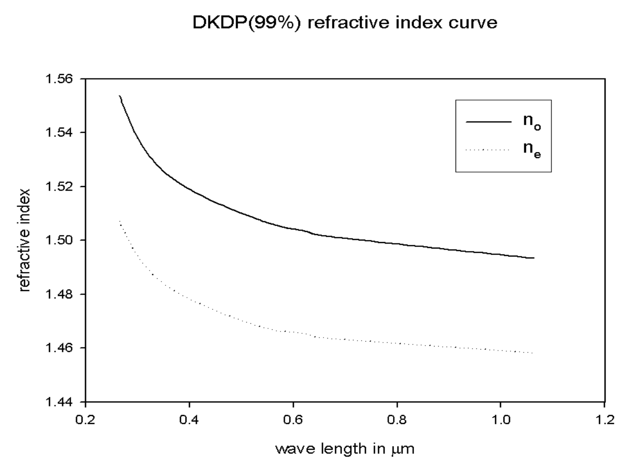
Crystal		KDP	DKDP	ADP
Chemical formula		KH_2PO_4	KD_2PO_4	$NH_4H_2PO_4$
Crystal Symmetry		$\bar{4}2m$	$\bar{4}2m$	$\bar{4}2m$
Density (g/cm^3)		2.332	2.355	1.799
Transmission Range (nm)		180~1550	200~2150	180~1500
Absorption (%/cm)		3	0.5	-
Damage Threshold (GW/cm^2) @1064nm		5	3	6
Nonlinear Optical Coefficient (pm/V)		0.43	0.40	0.52
Walk-off Angle (degree)		1.4(II)	1.4(II)	1.4(II)
Longitudinal Quarter wave voltage (kV)		-	3.6	-
Acceptance Bandwidth	Angular (mrad·cm)	3.7(II)	3.9(II)	3.7(II)
	Spectral (nm·cm)	11.2(II)	2.8(II)	18.8(II)
	Thermal (K·cm)	11(II)	6.7(II)	-
Group Velocity Mismatch (ps/cm)		1.3(II)	0.95(II)	1.47(II)
Thermal Expansion Coefficients (K^{-1})		-	$a_{11}=1.9\times10^{-5}$ $a_{33}=4.4\times10^{-5}$	-
Thermal Conductivity (W/cm·K^{-1})		-	$K_{11}=1.9\times10^{-2}$ $K_{22}=2.1\times10^{-2}$	-
Hygroscopic Susceptibility		High	High	High

Refractive Indices

Sellmeier Equation		$n^2=A+B/(\lambda^2-C)+D\lambda^2/(\lambda^2-E)$, λ in μm		
Sellmeier Coefficients		KDP	DKDP	ADP
A	n_o	2.2576	2.2409	2.3041
	n_e	2.1295	2.1260	2.1643
B	n_o	0.0101	0.0097	0.0111
	n_e	0.0097	0.0086	0.0097
C	n_o	0.0142	0.0156	0.0133
	n_e	0.0014	0.0120	0.0129
D	n_o	1.7623	2.2470	15.1086
	n_e	0.7580	0.7844	5.8057
E	n_o	57.8984	126.9205	400.0000
	n_e	127.0535	123.4032	400.0000

Following are the refractive index curves of KDP, DKDP.





Applications:

Frequency Conversion:

For frequency-doubling (Second Harmonic Generation, SHG) of Nd;YAG laser at 1064nm, both type I and type II phase-matching can be employed in KDP and DKDP. But for frequency-tripling (Third Harmonic Generation, THG) of Nd;YAG laser at 1064nm, only type II phase-matching is available. In the high power case, the KDP crystals are often employed with the standard site of $12x12x25mm^3$. For frequency-quadrupling (Fourth Harmonic Generation, 4HG, output at 266 nm) of Nd:YAG laser, KDP crystal is normally recommended. Following is the typical extra-cavity frequency conversion system.

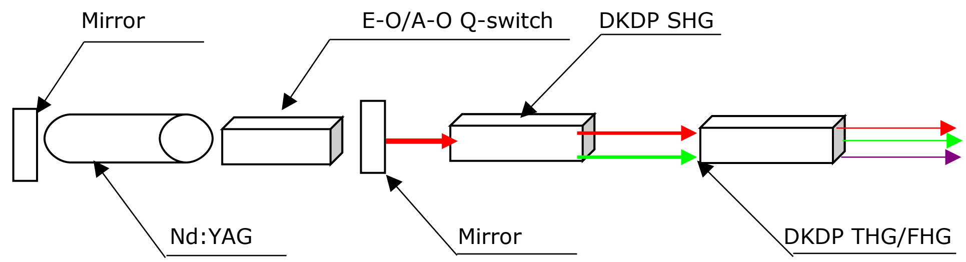
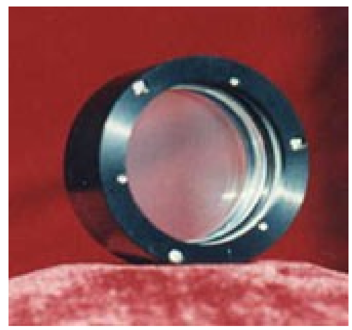


Figure 1. A typical Nd:YAG laser system with DKDP SHG, THG/FHG devices

The following are some KDP, DKDP and ADP devices from United Crystals.

Picture 2. Various DKDP, KDP devices.



Picture 3. KDP SHG with diameter of 75mm

Currently, we have some models in stock. Please contact our sales team for fast delivery. Customized devices also available upon request. In general, the estimated delivery is around 3 weeks.

Frequency doubling and tripling of ultra-short pulse lasers are also applicable to KDP, DKDP and ADP crystals. Now, United Crystals Co. can provide as thin as 100µm devices for this purpose.

Electro-Optical Applications:

KDP and isomorphic crystals are also widely used as electro-optical modulators. For details, please reference Pockels Cell part of this catalog.

United Crystals' Standard Specifications on DKDP Devices:

Clear aperture: > 90% central area
Dimension tolerance: (diameter +/- 0.1 mm) x (L + 0.2 mm/-0.1mm)
Wave front distortion: $\lambda/4$ at 633 nm
Flatness: $\lambda/8$ @ 633 nm
Optical Damage Threshold: > 3GW/cm^2 at 10Hz

Note:

For more details regarding our device dimension and other specifications, please download the data sheet for each device from our web site.

United Crystals Co. also provides as-cut (unpolished) and polished KDP, DKDP and ADP crystals. Contact our sales team for more details.

Due to the high Hygroscopic Susceptibility, the surfaces of KDP and its isomorphic crystals are easy to be moistened. Sealed housing with AR-coating windows is recommended for these crystals.

Potassium Titanyl Phosphate

Potassium Titanyl Phosphate, known as KTP ($KTiOPO_4$), is widely used in frequency doubling of Nd-doped laser systems for Green/Red output; parametric sources (OPG, OPA and OPO) for 600nm-4500nm tunable output; E-O modulators, Optical Switches, Directional Couplers; Optical Waveguides for Integrated NLO and E-O Devices etc.

Recently, with the development of KTP crystal growth technique, and high demand of compact green laser systems, the price of KTP devices drop dramatically, and the quality improved greatly at the same time, as well as its stability, no hygroscopic susceptibility, availability of large size, these facts make KTP more competitive and more attractive than ever.

Picture 1: KTP Crystal grown in United Crystals

United Crystals' KTP features high damage threshold, and low absorption, as well as high conversion efficiency.

KTP Basic Properties:

Crystal symmetry:	Orthorhombic
Point group:	mm2
Cell parameters:	a=6.404Å, b=10.616Å, c=12.814Å, Z=8
Melting point:	1172°C incongruent
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
Electronic conductivity:	3.5x10^{-8} s/cm (c-axis, 22°C, 1KHz)

KTP Optical Properties

Transmitting Range:	350nm ~ 4500nm			
Phase Matching Range:	984nm ~ 3400nm			
Refractive Indices:	@1064nm	1.7377(n_x)	1.7453(n_y)	1.8297(n_z)
	@532nm	1.7780(n_x)	1.7886(n_y)	1.8887(n_z)
Sellmeier Equations: (λ in μm)	$N_x^2 = 3.0065 + 0.03901 / (\lambda^2 - 0.04251) - 0.01327\lambda^2$			
	$N_y^2 = 3.0333 + 0.04154 / (\lambda^2 - 0.04547) - 0.01408\lambda^2$			
	$N_z^2 = 3.3134 + 0.05694 / (\lambda^2 - 0.05658) - 0.01682\lambda^2$			
Thermo-Optic Coefficient: (10^{-5}/°C)	dn_x/dT=1.1	dn_y/dT=1.3	dn_z/dT=1.6	
Absorption Coefficient:	a<0.1%/cm @1064nm and 532nm			

Nonlinear Optical Coefficients (pm/V) and Equation:	@1064nm	$d_{31}=2.54$	$d_{32}=4.35$	$d_{33}=16.9$
		$d_{24}=3.64$	$d_{15}=1.91$	
	$d_{eff}(II)=(d_{24}- d_{15})\sin2\phi \sin2\theta - (d_{15}\sin^2\phi + d_{24}\cos^2\theta)\sin\theta$			
Electro-optic coefficients:	Low Frequency (pm/V)		High Frequency (pm/V)	
r_{13}	9.5		8.8	
r_{23}	15.7		13.8	
r_{33}	36.3		35.0	
r_{51}	7.3		6.9	
r_{42}	9.3		8.8	
Di-electric constant:	$\varepsilon_{eff}=13$			

Applications:

Frequency Conversion:

KTP was first introduced as the NLO crystal for Nd doped laser systems with high conversion efficiency. Under certain conditions, the conversion efficiency was reported to 80%, which leaves other NLO crystals far behind it. Following is the typical intra-cavity frequency conversion system.

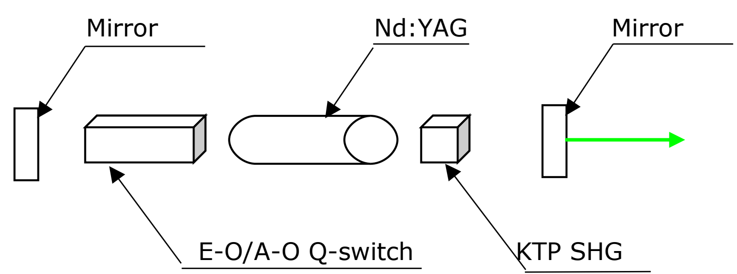


Figure 1. A typical intra-cavity Nd:YAG + KTP frequency doubling system

Recently, with the development of laser diodes, KTP is widely used as SHG devices in diode pumped $Nd:YVO_4$ solid laser systems to output green laser, and make the laser system very compact.

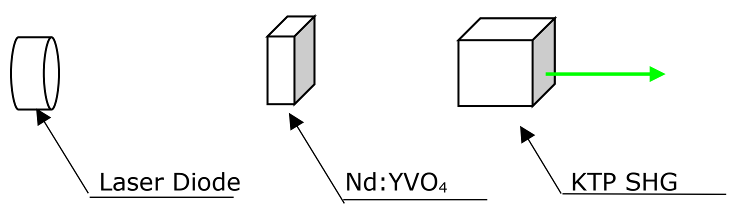


Figure 2. A compact diode pumped green laser system

Frequency doubling of ultra-short pulse lasers is also applicable to KTP crystal. Now, United Crystals can provide as thin as 100μm of devices for this purpose.

KTP for OPA, OPO Applications:

In addition to be widely used as frequency doubling devices in Nd-doped laser systems for Green/Red output, KTP is also one of the most important crystals in parametric sources for tunable output from visible (600nm) to mid-IR (4500nm) due to the popularity of its pumped sources, the fundamental and second harmonic of a Nd:YAG or Nd:YLF lasers.

One of the most useful applications is the non-critical phase-matched (NCPM) KTP OPO/OPA pumped by the tunable lasers to obtain the high conversion efficiency. The following table shows the output wavelength of Type II KTP NCPM OPO.

Picture 2: KTP SHG, OPO devices

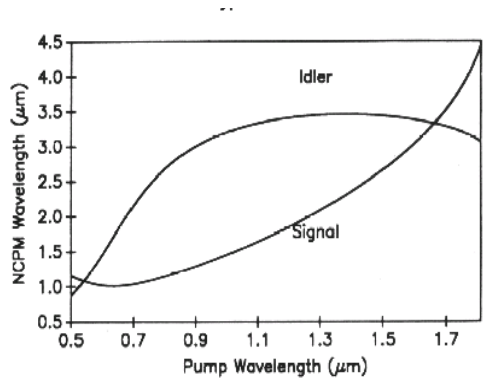


Figure 3: KTP TYPE II NCPM OPO

KTP OPO results in the stable continuous outputs of femto-second pulse of 108 Hz repetition rate and milli-watt average power levels in both signal and idler outputs. Pumped by Nd-doped lasers, KTP OPO has obtained above 66% conversion efficiency for degenerate conversion from 1060nm to 2120nm. The following two tables show the phase-matching angles and effective NLO coefficient for OPO/OPA pumped at 1064nm and 532nm in XZ plane.

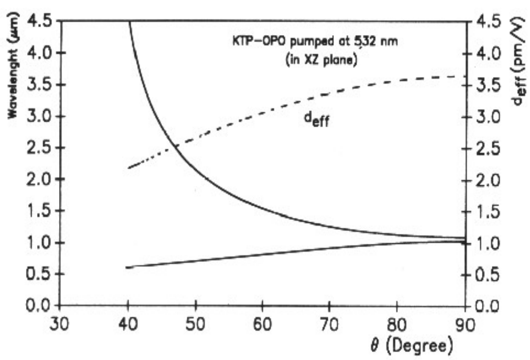


Figure 4: OPO pumped at 532nm

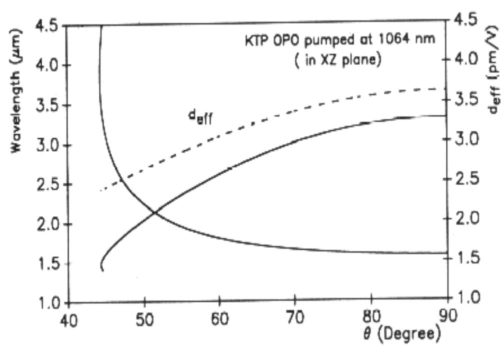


Figure 5: OPO pumped at 1064nm

Electro-Optical modulators:

KTP crystal can be used as electro-optical modulators. More information, please visit our web site at www.unitedcrystals.com

United Crystals' Standard Specifications on KTP Devices:

Dimension tolerance: (W ± 0.1 mm) x (H ± 0.1 mm) x (L + 0.2 mm/-0.1mm)
Transmitting wave-front distortion: less than λ/4 @ 633nm
Clear aperture: > 90% central area
Flatness: <λ/8 @ 633nm
Scratch/Dig code: 10/5 to MIL-O-13830A
Parallelism: better than 10 arc seconds
Perpendicularity: better than 5 arc minutes

Angle tolerance (degree): $D\theta < \pm 0.5$, $D\phi < \pm 0.5$

AR coating: R< 0.2% at 1064nm and R<1.0% at 532nm

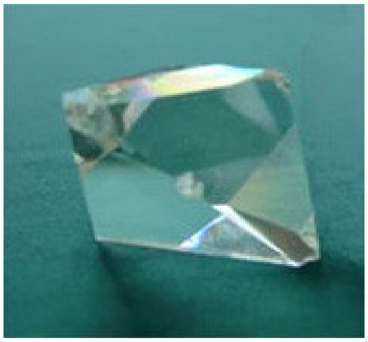
Note:

Currently, we have the capability of producing 5,000 pieces of KTP 3x3x5mm devices per month, along with 5,000 pieces of $Nd:YVO_4$ devices per month. To learn our competitive price and huge OEM discount, please contact our sales team for details.

Lithium Tri-borate

Lithium triborate, known as LBO (LiB_3O_5), is one of the most excellent nonlinear optical crystals ever discovered in the world.

Its high damage threshold make LBO crystal is very suitable for harmonic generation of high-intensity laser radiation in wide spectra. LBO allows to achieve the highly efficient SHG of nanosecond, Pico second, CW and diode pumped Nd:YAG and Nd:YLF laser systems for R&D, medical, industrial and military applications.



Picture 1: LBO Crystal grown in United Crystals

In addition to high damage threshold, the superiority of LBO is also proven by the SHG of Ti:Sapphire, Cr:LiSAF and Alexandrite laser systems, as well as the optical parametric amplifiers and oscillators pumped by Excimer laser systems or harmonics of Nd:YAG systems.

LBO's good transmission in the UV range allows obtaining tunable UV and VUV radiation by SFG.

LBO Basic Properties:

Crystal Structure:	Orthorhombic
Space group:	Pna21
Point group:	mm2
Cell parameters:	a=8.4473Å, b=7.3788Å, c=5.1395Å, Z=2
Melting point:	834°C
Mohs hardness:	6
Density:	2.47g/cm^3
Color:	colorless
Hygroscopic susceptibility:	no

LBO Optical Properties

Transmitting Range:	160nm ~ 2300nm			
Phase Matching Range:	550 to 3000nm (I) 790nm ~ 2200nm (II)			
Refractive Indices:	@1064nm	1.5648 ($n_{x=b}$)	1.5904 ($n_{y=c}$)	1.6053 ($n_{z=a}$)
	@532nm	1.5785 ($n_{x=b}$)	1.6065 ($n_{y=c}$)	1.6212 ($n_{z=a}$)
	@355nm	1.5973 ($n_{x=b}$)	1.6286 ($n_{y=c}$)	1.6444 ($n_{z=a}$)
Sellmeier Equations: (λ in μm)	$N_x^2=2.454140+0.011249/(\lambda^2-0.011350)-0.014591\lambda^2-6.60\times10^{-5}\lambda^4$			
	$N_y^2=2.539070+0.012711/(\lambda^2-0.012523)-0.018540\lambda^2+2.00\times10^{-4}\lambda^4$			
	$N_z^2=2.586179+0.013099/(\lambda^2-0.011893)-0.017968\lambda^2-2.26\times10^{-4}\lambda^4$			

Absorption Coefficient:	a<0.1%/cm @1064nm			
Damage Threshold:	$25GW/cm^2$ at 1.064um, 0.1ns pulse, 2.3J			
Nonlinear Optical Coefficients (pm/V) and Equation:	@1064nm	$d_{31}=d_{15}=0.85$	$d_{32}=d_{24}=-0.67$	$d_{33}=0.04$
	d_{eff}(I in XY plane)=$d_{32}\cos\varphi$ d_{eff}(I in XZ plane)=$d_{31}\cos^2\theta+d_{32}\sin^2\theta$ d_{eff}(II in YZ plane)=$d_{31}\cos\theta$ d_{eff}(II in XZ plane)=$d_{31}\cos^2\theta+d_{32}\sin^2\theta$			

Applications:

Frequency Conversion for Nd Laser Systems:

LBO is able to achieve phase matching for the SHG and THG of Nd:YAG and Nd:YLF lasers, using either type I or type II interaction. For the SHG at room temperature, type I phase matching can be reached, and has the maximum effective SHG coefficient in the principal XY and XZ planes in a wide wavelength range from 551 nm to about 3000nm. The effective SHG coefficients are as following:

$d_{eff}(I)=d_{32}\cos\varphi$ ----(in XY plane)

$d_{eff}(I)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ ----(in XZ plane)

The optimum type II phase matching falls in the principal YZ and XZ planes with the effective SHG coefficient as:

$d_{eff}(II)=d_{31}\cos\theta$ ----(in YZ plane)

$d_{eff}(II)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ ----(in XZ plane)

SHG conversion efficiencies of more than 70% for pulsed and 30% for cw Nd:YAG laser, and THG conversion efficiency over 60% for pulsed Nd:YAG laser have been observed.

More than 480mW output at 395nm is generated by frequency doubling a 2W mode-locked Ti:Sapphire laser (＜2ps, 82MHz). The wavelength range of 700-900nm is covered by a 5x3x8 mm^3 LBO crystal.

Over 80W green output is obtained by SHG of a Q-switched Nd:YAG laser in a type II 18mm long LBO crystal.

The frequency doubling of a diode pumped Nd:YLF laser (＞500μJ @ 1047nm, ＜7ns, 0-10KHz) reaches over 40% conversion efficiency in a 9mm long LBO crystal.

The VUV output at 187.7 nm is obtained by sum-frequency generation.

2mJ/pulse diffraction-limited beam at 355nm is obtained by intra-cavity frequency tripling a Q-switched Nd:YAG laser.

The phase matching angle for Nd:YAG laser system at maximum d_{eff} under room temperature is as following: ϴ=11.4° and Φ=0° for Type I, ϴ=90° and Φ=69.1° for Type II.

Non-Critical Phase-Matching Applications:

Non-Critical Phase-Matching (NCPM) of LBO is featured by no walk-off, very wide acceptance angle and maximum effective coefficient. It promotes LBO to work in its optimal condition. SHG conversion efficiencies of more than 70% for pulsed and 30% for cw Nd:YAG lasers have been obtained with good output stability and beam quality.

Properties of type I NCPM SHG at 1064nm

NCPM Temperature	148°C
Acceptance Angle	52 mrad-cm$^{1/2}$
Walk-off Angle	0
Temperature Bandwidth	4°C-cm
Effective SHG Coefficient	2.69d_{36}(KDP)

Both type I and type II non-critical phase matching can be achieved along x-axis and z-axis at room temperature, respectively.

LBO can reach both temperature NCPM and spectral NCPM (very wide spectral bandwidth) at 1300nm. This is favorable to the SHG of Nd lasers working at 1300nm for red light output.

LBO for OPA, OPO Applications:

LBO is an excellent NLO crystal for OPOs and OPAs with a widely tunable wavelength range and high powers. Both OPO and OPA, pumped by the SHG and THG of Nd:YAG laser and XeCl excimer laser at 308nm, have been reported. The unique properties of both type I and type II phase matching, along with the NCPM, leave a big room for research and industry.

A quite high overall conversion efficiency and 540-1030nm tunable wavelength range were obtained with OPO pumped at 355nm.

Type I OPA pumped at 355nm with the pump-to-signal energy conversion efficiency of 30% has been reported.

Type II NCPM OPO pumped by a XeC1 excimer laser at 308nm has achieved 16.5% conversion efficiency, and moderate tunable wavelength ranges can be obtained with different pumping sources and temperature tuning.

By using the NCPM technique, type I OPA pumped by the SHG of a Nd:YAG laser at 532nm was also observed to cover a wide tunable range from 750nm to 1800nm by temperature tuning from 106.5°C to 148.5°C.

Pumped by a 4.8mJ, 30ps laser at 354.7nm, a narrow line-width (0.15nm) and high pump-to-signal energy conversion efficiency (32.7%) were observed by using LBO with type II NCPM as an optical parametric generator (OPG) and BBO with type I critical phase matching as an OPA. By increasing the temperature of LBO and rotating BBO, we can obtain laser radiation from 415.9nm to 482.6nm.

The calculated results and tuning curves of both type I and type II OPO of LBO pumped by the SHG, THG and 4HG of Nd:YAG laser are available upon request.

Others:

Customized LBO devices are also available upon request.

United Crystals' Standard Specifications on LBO Devices:

Dimension tolerance: (W ± 0.1 mm) x (H ± 0.1 mm) x (L + 0.2 mm/-0.1mm)

Transmitting wave-front distortion: less than λ/4 @ 633nm

Clear aperture: > 90% central area

Flatness: <λ/8 @ 633nm

Scratch/Dig code: 10/5 to MIL-O-13830A
Parallelism: better than 10 arc seconds
Perpendicularity: better than 5 arc minutes
Angle tolerance (degree): $D\theta < \pm 0.5$, $D\phi < \pm 0.5$
AR coating: R< 0.2% at 1064nm and R<1.0% at 532nm

Note:

For more information regarding this product and/or ordering, please visit our web site at www.unitedcrystals.com or e-mail to info@unitedcrystals.com.

Lithium Iodate (α-$LiIO_3$) Crystal

Lithium Iodate (α-$LiIO_3$) crystal is a uniaxial nonlinear crystal with high nonlinear optical coefficients and wide transparency range. It is used to frequency doubling of the low and medium power Ti:Sapphire, Alexandrite, Cr:$LiSrAlF_6$ and Cr:$LiCaAIF_6$ lasers. In some cases, it is also used for frequency-doubling and frequency-tripling of Nd:YAG lasers and autocorrelations for measuring ultra short pulse width. Other applications include autocorrelators, AO devices and piezoelectric sensors.

Picture 1. $LiIO_3$ crystal grown in United Crystals

Picture 2. $LiIO_3$ devices

$LiIO_3$ Basic Properties:

Crystal Symmetry:	Hexagonal
Point Group:	6
Lattice Constant**:**	a =b=5.4815 Å, c = 5.1709Å
Density:	4.487 g/cm^3
Mohs Hardness:	4
Melting Point:	420˚C
Phase Transition Point:	247˚C
Color:	colorless
Hygroscopic susceptibility:	high
Thermal Expansion Coefficient (at 300K):	$Z_{\|\|}$ = 48x10^{-6}/K; $Z\perp$= 28x10^{-6}/K
Specific Heat (J/g/°C):	0.55

$LiIO_3$ Optical Properties

Transmitting Range:	300nm ~ 5000nm (> 85% at 350nm)		
Phase Matching Range:	570nm ~ 4000nm		
Refractive Indices:	@1064nm	1.8571(n_o)	1.7165(n_e)
	@632.8nm	1.8815(n_o)	1.7351(n_e)
	@354.7mm	1.9822(n_o)	1.8113(n_e)
Sellmeier Equations:(λ in µm)	N_o^2 =3.4157+0.04703/(λ^2-0.03531)-0.008801λ^2		
	N_e^2 =2.9187+0.03515/(λ^2-0.02822)-0.003641λ^2		
Half Wave Voltage @ 0.63µm: (for r_{33}-r_{13} transverse mode)	52kV		

Absorption Coefficient:	a<0.5%/cm @1064nm		
Nonlinear Optical Coefficients:	@1064nm	d_{31}=- 7.1pm/V	d_{33}= - 7.0 pm/V
Effective SHG Coefficient:	8.5 X d_{36} (KDP)		
Laser Damage Threshold:	250MW/cm^2 at 1064nm		
Electro-optic coefficients:	Frequency at 64-76Mhz (pm/V)		
r_{13}	4.1±0.6		
r_{33}	6.4±1.0		
r_{51}	3.3±0.7		
r_{41}	1.4±0.2		
Phase matching Angle for SHG:	θ, Degrees to c axis		
0.580μm	90°(calculated)		
0.61μm	64°		
0.9460μm	34.1°		
1.0648μm	29.4°		
1.0845μm	28.9°		
1.1523μm	27.2°		
1.32μm	23.0°		
1.338μm	22.7°		

United Crystals' Standard Specifications on $LiIO_3$ Devices:

Dimension tolerance: ± 0.05mm

Transmitting wave-front distortion: less than λ/4 @ 633nm

Optical Axis Orientation: ±0.5°

Flatness: <λ/8 @ 633nm

Scratch/Dig code: 10/5 to MIL-O-13830A

Parallelism: better than 10 arc seconds

Perpendicularity: better than 5 arc minutes

Note:

$LiIO_3$ is highly hygroscopic. Please keep it in dry environment. We offer various housing with AR coating windows.

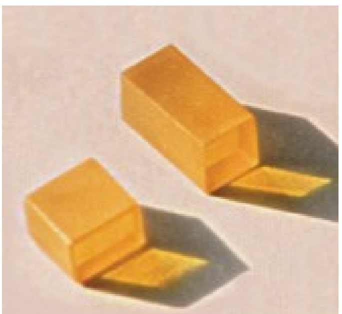
The damage threshold of $LiIO_3$ is low, so it is not recommended for high power applications.

Tight focusing is not recommended because $LiIO_3$ has small acceptance angles and large walk-off angle.

For more information regarding this product and/or ordering, please visit our web site at www.unitedcrystals.com or e-mail to info@unitedcrystals.com

$AgGaS_2$ and $AgGaSe_2$ Crystals

$AgGaSe_2$ and $AgGaS_2$ crystals are the ideal candidates for the frequency doubling of infrared radiation such as the 10.6um, the output of popular CO_2 lasers. They have also been shown to be the efficient crystals for nonlinear three-wave interactions. With suitable pump lasers, $AgGaS_2$ and $AgGaSe_2$ optical parametric oscillators (OPO's) can produce continuously tunable radiation over a wide range of wavelengths in the infrared.



Picture 1. $AgGaS_2$ devices

Pumped by 2.05μm lasers, the $AgGaSe_2$ OPO could be turned into a tunable laser source from 2.5 to 12um. With the sum or difference frequency mixing (SFM/DFM), the output range can be extended dramatically.

A wide range from the visible to mid-IR could be covered by the various SFM/DFM interactions of $AgGaS_2$. These include non-critically phase matched DFM using selected wavelengths (available from tunable dye and Ti:sapphire lasers), and OPO's pumped by Nd:YAG lasers.

Their excellent properties include a high nonlinear coefficient, high damage threshold, and a wide transmission range, as well as low optical absorption, scattering and low wavefront distortion. Among commercially available crystals, $AgGaSe_2$ has the highest figure of merit for nonlinear interactions in the near and deep infrared. Their applications include wavelength selectable medical procedures, LIDAR, a solid-state equivalent of an IR dye laser, and a wide variety of spectroscopic applications.

Basic Properties of $AgGaS_2$/$AgGaSe_2$ Crystals

Crystal Symmetry:	Tetragonal
Point Group:	$\bar{4}$ 2m
Lattice Constant:	a=5.7566Å; c=10.3016Å/ a=5.9920Å; c=10.88626Å
Density (g/cm^3):	4.7 / 5.7
Melting Point:	997°C / 851°C
Hygroscopic susceptibility:	none
Thermal Expansion Coefficient (at 300K):	$Z_{\parallel}$=12.5/K; Z⊥=-13.2/K / $Z_{\parallel}$= 6.8/K; Z⊥=-7.8/K
Heat Capacity (J/mole/°C):	99.8 / 97

$AgGaSe_2$ and $AgGaS_2$ Optical Properties

		$AgGaS_2$	$AgGaSe_2$
Transmitting Range (in μm):		0.50 to 13.2	0.78 to 18.0
Phase Matching Range:		1.8 to 11.2(I); 2.5 to 7.7(II)	3.1 to 12.8(I); 4.7 to 8.1(II)
Refractive Indices (in μm):	13.5		2.5731(n_o), 2.5404(n_e)
	12.0	2.3266(n_o), 2.2716(n_e)	
	10.6	2.3472(n_o), 2.2934(n_e)	2.5912(n_o), 2.5579(n_e)

	5.3	2.3945(n_o), 2.3408(n_e)	2.6134(n_o), 2.5808(n_e)
	3.0	2.4080(n_o), 2.3545(n_e)	2.6245(n_o), 2.5925(n_e)
	1.064	2.4521(n_o), 2.3990(n_e)	2.7010(n_o), 2.6792(n_e)
	0.589	2.5834(n_o), 2.5406(n_e)	
dn/dT (10^{-6}/°C)	1.06μm	dn_o/dT= 167; dn_e/dT= 176	dn_o/dT= 98; dn_e/dT= 66
	3.39μm	dn_o/dT= 154 ; dn_e/dT= 155	dn_o/dT= 74; dn_e/dT= 43
	10.6μm	dn_o/dT= 149; dn_e/dT= 156	dn_o/dT= 58; dn_e/dT= 46
Absorption Coefficient:		a<1%/cm @1.064μm	a<2%/cm @1.064μm
		a<10%/cm @1.8μm	a<2%/cm @1.8μm
		a<2%/cm @2.1μm	a<5%/cm @2.1μm
		a<6%/cm @10.6μm	a<2%/cm @10.6μm
Laser Damage Threshold:		25MW/cm^2 at 10.6μm	25MW/cm^2 at 10.6μm
Electro-optic coefficients: (pm/V)		r_{41}= 4.0	r_{41}= 4.5
		r_{63}= 3.0	r_{63}= 3.9
Phase matching Angle for SHG:		71.5° @10.6μm (Type I)	57.0° @10.6μm (Type I)

United Crystals' Standard Specifications on $AgGaSe_2$ and $AgGaS_2$ Devices:

Dimension tolerance: ± 0.05mm

Transmitting wave-front distortion: less than λ/4 @ 633nm

Optical Axis Orientation: ±0.5°

Flatness: <λ/8 @ 633nm

Scratch/Dig code: 10/5 to MIL-O-13830A

Parallelism: better than 10 arc seconds

Perpendicularity: better than 5 arc minutes

Note:

For more information regarding this product and/or ordering, please visit our web site at www.unitedcrystals.com or e-mail to info@unitedcrystals.com

$Nd:YVO_4$ Crystal

$Nd:YVO_4$ crystal is one of the most excellent laser host materials, it is suitable for diode laser-pumped solid state laser. The crystal has these main features: low lasing threshold, high slope efficiency, large stimulated emission cross-section, high absorption over a wide pumping wavelength bandwidth, easy tuning for single mode and high tolerance for pumping wavelength. Recent developments have shown that $Nd:YVO_4$ micro-lasers can produce powerful and stable IR and green or red laser with the design of $Nd:YVO_4$+KTP.

Compared with Nd:YAG and Nd:YLF for diode laser pumping, $Nd:YVO_4$ lasers possess the advantages of lower dependency on pump wavelength and temperature control of a diode laser, wide absorption band, higher slope efficiency, lower lasing threshold, linearly polarized emission and single-mode output. For the applications in which more compact design and the single-longitudinal-mode output are needed, $Nd:YVO_4$ shows its particular advantages over other commonly used laser crystals. The diode laser-pumped $Nd:YVO_4$ compact laser and its frequency-doubled green, red or blue laser will be the ideal laser tools of machining, material processing, spectroscopy, wafer inspection, light show, medical diagnostics, laser printing and the most widespread applications.

Picture 1: $Nd:YVO_4$ Crystal grown in United Crystals Picture 2: $Nd:YVO_4$ rods (phi3.5x12mm)

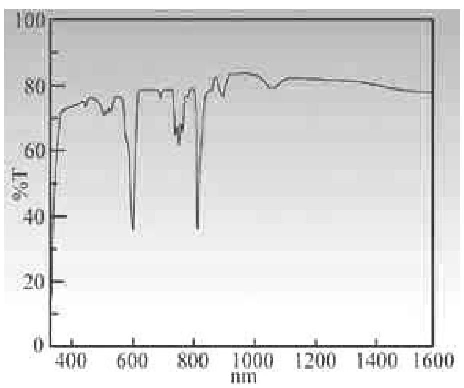
$Nd:YVO_4$ Basic Properties:

Crystal symmetry	Zircon Tetragonal, space group D_{4h},
Lattice constant	a = b =7.118Å ,c = 6.293Å
Mohs hardness	4.6 ~ 5
Melting point	1810±25℃
Density (g/cm^3)	4.22
Thermal conductivity coefficient	∣∣C: 5.23 W/m/K; ⊥C: 5.10 W/m/K
Thermal expansion coefficient	$\alpha a = 4.43\times10^{-6}$/K; $\alpha c = 11.4\times10^{-6}$/K

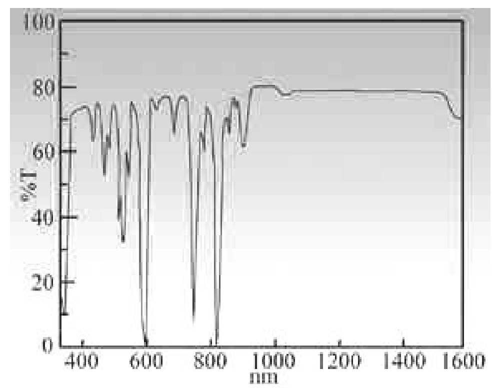
$Nd:YVO_4$ Optical Properties (typically for 1.1 atm% Nd:YVO4, a-cut crystals):

Lasing Wavelengths:	914nm, 1064 nm, 1342 nm		
Refractive Indices:	@1064nm	1.9573 (n_o)	2.1652 (n_e)
	@808nm	1.9721 (n_o)	2.1858 (n_e)
	@532nm	2.0210 (n_o)	2.2560 (n_e)

Sellmeier Equations: (λ in µm, for pure YVO4 crystals)	$n_o^2=3.77834+0.069736/(\lambda^2 - 0.04724) - 0.0108133\lambda^2$
	$n_e^2=4.59905+0.110534/(\lambda^2 - 0.04813) - 0.0122676\lambda^2$
Stimulated Emission Cross-Section	$25.0\times10^{-19}cm^2$ @1064 nm
Fluorescent Lifetime	90 µs (about 50µs for 2 atm% Nd doped) @ 808 nm
Absorption Coefficient	31.4 cm^{-1} @ 808 nm
Absorption Length	0.32 mm @ 808 nm
Intrinsic Loss	Less 0.1% cm^{-1} @1064 nm
Gain Bandwidth	0.96 nm (257 GHz) @ 1064 nm
Polarized Laser Emission	π polarization; parallel to optic axis (c-axis)
Diode Pumped Optical to Optical Efficiency	> 60%
Thermal Optical Coefficient:	$dn_a/dT=8.5\times10^{-6}/K$, $dn_c/dT=3.0\times10^{-6}/K$



Picture 1. Absorption Curve of 0.5% doping YVO_4



Picture 2. Absorption Curve of 3.0% doping YVO_4

Applications:

1. Diode Laser-Pumped $Nd:YVO_4$ Lasers

A threshold of 78mW and a slope efficiency of 48.5% at 1064nm were obtained by using an a-cut 3 mm long $Nd:YVO_4$ crystal with output coupler R = 96%. Under the same conditions, a 5 mm long Nd:YAG crystal has a threshold of 115mW and a slope efficiency of 38.6%.

Recently, over 30W of TEM_{00} output power was achieved by using a-cut $Nd:YVO_4$ and pumped by 60W fiber coupled diode lasers. The optical conversion efficiency exceeds 50%. High power and stable infrared output @1064nm and 1342nm has been available with diode pumped $Nd:YVO_4$ lasers.

Single-longitudinal-mode oscillation of a $Nd:YVO_4$ microchip laser has been achieved with high power and high slope efficiency. Such a single mode source has been developed for the use of a master oscillator for injection locking of Nd laser systems.

Because of its large stimulated emission cross section at 1.34mm, $Nd:YVO_4$ is also an efficient laser crystal for diode laser-pumped 1.3mm laser. By using 1mm long $Nd:YVO_4$ crystal and pumped by an 850mW diode laser at 808nm, 50mW output at 1.34mm has been observed, compared to 34mW from 2mm long Nd:YAG.

2. Frequency-doubled $Nd:YVO_4$ Lasers

By using the compact design of $Nd:YVO_4$ + KTP crystals, high power green or red light output can be generated in a diode laser pumped $Nd:YVO_4$ laser. When pumped by a 890mW diode laser, more than 76mW single mode (TEM_{00}) green output was obtained with a 3x3x1 mm^3 $Nd:YVO_4$ and a 3x3x5 mm^3 intra-cavity KTP.

Diode pumped green lasers has been commercialized with the compact design of $Nd:YVO_4$ + KTP crystals. 2.5mW green output was achieved in a $Nd:YVO_4$ microchip laser with a very short (9mm) laser cavity when pumped by a 50mW diode laser.

Over 10W and high stable CW green output at 532nm was commercially available with diode pumped $Nd:YVO_4$ and frequency double using NCPM LBO crystals. Single longitudinal mode (SLM) green output, Q-switched green and UV outputs were also obtained.

Over 400mW blue laser at 457nm based on $Nd:YVO_4$+ BBO crystals, is commercially available.

Following is the simple demonstration of the compact diode pumped green laser system.

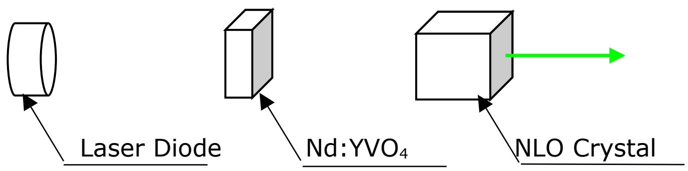


Figure 1. A compact diode pumped green laser system

United Crystals' Standard Specifications on $Nd:YVO_4$ Devices:

Dimension tolerance: (W ± 0.1 mm) x (H ± 0.1 mm) x (L + 0.2 mm/-0.1mm)

Transmitting wave-front distortion: less than $\lambda/4$ @633nm

Clear aperture: > 90% central area

Flatness: $<\lambda/8$ @ 633nm

Scratch/Dig code: 10/5 to MIL-O-13830A

Parallelism: better than 10 arc seconds

Perpendicularity: better than 5 arc minutes

Angle tolerance (degree): $D\theta < \pm 0.5$, $D\phi < \pm 0.5$

AR coating: available upon request

Note:

Currently, we have the capability of producing $Nd:YVO_4$ 3x3x1mm, 5,000 pieces per month. To learn our competitive price and huge OEM discount, please contact our sales team for details.

Nd:YAG Crystal

Nd:YAG crystal is the most widely used solid-state laser crystal since it has been discovered. The development of laser diodes makes Nd:YAG laser systems more powerful and compact than ever.

As the leading YAG crystal manufacturer, United Crystals make every effort to improve the quality and decrease the costs of YAG products. Right now, we can offer Nd:YAG rods with Nd concentrate as high as **1.2%**.

Picture 1: Nd:YAG rod (phi10x150mm)

Nd:YAG Basic Properties **(1.0 atm% Nd doped)**:

Chemical Formula	Nd:$Y_3Al_5O_{12}$
Crystal symmetry	Cubic
Lattice constant	12.01 Å
Concentration	~ 1.2 x 10^{20} cm^{-3}
Mohs hardness	8.5
Melting point	1970°C
Density (g/cm^3)	4.56
Thermal conductivity coefficient (W/m/K)	14 @20°C, 10.5 @100°C
Thermal expansion coefficient	7.8 x 10^{-6} /K [111], 0 - 250°C
Refractive Index	1.82
Lasing Wavelength	1064 nm
Stimulated Emission Cross Section	2.8x10^{-19} cm^{-2}
Relaxation Time of Terminal Lasing Level	30 ns
Radiative Lifetime	550 ms
Spontaneous Fluorescence	230 ms
Loss Coefficient	0.003 cm^{-1} @ 1064 nm
Effective Emission Cross Section	2.8 x 10^{-19} cm^2
Pump Wavelength	807.5 nm
Absorption band at pump wavelength	1 nm
Linewidth	0.6nm
Polarized Emission	Unpolarized
Thermal Birefringence	High

Picture 2. Ho:Cr:Tu:YAG Rod **Picture 3.** Nd:YAG Slab with Brewster Angles

United Crystals' Standard Specifications on Nd:YAG Devices:

Dimension tolerance: (diameter ± 0.1mm) x (L + 0.2mm/ - 0.1mm)
Dopant Concentration (atomic %): 0.9%~ 1.2%
Chamfer: <0.1 mm @45 degrees
Clear Aperture: extend over the entire faces to the chamfered edges
Transmitting wave-front distortion: less than $\lambda/8$ @633nm
Scratch/Dig code: 10/5 to MIL-O-13830A
Parallelism: better than 10 arc seconds
Perpendicularity: better than 5 arc minutes
Flatness: <$\lambda/8$ @ 633nm
Angle tolerance (degree): $D\theta < \pm 0.5$, $D\phi < \pm 0.5$
Anti-Reflection Coating: Single layer MgF2 coating with high damage threshold for high power laser operation. Reflectivity R<0.25% @1064nm per surface. Damage threshold over 750 MW/cm^2 @1064nm, 10ns and 10HZ.
Standard HR coating: R>99.8% @1064nm and R<5% @808nm. Other HR coatings, such as HR @1064/532nm, HR @946nm, HR 1319nm and other wavelengths are also available upon request.

Note:

We also have other ion doped YAG, such as Cr:YAG, Ho:YAG, and pure YAG available upon request. To learn more details and our competitive price, please contact our sales team for details.

ELECTRO-OPTIC DEVICES

Electro-optic device is one kind of the most important optical components in laser systems from modulating signals to intensifying the output power of lasers. The most commonly used crystals for Electro-optical applications are DKDP, BBO, $LiNbO_3$, KTP and $LiTaO_3$. United Crystals provides various electro-optic devices to meet our customer's different needs.

THE POCKELS ELECTRO-OPTIC EFFECT

Crystals, which belong to twenty symmetry classes, which lack a center of symmetry, can show a linear electro-optic effect, that is, a change in refractive indices directly proportional to an applied voltage. The symmetry conditions for the occurrence of this effect are exactly the same as for the occurrence of the piezoelectric effect. Thus, there is an exact symmetry analogy between the linear electro-optic effect (refractive index a linear function of electric field) and the converse piezoelectric effect (geometric deformation a linear function of electric field). The linear electro-optic effect has the same relation to the Kerr effect (refractive index a quadratic function of electric field) as converse piezoelectricity has to electrostriction (geometric deformation a quadratic function of electric field). The linear change in refractive index obtained at room temperature with practical electric fields (up to 20kV/cm) is only of the order of 10^{-4}. Although this is too little to change refraction angles for most practical purposes, it is sufficient to produce retardations of the order of one wavelength and hence lead to interference phenomena. These interference phenomena are used to modulate light phase or intensity. A one-half wavelength relative retardation can change the transmission of polarized light from 0 to 100 percent. An ac voltage producing a peak retardation of one-fourth wavelength can give 100 percent modulation of the carrier.

The linear electro-optic effect may be retarded as a special case of second order (non-linear!) electric interaction in the crystal: The action of a low frequency applied field and the electric field of the optic-frequency electro-magnetic wave combine to cause electric polarization at the optic frequency.

Linear electro-optic phenomena were discovered by Roentgen in quartz and thoroughly investigated in several crystals before the turn of the century by Pockels, in whose honor the effect is now generally called the Pockels effect. The broader study of higher order interaction in crystals began with Franken's discovery of frequency doubling of laser beams in quartz and KH_2PO_4.

In many linear electro-optic devices, the longitudinal effect is used, that is, the light beam and electric field are parallel. Longitudinal effect devices are particularly useful for light beams of large cross-sectional area. Other electro-optic devices use the transverse effect with the light beam perpendicular to the applied field. Transverse effect devices avoid the use of transparent electrodes in the light path. In addition, increasing the ratio of the light path length to the electrode spacing can reduce the voltage required for a given retardation, whereas in longitudinal effect devices the required voltage is independent of the dimensions of the crystal.

From symmetry perspective, it can be shown that a longitudinal effect free of background birefringence and optical activity is obtained only with crystals of two classes: the class $\bar{4}3m$ of the cubic system and the class $\bar{4}2m$ of the tetragonal system.

Class $\bar{4}2m$ is represented by KH_2PO_4 (KDP) and its isomorphs. Relatively large electro-optic effects and the availability of large crystals of high perfection have given crystals of this group continuing major importance for both "longitudinal" and transverse modulators as well as frequency doubling and mixing devices. These crystals are transparent throughout the visible and ultra-violet; one of the isomorphs (KH_2P0_4) is transparent to below 0.18μm. The infrared cutoff is near 1.5μm for the dihydrogen phosphates and near 2.1μm for KD_2PO_4.

Large strain-free crystals of KDP and a number of its isomorphs are available from United Crystals. And all DKDP Pockels Cells from United Crystals are longitudinal. More details are available in our web site, and printed materials are also available upon requests.

DKDP Pockels Cell:

Due to its lower half wave voltage, DKDP is the first choice for this kind of application. Currently, we have the following models in stock.

Picture 1. Single and Dual Crystal Pockels Cells


Picture 2. Brewster-cut Q-Switch

Dual crystal Pockels Cells, Brewster-Cut Pockels Cells, and other customized electro-optical devices also available upon request.

All DKDP Pockels Cells from United Crystals come with the following standard specifications, except customers' special demands.

United Crystals' Standard Specifications on DKDP Pockels Cells:

Deuteration Level: >98%
Clear aperture: > 90% central area
Dimension tolerance: (diameter ± 0.1 mm) x (L + 0.2 mm/-0.1mm)
Active extinction ratio @1064nm: >1000:1
Single Pass Transmission: >= 95%
Wavefront distortion: $\lambda/4$ at 633 nm
Flatness: $\lambda/8$ @ 633 nm
Optical Damage Threshold: > 1GW/cm^2 at 10Hz
Rise time: <2ns
Capacitance: <10 pf
Quarter wave voltage: < 3.6KV @ 1064nm
Windows AR coating: R< 0.1% at 1064nm
Index matching fluid: available upon request
Electrode type: based upon customers' request

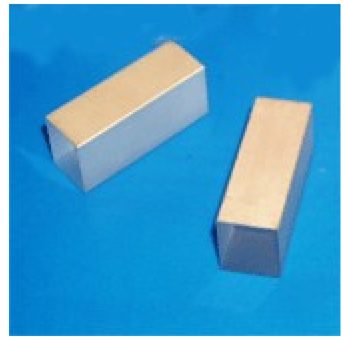
$LiNbO_3$/ $LiTaO_3$ Q-switches:

LiNbO3 (including MgO:LiNbO3) is the most common E-O crystal due to their relatively larger E-O coefficient, and no hygroscopicity. LiNbO3 Q-switches are ideal for low power Nd:YAG systems with small beam sizes. Due to their low damage threshold, LiNbO3 and LiTaO3 are not recommended for high power systems.

Unlike DKDP, $LiNbO_3$ commonly work in the transverse mode, which means the ¼ or ½ wave voltage could be modified by the changing the ratio of width and length. For example, 3x3x12mm Z-cut $LiNbO_3$ transverse Q-switch, its half-wave voltage at 1064nm is only about 2.1KV.

For Q-switches, the most common configuration is Z-cut $LiNbO_3$ bar with electric filed along X-axis to use the r_{22}, which is around 6.7×10^{-10}cm/V.

Picture 3. LiNbO3 crystal boule



Picture 4. LN Q-switches with Au Coating

Besides the regular $LiNbO_3$ Q-switches, United Crystals also offers Brewster-cut $LiNbO_3$ Q-switches to take advantage of Brewster-angle to eliminate the polarizer from the system.

$LiTaO_3$ is a little bit different from $LiNbO_3$, since its r_{22} is not big enough for any E-O effect. Thus, it works in the way with light propagating along Y-axis and the electric field along Z-axis. To cancel the birefringence and compensate the temperature variation, two crystals are normally needed. To use a $LiTaO_3$ Q-switch is not as usual as $LiNbO_3$.

In summery, $LiNbO_3$ Q-switches are suitable for low and middle-level power system, operated in visible and IR range, especially in the cases, where lower control voltage is mandatory. They are not recommended for high power application or the applications in UV range. For more details, please contact our experienced engineers.

United Crystals' Standard Specifications on LiNbO3/LiTaO3 Q-switches:

Clear aperture: > 90% central area
Dimension tolerance: (diameter ± 0.1 mm) x (L + 0.2 mm/-0.1mm)
Static extinction ratio @1064nm: 1000:1
Wavefront distortion: better than $\lambda/8$ at 633 nm
Flatness: $\lambda/8$ @ 633 nm
Optical Damage Threshold: > 200MW/cm^2 at 10Hz
AR coating: R< 0.1% at 1064nm
Electrode type: Cr, Au coating electrodes

BBO Q-switches:

The most significant advantage of BBO Q-switches is BBO's highest damage threshold, which make the BBO Q-switches irreplaceable in high power systems.

In addition to the high damage threshold, the excellent transparency of BBO at deep UV, makes it the best shutter in UV applications.

BBO Q-switches work in transverse mode too.

BBO is little bit hygroscopic, so AR-coating or Protection coating is recommended to protect the polished surfaces.

United Crystals has the capability to fabricate any BBO Q-switches based on the customers' design at a reasonable price.

E-O Modulators:

Another common application of the Pockels effect is E-O modulators. For modulators, low control voltage and high repetition rate are always required. To reduce the control voltage, transverse mode is the only choice.

The most usual materials for this kind of applications are ADP, DKDP, LiNbO3 and LiTaO3.

In order to cancel the birefringence and stabilize the operation, multiple crystals (2 or 4) are needed, in general.

For more details, please contact our experienced engineers.

Note:

Other customized electric-optical devices, such as dual crystal Pockels Cell, are also available upon request. Please contact our sales engineers for details.

YVO_4 Crystal

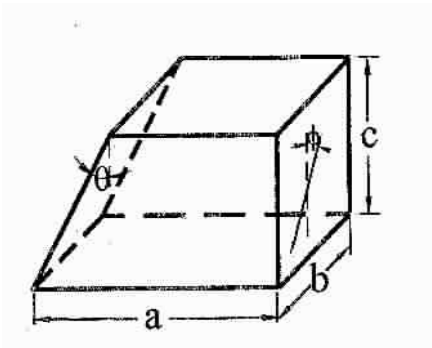
The pure YVO_4 is one of the most widely used birefringence crystals. Its wide transparency range, large birefringence, and good temperature stability make it ideal for optical polarizing components. It is an excellent synthetic substrate for Calcite ($CaCO_3$) and Rutile (TiO_2) crystals in many applications including fiber optic isolators and circulators, beam displacers and other polarizing optics, etc.

YVO_4 Basic Properties:

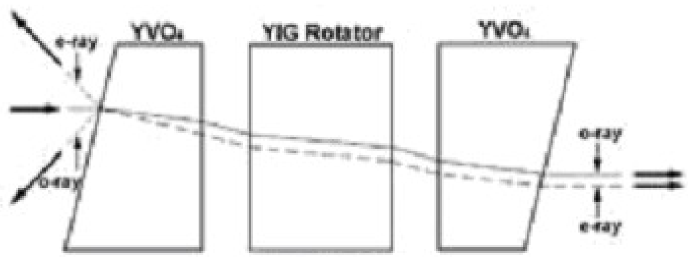
Transparency Range		High transmittance from 400 to 5000nm
Crystal Symmetry		Zircon Tetragonal, space group D_{4h}
Crystal Cell		a=b=7.12Å, c=6.29Å
Density		4.22 g/cm^3
Mohs Hardness		5
Hygroscopic Susceptibility		Non-hygroscopic
Thermal Expansion Coefficients		a, 4.43x10^{-6}/K; c, 11.37x10^{-6}/K;
Thermal Conductivity Coefficient		||c, 5.23 W/m/K; ⊥c, 5.10 W/m/K;
Crystal Class		Positive uniaxial with $n_o=n_a=n_b$, $n_e=n_c$
Thermal Optical Coefficient		$dn_a/dT=8.5x10^{-6}/K$; $dn_c/dT=3.0x10^{-6}/K$
Refractive Indices, Bi-refringence ($dn=n_o-n_e$) and Walk-off Angle at 45° (p)	@630nm	$n_o=1.9929$, $n_e=2.2154$, dn=0.2225, p=6.04°
	@1300nm	$n_o=1.9500$, $n_e=2.1554$, dn=0.2054, p=5.72°
	@1550nm	$n_o=1.9447$, $n_e=2.1486$, dn=0.2039, p=5.69°
Sellmeier Equation (λ in μm)		$n_o^2=3.77834+0.069736/(\lambda^2 - 0.04724) - 0.0108133\lambda^2$
		$n_e^2=4.59905+0.110534/(\lambda^2 - 0.04813) - 0.0122676\lambda^2$

Applications:

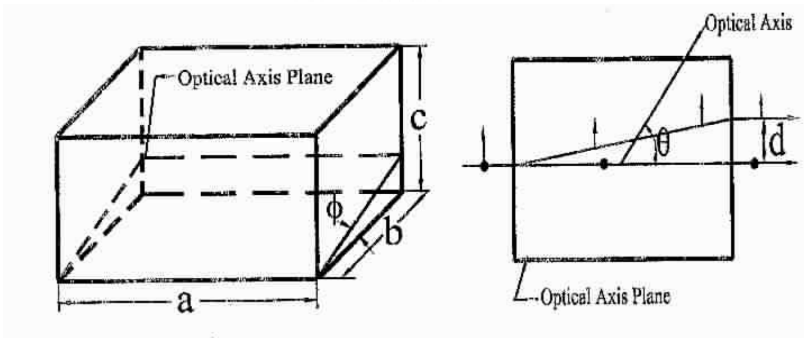
Following drawings are the simple demonstrations of how the YVO_4 crystals are used in Fiber Optic Isolator, Beam Displacers and Circulators.



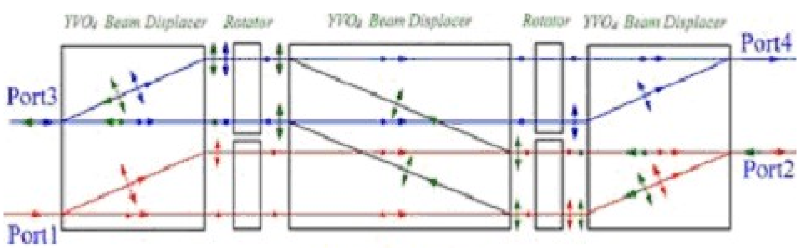
Fiber Optical Wedge



ISOLATOR



Fiber Optical Displacer



Circulator

Others:

Other applications of YVO_4 devices are also available upon request.

United Crystals' Standard Specifications on YVO_4 Devices:

Dimension tolerance: ± 0.05mm
Transmitting wave-front distortion: less than $\lambda/4$ @ 633nm
Optical Axis Orientation: ±0.5°
Flatness: $<\lambda/8$ @ 633nm
Scratch/Dig code: 10/5 to MIL-O-13830A
Parallelism: better than 10 arc seconds
Perpendicularity: better than 5 arc minutes
AR coating: R<0.2% @ 1550 or 1310 nm

Note:

Currently, we have the capability of producing 2,000 pieces of various YVO_4 components per month. To learn our competitive price and huge OEM discount, please contact our sales team for details.

Polarizing/Splitting Prisms

Polarization is one of most important division of Optics. It has been applied in almost every aspect of modern optics. There are many polarizing devices, such polarizers, prism, splitters, wave plates, etc.

According to the different methods of polarization, there are three types of polarization; one is reflection, absorption, and prism. Among them, prism polarizers are the most common devices in laser systems and other modern optical applications. The benefits of prism poloarizers include high extinction ratio, high transmittance, high damage threshold, and wide transparent range.

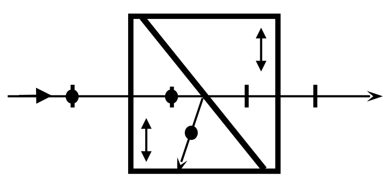
The most common material for polarizing prisms is Calcite, which is of big birefringence, no deliquescence, and chemical stability.

United Crystals specializes in frication of various laser polarizing prisms, splitters, and wave plates, such as Glan-Taylor Prism, Glan-Thompson Prism, Rocho Prism, Wollaston Prism, Double Wollaston Prism, 45° Glan-Thompson Splitting Prism, etc.

Please note: Other customized prisms are also available upon request.

Glen-Taylor Prism

Glan-Taylor Prism Polarizer belongs to Glan Prism family, with the air gap structure. It feathers with high damage threshold, high extinction ratio, as high as $1x10^{-5}$. It's suitable for high and middle power level laser systems and other polarization applications.



Glan-Taylor Prism Polarizer

Picture 1. Glan-Taylor Prism with Escape Window

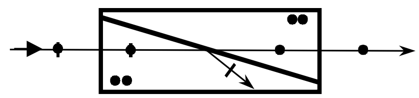
United Crystals' Glan-Taylor Prisms come with the following standard specifications.

Aperture:	3~28mm
Transmittance (633nm):	>85%
Transparent Range:	300~2800nm
Extinction Ratio:	$1x10^{-5}$
Angular Field:	6°
Wavefront Distortion (633nm):	$\lambda/8$
Damage Threshold (CW):	$30W/cm^2$
Damage Threshold (Pulse):	$500MW/cm^2$
Coating:	AR-coating available upon request

Customized Glan-Taylor Prisms are also available upon request. Please contact our sales engineers for details.

Glan-Thompson Prism

Glan-Thompson Prism Polarizer belongs to Glan Prism family, with the optical cement structure. It feathers with stability, big angular field, high extinction ratio, as high as 5x10^{-7}. It's suitable for high precise optical instruments and experiments need high extinction ratio, as well as laser systems.



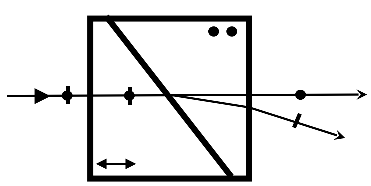
Glan-Thompson Prism Polarizer

United Crystals' Glan-Thompson Prisms come with the following standard specifications.

Aperture:	3~15mm
Transmittance (633nm):	>90%
Transparent Range:	320~2500nm
Extinction Ratio:	1x10^{-5}
Angular Field:	12°
Wavefront Distortion (633nm):	λ/8
Damage Threshold (CW):	8W/cm^2
Damage Threshold (Pulse):	100MW/cm^2
Coating:	AR-coating available upon request

Customized Glan-Thompson Prisms are also available upon request. Please contact our sales engineers for details.

Rochon Prism



Rochon Prism

One of the output polarizing beams from Rochon Prism does not change the direction. The beam deviation is determined by the design (less than 10°, in general).

It feathers with stability, high extinction ratio, as high as 1x10^{-5}. It's suitable for high precise optical instruments and experiments need beam splitting, as well as laser systems.

United Crystals' Rochon Prisms come with the following standard specifications.

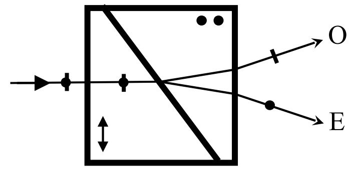
Aperture:	10x10~20x20mm
Transmittance (633nm):	>90%
Transparent Range:	320~2500nm
Extinction Ratio:	1x10^{-5}
Beam Deviation Angles:	2.5°, 5.0°, and 7.5°
Damage Threshold (CW):	10W/cm^2
Damage Threshold (Pulse):	100MW/cm^2
Coating:	AR-coating available upon request

Customized Rochon Prisms are also available upon request. Please contact our sales engineers for details.

Wollaston Prism

Wollaston Prism feathers with the big beam deviation angle (great than 15°).

In addition, Wollaston Prism also feathers the high extinction ratio, and high damage threshold. It's suitable for high precise optical instruments and experiments need beam splitting, as well as laser systems.



Wollaston Prism

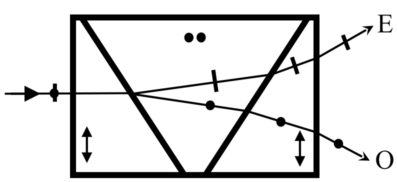
United Crystals' Wollaston Prisms come with the following standard specifications.

Aperture:	10x10~18x18mm
Transmittance (633nm):	>85%
Transparent Range:	320~2500nm
Extinction Ratio:	$1x10^{-5}$
Beam Deviation Angles:	5.0°, 10.0°, and 15.0°
Damage Threshold (CW):	$10W/cm^2$
Damage Threshold (Pulse):	$100MW/cm^2$
Coating:	AR-coating available upon request

Customized Wollaston Prisms are also available upon request. Please contact our sales engineers for details.

Double Wollaston Prism

Double Wollaston Prism is made of three elements, and able to produce bigger deviation angle than regular Wollaston Prism.



Double Wollaston Prism

It feathers with high extinction ratio, and stability. It's suitable for applications need bigger beam deviation angle. In general, this angle is greater than 20°. Customers can specify their own deviation angles.

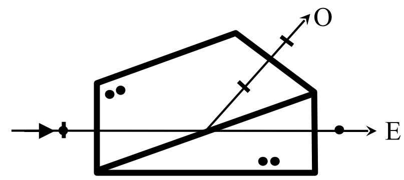
United Crystals' Double Wollaston Prisms come with the following standard specifications.

Aperture:	10x10~18x18mm
Transmittance (633nm):	>85%
Transparent Range:	320~2500nm
Extinction Ratio:	$1x10^{-5}$
Beam Deviation Angles:	>20°
Damage Threshold (CW):	$10W/cm^2$
Damage Threshold (Pulse):	$100MW/cm^2$
Coating:	AR-coating available upon request

45° Glan-Thompson Splitting Prism

45° Glan-Thompson Splitter belongs to Glan Prism Family, with optical cement structure.

The output o and e beams form a 45° angle. It feathers with high transmittance, high extinction ration, and low wavefront distortion. It's suitable for 45° beam splitting applications.



45° Glan-Thompson Prism Splitter

United Crystals' Double Wollaston Prisms come with the following standard specifications.

Aperture:	5x5~12x12mm
Transmittance (633nm):	>90%
Transparent Range:	320~2500nm
Extinction Ratio:	$1x10^{-5}$
Beam Deviation Angles:	>45°
Damage Threshold (CW):	$10W/cm^2$
Damage Threshold (Pulse):	$100MW/cm^2$
Coating:	AR-coating available upon request

Note:

Other polarizers and customized Prisms are also available upon request. Please contact our sales engineers for details.

Retardation Devices

Wave plates, as an optical component, are playing very important role in many optical modulation applications.

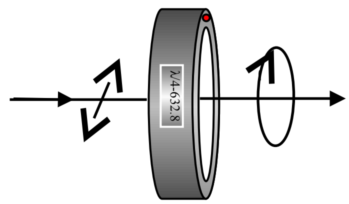


Figure 1. λ/4 wave plate with 10mm Aperture

Currently, United Crystals Inc. provides two kinds of wave plates, mica and quartz.

Mica Wave Plates

United Crystals' Mica Wave Plates come with the following standard specifications.

Aperture:	8~35mm
Transmittance (633nm):	>90%
Transparent Range:	400~1500nm
Retardation:	λ/8 and up
Retardation tolerance:	<3%
Damage Threshold (CW):	30W/cm^2
Damage Threshold (Pulse):	300MW/cm^2
Coating:	AR-coating available upon request

Customized Mica Wave Plates are also available upon request.

Quartz Wave Plates

United Crystals' Quartz Wave Plates come with the following standard specifications.

Aperture:	10~30mm
Transmittance (633nm):	>90%
Transparent Range:	400~1500nm
Retardation:	λ/8 and up
Retardation tolerance:	<5%
Damage Threshold (CW):	30W/cm^2
Damage Threshold (Pulse):	300MW/cm^2
Coating:	AR-coating available upon request

Customized Quartz Wave Plates are also available upon request.

Appendix

Purchasing Information

Quotation
You can request a quotation via online forms, distributors or our sales team. We offer special discounts and high quantity discounts for trial sample production and OEM orders. Please contact us for details

Orders
Orders placed by mail, Fax or E-mails are all acceptable. A formal confirmation letter will be issued within one business day after your PO received. If you do not receive any confirmation after one business day, please contact United Crystals Inc. immediately.

Terms
In general, the payment term is net 30 days by Bank Transfer or Checks, others terms are also acceptable based on the agreement.

Guarantee
All United Crystals' products are guaranteed to be free from defects in materials and components Repair or replacement will be made at no charge if we are notified of the defects within 30 days of shipment of the goods.

Shipment
Shipment is normally made via UPS (International Express), Federal Express (FedEx), DHL, EMS, or other ways required by customers.

Delivery
All standard and stock crystals are available for immediate shipments. All others are subject to the delivery term in quotations or orders.

Technical Assistance
We are always ready to provide comprehensive technical support and cost reduction assistance. Free technical consulting services are offered upon request

Contact Information

United Crystals Inc.
65 Linwood Road North,
Port Washington, NY 11050, USA
Phone: (516) 724-3288
Fax: (516) 883-2937
Email: contact@unitedcrystals.com
Web: http://www.unitedcrystals.com

Local Distributor

United Crystals Inc.

65 Linwood Road North, Port Washington, NY 11050-1439
Phone: (516) 724-3288 Fax: (516) 883-2937
Web: www.unitedcrystals.com
Email: contact@unitedcrystals.com